A MANUAL

OF

PHYSIOLOGY.

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"LABOR OMNIA VINCIT."

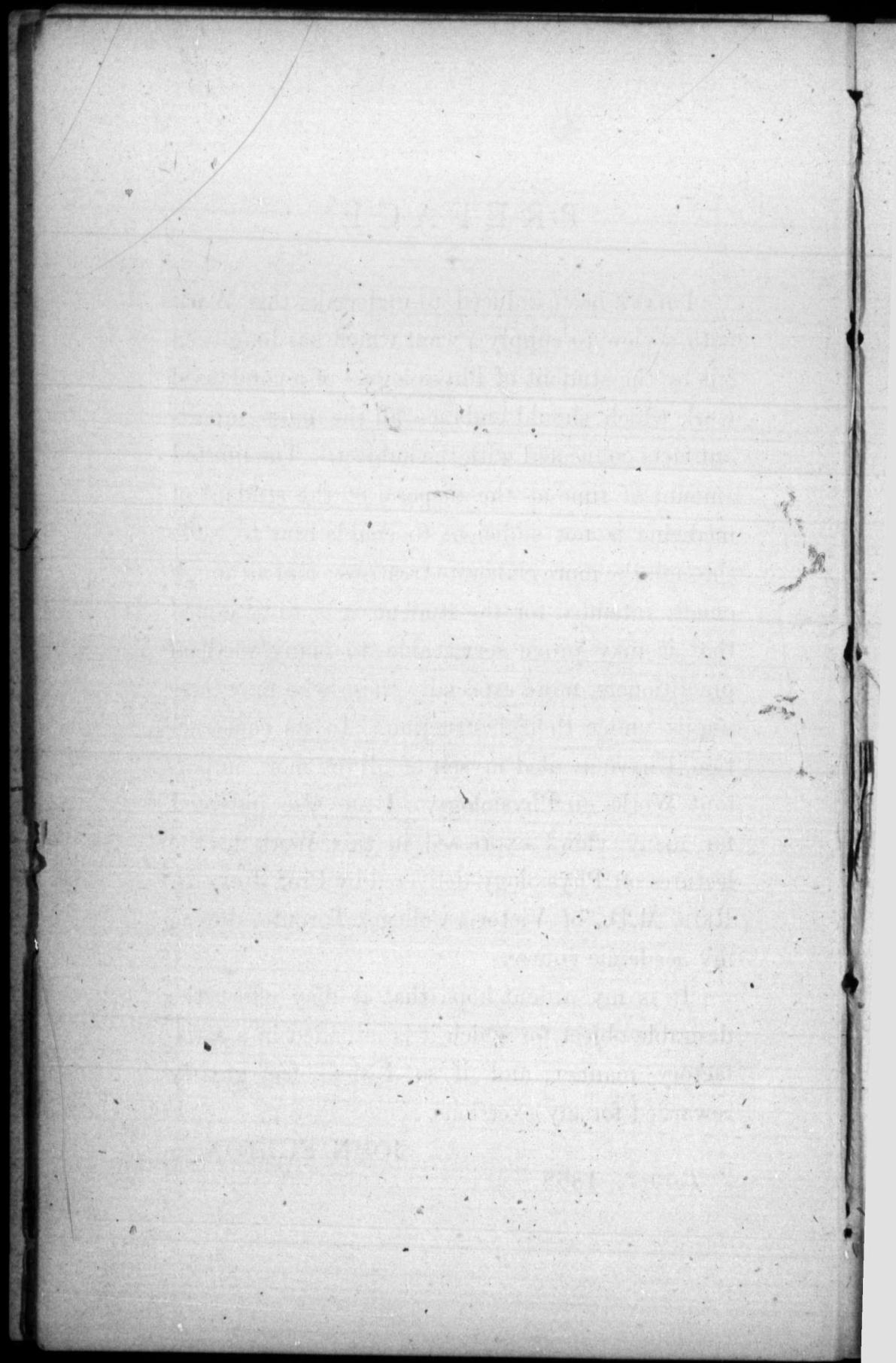# PREFACE.

I HAVE been induced to undertake this Work with a view to supply a want which has long been felt by the student of Physiology—of a condensed work which should embrace all the most important facts connected with the subject. The limited amount of time at the disposal of the student of medicine is not sufficient to enable him to wade through the more elaborate treatises ; and although chiefly intended for the student, it is to be hoped that it may prove serviceable to many medical practitioners, more especially those who may have pupils under their instruction. In its construction, I have availed myself of all the more important Works on Physiology. I am also indebted for many views expressed in this Work to the lectures on Physiology delivered by Prof. JOHN N. REID, M.D., of Victoria College, Toronto, during my academic course.

It is my ardent hope that it may effect the desirable object for which it is intended in a satisfactory manner; and if so, I shall feel greatly rewarded for my exertions.

JOHN FULTON.

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HUMAN PHYSIOLOGY.

PHYSIOLOGY, from φυσις, "nature," and λογος, " a description," in its general sense, has for its province the investigation of the active phenomena presented by organized bodies, and is divided into two parts, viz:— Animal and Vegetable Physiology: the former treats of the laws that control the Animal Kingdom, the latter relates to those of the Vegetable Kingdom. Animal Physiology may also be divided into two parts, viz: Human Physiology, and Comparative Physiology, or the Physiology of the lower animals.

Human Physiology treats of the vital phenomena of the human species, and is of much more practical importance to the medical student than the Physiology of the lower animals, on account of its relation to Pathology and Therapeutics.

The study of Physiology presupposes an intimate knowledge of Anatomy and Chemistry, in order that the student may be able to comprehend the character of the structure he is examining and the substance of which it is composed. Animal bodies are composed of solids and fluids: the former embrace the various textures and viscera; the latter the blood, chyle, lymph and glandular secretions.

The same substance may be fluid in one part of the body and solid in another; for example, phosphate of lime is in solution in the albumen of the blood, but is solid in the bones. A *law* in Physiology is a certain phenomenon, always taking place in the presence of certain conditions.

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CHAPTER I.

PROXIMATE PRINCIPLES.

EVERY animal tissue and fluid contains a number of proximate principles mingled together in various proportions.

A proximate principle may be defined to be " any substance, whether simple or compound, chemically speaking, which exists under its own form in the animal solid or fluid, and which can be extracted by means which do not alter or destroy its chemical properties."

But it must not be supposed that every substance which can be extracted from an organized solid or fluid by chemical means is a proximate principle; for example, chloride of sodium is a proximate principle ; but chlorine is not, because it does not exist as such in the body. Phosphate of lime is a proximate principle of bone; but phosphoric acid is not, because it does not exist in a free state in the bony tissue; still less phosphorus, which is obtained only by the decomposition of phosphoric acid.

Again, fibrous tissue, when boiled steadily for thirty-six or forty hours, yields a substance called gelatine; but this is not a proximate principle, since it is produced only by long-continued boiling.

In extracting the proximate principles from the animal body, only the simplest chemical means should be employed.

First, evaporate the substance, to extract and estimate the amount of water. The temperature should not be above 212°F., because a higher degree would change

some of the animal ingredients.   Then dissolve out the salts with water.

Coloring matter, or pigments, may be extracted by alcohol; oils and fats by ether.   Some of the salts may be removed by double decomposition.   Thus, glyko-cholate or tauro-cholate of soda may be precipitated by acetate of lead, forming glyko-cholate or tauro-cholate of lead, which may, in its turn, be decomposed by carbonate of soda, forming the original glyko-cholate or tauro-cholate of soda.   Sometimes a proximate principle cannot be separated in an entirely unaltered state.   Thus the fibrin of the blood can be entirely separated only by allowing it to coagulate ; hence it loses its original character of fluidity, and is permanently altered.

The proximate principles are divided into three classes :

1st. Crystallizable substances of inorganic origin, as water, chloride of sodium, carbonate and phosphate of lime, &c.   They are derived mostly from exterior sources. They are found in organized as well as in unorganized bodies, and have a definite chemical composition.

(In this class may also be included the gases, as oxygen, hydrogen, nitrogen, carbonic acid, carburetted and sulphuretted hydrogen).

2nd. Crystallizable substances of organic origin, or non-nitrogenized substances, as starch, sugars, oils, and fats.   They are found only in organized bodies, are crystallizable (excepting starch), and have a definite chemical composition.

3rd. Organic substances proper, "nitrogenized substances,""albuminoid substances," or "protein compounds," as albumen, fibrin, casein, &c.   They are exclusively organic in their origin, are not crystallizable, and are not definite in their chemical composition, that is to say,

they do not always contain the same proportions of oxygen, hydrogen, carbon and nitrogen; but the relative quantities of these elements may vary, within certain limits, in different individuals, and in the same individual at different times, without changing in any material degree the peculiar properties of the substance which they form. This is characteristic of organic substances. They all closely resemble albumen, hence called albuminoids. They were regarded by Mulder as compounds of a theoretical radical, which he called protein. This gave them the name of protein compounds. Mulder's theory, however, is not generally received. Some of these organic substances are fluid, and others semi-solid, or solid, depending upon the amount of water which they contain. When subjected to evaporation they all lose water, and are reduced to a solid state. Their reaction is neutral. They have, in fact, no combining equivalent.

The organic substances which are naturally fluid may be coagulated. Thus fibrin coagulates spontaneously when removed from the vessels; albumen, on the application of a temperature of 160°F.; and casein on being placed in contact with an acid.

An organic substance, once coagulated, cannot be restored to its original condition. It may be dissolved by certain re-agents, as e. g., the caustic alkalies; but in this it only suffers a still further alteration; nevertheless it is necessary to resort to coagulation in some instances to remove an organic substance from the other proximate principles with which it is associated, as for example, the fibrin of the blood. This is obtained by switching freshly-drawn blood with a bundle of twigs. Thus obtained it is in an unnatural condition, having lost its original character of fluidity.

These organic substances, when the vital force is removed, are liable to putrefaction. This process is peculiar to organic nitrogenized substances, and distinguishes them from all other kinds of proximate principles. When in a state of putrefaction, they are capable of inducing in certain other substances a process of fermentation, as for example, the decaying organic matters of the grape give rise to fermentation of the sugar, converting it into alcohol and carbonic acid. The putrescent body is called a ferment, and acts by catalysis, or by its mere presence, having nothing to do chemically with the process.

PROXIMATE PRINCIPLES OF THE FIRST CLASS.

WATER, HO.—Water is the most important of the inorganic principles, and is found in all parts of the body. In the solids it does not exist in a fluid state, but is incorporated with the substance of the tissue. It may be called "*water of composition*," in contradistinction to what is called in chemistry "*water of crystallization.*" It constitutes about two-thirds of the entire weight of the body.

The following table shows the proportion of water per 1,000 parts in different solids and fluids :—

QUANTITY OF WATER IN 1,000 PARTS.

	Solids		Fluids
In the Enamel of the Teeth,	2	Blood	780
" Epidermis	37	Bile	880
" Teeth	100	Milk	887
" Bones	130	Pancreatic Juice	900
" Tendons	500	Chyle	904
" Cartilage	550	Urine	936
" Skin	575	Lymph	960
" Liver	618	Gastric Juice	975
" Muscles	750	Perspiration	986
" Ligaments	767	Saliva	995

ORIGIN AND DISCHARGE OF WATER.—It is introduced with the fluid and solid elements of the food. The amount of water taken into the system by an adult, in the course of 24 hours, varies from $3\frac{1}{2}$ to 4 pounds. It is discharged from the body in four different ways—by the urine, fæces, perspiration, and breath,—about 48 per cent. being discharged by the urine and fæces, and 52 per cent. by the perspiration and breath. These proportions will vary according to circumstances; for example, in warm weather, when the skin is more active, and the perspiration more abundant, the quantity of urine is diminished. The quantity of water discharged by the lungs varies, also, with the state of the atmosphere and the pulmonary circulation. The water is not discharged pure, but is mingled with various salts, animal matters, and odoriferous substances.

FUNCTION.—It holds in solution different salts and substances of excretion, and gives fluidity to the blood and secretions. It is a most important article of diet, and is necessary both for the introduction of substances into the body, and their elimination from it. It gives to cartilage its elasticity, and to tendons their toughness and pliability. For, if water be expelled from a piece of cartilage by evaporation, it becomes dark in colour, semi-transparent, hard and inelastic. The same thing is true of muscles, tendons, &c.

CHLORIDE OF SODIUM, NaCl.—Chloride of Sodium is next in importance, and is found in all parts of the body except the enamel of the teeth. The entire quantity in the body has never been estimated. It exists in the greatest quantity in the fluids. In blood, for example, it is more abundant than all the other salines taken together. The following is a list of the quantities in the most important solids and fluids :—

QUANTITY OF CHLORIDE OF SODIUM IN 1,000 PARTS.

In the Muscles	2	Lymph	4.1
" Bones	2.5	Blood	4.5
" Milk	1	Chyle	5.3
" Saliva	1.5	Mucous	6
" Urine	3	Aqueous Humor	11
" Bile	3.5	Vitreous "	14

ORIGIN AND DISCHARGE.—It is introduced with the different kinds of animal and vegetable food and fluids, and as a condiment. Being soluble, it is taken up by absorption from the intestines, and is deposited in different parts of the body. About $\frac{4}{5}$ is discharged from the body in the urine, fæces, perspiration and mucus, the remaining $\frac{1}{5}$ being lost in the body by double-decomposition with phosphate of potassa, resulting in the formation of phosphate of soda and chloride of potassium. It is also supposed to furnish the soda to all the salts that have a soda base.

FUNCTION.—It regulates, to a certain extent, the phenomena of osmosis, for we know that a solution of chloride of sodium permeates an animal membrane much less readily than pure water. In the blood it holds in solution the albumen and earthy phosphates, and preserves the integrity of the blood corpuscle. As an article of diet, it stimulates the secretion of saliva and gastric juice, and aids in digestion. The importance of chloride of sodium in this respect has been demonstrated by Boussingault in the fattening of animals. A small herd of animals were experimented upon, all of the same age, size and vigour. They were divided into two lots, and all supplied with an abundance of nutritious food. One of these lots was deprived of this salt (except what was contained in the food), while the other received about 500 grains per day. No difference was observable for four or five months; from that time to the end of

the year a marked difference was noticed. Those animals which received the chloride of sodium had a fine, sleek, healthy aspect, contrasting strongly with the listless and inanimate appearance of the others.

CHLORIDE OF POTASSIUM, KCl.—This substance is found in the muscles, liver, milk, chyle, blood, gastric juice, bile, saliva, mucus and urine. It is quite soluble in the fluids, and is more abundant in muscle than chloride of sodium.

ORIGIN AND DISCHARGE.—It is introduced with the food, and is also formed in the interior of the body by double-decomposition between phosphate of potassa and chloride of sodium, forming phosphate of soda and chloride of potassium. This may be shown by feeding a considerable quantity of chloride of sodium to a sheep, and, upon examination of the urine, it will be found to contain an increased quantity of chloride of potassium, the proportion of chloride of sodium remaining unchanged.

Chloride of potassium is discharged in the urine and mucus.

FUNCTION.—Its function is probably identical with chloride of sodium.

PHOSPHATE OF LIME, $3CaO,PO_5$.—Phosphate of lime is found in all the solids and fluids of the body, but is more abundant in the solids, and increases as age advances. It exists in a solid state, as in the bones, and also in a fluid state, as in the blood. It is insoluble in water; but is held in solution in the fluids of the body by albumen and the alkaline chlorides. In the urine, it is held in solution by the biphosphate of soda. In bone or cartilage, it does not exist as a granular powder, but is intimately united with the animal matter, and may be dissolved out by maceration in dilute muriatic acid,

leaving behind the animal substance. When a long bone like the fibula is immersed in this way for some time, it loses its brittleness, and may be bent double, or tied in a knot, without breaking. If immersed in a solution of carbonate of lime, its rigidity may be again restored to a certain extent.

QUANTITY OF PHOSPHATE OF LIME IN 1,000 PARTS.

Solids.			*Fluids.*	
Enamel	885.	Urine	25.7
Dentine	643.	Milk	2.5
Bone	550.	Gastric Juice	.4
Cartilage	40.	Blood	.3
Muscle	2.5	Saliva	.6

ORIGIN AND DISCHARGE.—This substance is derived exclusively from exterior sources. It is introduced with the food, and is eliminated by the urine, perspiration, and mucus; most by the urine, a small quantity by the fæces.

FUNCTION.—Its use is to give consistence and strength to parts; for example, in the enamel of the teeth, which is the hardest tissue in the body, it is most abundant, and in dentine more abundant than in bone. Its absence is said by some to account for scurvy, as in long sea voyages; but it is more likely that it is due to the absence of vegetables and their acids.

CARBONATE OF LIME, CaO,CO_2.—This substance exists in the bones, teeth, cartilage, blood, sebaceous matter, internal ear, and sometimes in the urine. In bone it is not so abundant as phosphate of lime, the proportion being about 113 parts in 1000. It is held in solution in the blood and urine by the free carbonic acid and chloride of potassium.

ORIGIN AND DISCHARGE.—It is introduced into our bodies with the food and drink. Spring water contains a variable amount, held in solution by the free carbonic acid which the water contains.

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FUNCTION.—Its function is analogous to that of phosphate of lime.

CARBONATE OF SODA, NaO,CO_2.—Carbonate of soda is found in the bones, blood, lymph, saliva, and urine. It gives to the blood its alkaline reaction. Claude Bernard has shown that the alkalinity of the blood is necessary to life; for if a mineral acid be injected into the blood of a living animal, so dilute as not to coagulate the albumen, death takes place before its alkaline reaction has been completely neutralized.

ORIGIN AND DISCHARGE.—It is introduced in small quantities in the food. It is principally formed within the body by decomposition of other salts, as malates, tartrates, and citrates of soda and potassa. These salts when introduced into the body in the food are decomposed. Their organic acid is destroyed and replaced by carbonic acid, forming carbonate of soda and potassa. It is discharged in the urine and mucus.

FUNCTION.—Its function is to maintain the fluidity of the fibrin and albumen, and to assist in preserving the form and consistence of the blood corpuscles.

CARBONATE OF POTASH, KO,CO_2.—This salt is found in nearly the same situation as the preceding—is produced in the same way, and its function is analogous.

PHOSPHATES OF MAGNESIA, SODA, AND POTASSA.— These salts are found in small quantities in all the solids and fluids of the body. They are introduced in the food. Phosphate of soda and potassa are soluble in water. Phosphate of magnesia is dissolved in the fluids by the alkaline chlorides and phosphates, and in the urine by the biphosphate of soda. The fluids of the herbiverous animals contain a preponderance of the carbonates—the carnivorous a preponderance of the phosphates. The

latter is owing to the phosphates found in the animal tissues upon which the carnivora feed. They are discharged in the urine and fæces. The remaining proximate principles of this class are the sulphates of soda, lime, and potassa, and chloride of ammonium.

The proximate principles of the first class exist in the animal tissues in the same form in which they occur in the inorganic world. Carbonate of lime in the bones is the same as that which is found in limestone rock; and chloride of sodium is similar to that which is found in solution in sea water.

GASES.—Oxygen, nitrogen, hydrogen, carbonic acid, carburetted hydrogen and sulphuretted hydrogen, exist in a gaseous state, and also in solution in some of the fluids of the body.

Oxygen is necessary to the respiratory process. It changes the shape of the blood corpuscle, rendering it biconcave, and giving to the arterial blood its bright-red colour. Arterial blood contains about 10 to $12\frac{1}{2}$ per cent. of oxygen. Nitrogen exists in very small quantity in the blood and lungs. It is also found in the intestines. Carburetted and sulphuretted hydrogen, also pure hydrogen, are found in the alimentary canal, and in small quantities in expired air. Carbonic acid is an excretion given off principally by the lungs. From 20 to 25 per cent. is found in venous blood.

PROXIMATE PRINCIPLES OF THE SECOND CLASS.

STARCH, $(C_{12} H_{10} O_{10})$—This substance, though not crystallizable, is so closely allied to the others in its general properties, and so easily converted into sugar, which *is itself* crystallizable, that it is naturally included in the proximate principles of the second class. It is not amorphous, but assumes a distinct granular

form. It is found in nearly all the flowering plants, and is the principal ingredient in sago, tapioca, arrowroot, &c.

TABLE OF QUANTITY OF STARCH IN 100 PARTS.

In Rice	85	Wheat Flour	56
" Maize	80	Iceland Moss	44
" Barley Meal	67	Kidney Bean	35
" Rye "	61	Peas	32
" Oat "	59	Potatoes	15

PHYSICAL APPEARANCE OF STARCH.—It is a white powder, consisting of solid granules, which vary in shape, size, and physical appearance, in different vegetables. It produces a crackling sensation when rubbed between the fingers. The starch granule of potato varies from $\frac{1}{10000}$ to $\frac{1}{400}$ of an inch in diameter, is pear-shaped in its outline, and marked by concentric rings surrounding a minute pore, called the *hilus*, which is situated near the small extremity of the granule. The granules of arrowroot being smaller and more uniform, vary from $\frac{1}{2000}$ to $\frac{1}{500}$ of an inch in diameter, and are oval in shape. The hilus is in the shape of a circular pore or transverse slit. The starch grains of wheat vary from $\frac{1}{10000}$ to $\frac{1}{700}$ of an inch in diameter, nearly circular in form, with a round or transverse hilus, but without any distinct laminar appearance. The granules of Indian corn are the same size as the preceding; they are irregular in shape, and present a crucial or (T) shaped pore.

ORIGIN AND PROPERTIES.—It is found in most vegetable substances used as food, and in that way is introduced into the body. It is also found in the animal body in the lateral ventricles of the brain, fornix and septem lucidem. It was first observed by Purkinje, and afterwards by Kölliker and Virchow. The granules are called corpora amylacea. They vary in size from $\frac{1}{4700}$ to $\frac{1}{1100}$ of an inch in diameter. They are transparent, softer than in vegetable starch, irregularly rounded, and

present a faint laminar arrangement, having a circular pore (near the centre), with lines radiating from it— star-shaped.

Starch is insoluble in cold water, but the granules swell out, become gelatinous, and are readily dissolved in boiling water. It is then said to be hydrated. This is simply a mechanical change. Starch may be converted into sugar in three different ways.

First, by boiling in dilute nitric, muriatic, or sulphuric acid for 36 or 40 hours. The starch is gradually converted into sugar, at the same time losing its property of responding to the iodine test.

Secondly, by contact with an animal or vegetable substance, at a temperature of 100°F. Boiled starch mixed with the saliva is converted into sugar in a few minutes.

Thirdly, by the process of nutrition and digestion in animals and vegetables. The starch found in seeds and roots must first be converted into sugar and thus rendered soluble before it can be taken up to nourish the plant during its growth.

FUNCTION.—Its office in the animal economy is to form sugar. Starch is converted into sugar during digestion by the action of the pancreatic and intestinal juices. It is necessary for the process of development and nutrition at all periods of life.

TEST.—In whatever state it exists, its presence may be detected by its reaction with free iodine, giving a blue color.

SUGARS.—These substances are soluble in water, crystallize on evaporation, and are converted into alcohol and

carbonic acid in the process of fermentation.   The ordinary varieties of sugar are the following:

VEGETABLE SUGARS.	ANIMAL SUGARS.
Cane Sugar, $C_{12} H_{11} O_{11}$	Milk Sugar, $C_{12} H_{12} O_{12}$
Grape " $C_{12} H_{14} O_{14}$	Liver " $C_{12} H_{14} O_{14}$
Sug'r of Starch or Glucose $Cl_2 H_{14} O_{14}$	Sugar of Honey $\left\{ \begin{array}{l} \text{A mixture of} \\ \text{Cane and Grape} \\ \text{Sugar.} \end{array} \right.$

Cane sugar is more soluble than any other variety and is therefore sweeter.   Liver sugar and sugar of honey crystallize only with great difficulty; some of the sugars, as grape and liver sugar, ferment very easily; while others, as cane and milk sugar, do so with difficulty.

TABLE OF QUANTITY OF SUGAR IN 100 PARTS.

In Figs	62.50	Wheat Flour	4 to 8.48
" Cherries	18.52	Rye do	3.28
" Peaches	16.48	Ind'n Corn do	1.45
" Tamarinds	12.50	Peas	2.00
" Pears	11.52	Cow's Milk	4.77
" Beets	9.00	Asses' do	6.08
" Barley	5.21	Human do	6.50

ORIGIN AND FUNCTION OF SUGAR.—It is an important article of diet.   It is introduced with the milk in the food of the child.   In the adult it is introduced partly in the food as sugar; but mostly in the form of starch, which is converted into sugar during digestion by the action of the pancreatic and intestinal juices.   It is also formed in the interior of the body, in the liver, mammary gland, and in the placenta of the fœtus during the first three months of fœtal life.   It is found in the portal and hepatic veins, but disappears from the blood in its passage through the lungs, being probably converted into lactic acid.   It is necessary in the process of nutrition at all periods of life, and is also supposed to assist in maintaining the animal heat of the body. Sugar is never discharged from the body in health (except in the female during lactation); but in certain diseased con-

ditions of the system, it is rapidly produced in the liver, and is discharged in the urine, constituting *diabetes mellitus.*

TESTS.--FIRST, TROMMER'S TEST.--To the suspected liquid add one or two drops of a solution of sulphate of copper; render it alkaline by the addition of a solution of caustic potassa. The whole solution then assumes a blue color. Then boil it for a few minutes, and if sugar be present, the suboxide of copper is thrown down as a yellowish or reddish-brown precipitate. If no sugar be present, the liquid remains blue. The principle of this test depends upon the power sugar has in reducing the protoxide to the suboxide of copper. The alkali is added to liberate and neutralize the sulphuric acid. This test is not applicable to cane or beet sugar; but by boiling them in dilute sulphuric acid they are converted into glucose, which responds readily. Sugar of honey, grape, glucose, liver, and milk sugar, all act promptly with Trommer's test. Care should be taken that only a small quantity of sulphate of copper be added, as there might not be sufficient sugar in the solution to reduce it.

Organic substances, as albuminose, interfere with this test. This substance may be precipitated by alcohol, and removed. Albuminose will be described in the proximate principles of the 3rd class.

FERMENTATION TEST.--Add a few drops of fresh yeast to the saccharine liquid, and keep it at a temperature of from 70° to 100° F. In this way the sugar is converted into alcohol and carbonic acid; the latter should be collected in a vessel and examined. Every cubic inch of carbonic acid is equal to about one grain of sugar. The presence of carbonic acid may be proved by introducing into the vessel a lighted taper, which will be immediately extinguished, or by agitating with lime

water, which will be rendered turbid by the formation of insoluble carbonate of lime.

TORULÆ.—This is a vegetable growth presenting a number of growths or joints, oval in shape, and connected together, which may be observed on the surface of diabetic urine, and are called "Torulæ Cerevisiæ." They break up after a time and fall to the bottom of the vessel, in minute oval spores.

MOORE'S TEST, *or, the Potash Test.*—A little caustic potash. in solution is added to the suspected liquid, and boiled in a test tube. If sugar be present, it acquires a brownish color.

BARRESWILL'S TEST.—The principle is the same as in Trommer's test. The solution is prepared according to the following formula, given by Bernard:

Potass Bitart..383 grains.
Soda Carb...309   "
Cupri Sulph..231   "
Caustic Potassa...................................309   "
Aqua... 18 oz. MIX.

Add to the suspected mixture enough of the solution to give it a blue tinge, and boil. If sugar be present, the yellow suboxide or copper is thrown down, as in Trommer's test.

BÖTTGER'S TEST.—This is also analogous to Trommer's test. To the suspected liquid add a few drops of a weak solution of nitrate of bismuth in nitric acid; render it alkaline by a solution of carbonate of soda, and boil; a dark precipitate will be produced, if sugar be present.

MAUMENE'S TEST.—Saturate strips of woollen in a solution of bichloride of tin, and dry; then dip them in the suspected liquid, and dry quickly; if sugar be present, the strips assume a brown color.

OILS AND FATS.—These substances are found in both animal and vegetable tissues. Fat exists in the animal

economy in three varieties, viz: Oleine—$C_{94} H_{87} O_{15}$;
Margarine—$C_{76} H_{75} O_{12}$; and Stearine—$C_{142} H_{141}$
O_{17}. By the chemist these bodies are considered as
salts, formed by the union of fat acids with the base—
glycerine—thus:—

Oleine..... $\left\{\begin{array}{l} \text{Oleic Acid } (C_{36} H_{34} O_4) \\ \text{and} \\ \text{Glycerine } (C_6 H_8 O_6 \text{.......} \end{array}\right\}$ ....Oleate of Glycerine.

Margarine $\left\{\begin{array}{l} \text{Margaric Acid } (C_{34} H_{34} O_4) \\ \text{and} \\ \text{Glycerine } (C_6 H_8 O_6) \text{.........} \end{array}\right\}$ ...Margarate of Glycerine.

Stearine.. $\left\{\begin{array}{l} \text{Stearic Acid } (C_{36} H_{35} O_4) \\ \text{and} \\ \text{Glycerine } (C_6 H_8 O_6) \text{........} \end{array}\right\}$ ....Stearate of Glycerine.
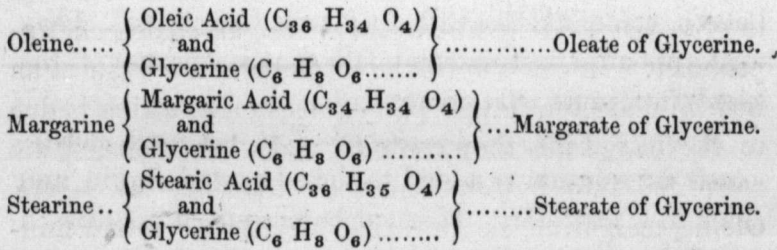
SAPONIFICATION.—When oleine, margarine, or stearine,
is boiled in a solution of caustic alkali, it is decomposed
into a fat acid, as oleic, margaric, or stearic, and a sweet-
ish viscid fluid called glycerine. The acid unites with
the alkali and forms soap, and the glycerine is set free.

The fat acid may be separated from the base glycer-
ine by passing steam through fat at a temperature of
$572°$ F. The human body, when immersed in water
for a length of time, becomes changed into a substance
called *adipocere,* or saponified fat. This is supposed to
be a process of saponification, caused by the union of
margaric, stearic and oleic acids with ammonia, which
is developed during the process of decomposition.

PHYSICAL APPEARANCE AND PROPERTIES OF FAT.—
It exists in two forms in the body. First, in the form
of large cells or vesicles, varying in diameter from $\frac{1}{800}$ to
$\frac{1}{300}$ of an inch, as in adipose tissue. Secondly, in the
form of oil globules, varying from $\frac{1}{20000}$ to $\frac{1}{4000}$ of an
inch, as in the chyle, in which it is said to be emul-
sified. This is a mechanical subdivision of the fat cells,
and is the only form in which it can be absorbed. Fats
may be emulsified in mucilage and white of egg. The

fat cell is characterized by a dark border surrounding a bright centre. It does not possess a nucleus or nucleolus at maturity. It is generally rounded in shape, but is found irregular in outline, depending on pressure. The small globules appear as minutely dark granules, so as to give the fluid in which they float an opalescent appearance. In cow's milk, the oil globules are $\frac{1}{4000}$ of an inch in diameter, have a pasty consistence, which is due to the margarine they contain; and when churned, are converted into butter, from their tendency to cohere. Oleine, margarine, and stearine, are always found mingled together in the body; but they are never associated with any of the other proximate principles of the body, as water, sugar, &c. The only exception is the nerve tissue, in which they are combined with albumen, and also in the bile dissolved in the salts. They are united with phosphorus, constituting the phosphorized fats of nerve tissue. This union is supposed to take place in the lungs, under the influence of oxygen. In the living body, the fats are fluid, or nearly so, being held in solution by oleine; but after death, they assume the solid condition. Stearine and margarine are crystallizable, and sometimes present a very beautiful appearance. The crystals are needle-shaped, and are deposited in a radiated form, but sometimes curved and branching. Stearine predominates in hard, margarine in soft, and oleine in liquid fats. The melting point of stearine is 143 ° F., margarine 118 °. F., and oleine 100 ° F. They are insoluble in water, but are soluble in ether and hot alcohol.

TABLE OF QUANTITY OF FAT IN 100 PARTS.

In Filberts	60	Ordinary Meat ... 14.30
" Walnuts	50	Liver of Ox ... 3.89
" Cocoa Nuts	47	Cow's Milk ... 3.13
" Linseed	22	Human " ... 3.55
" Indian Corn	9	Asses'. " ... 0.11
" Yolk of Egg	28	Goats' " ... 3.82

ORIGIN AND FUNCTION.—It is found in all parts of the body except in the compact tissue of the bones, teeth, tendons, beneath mucous membranes, in the cutis, between the rectum and bladder, beneath the epicranial aponeurosis ·in ligaments, scrotum and eyelids. It is introduced in the food, and is emulsified by the pancreatic juice during digestion and previous to absorption. It is also formed in the interior of the body. This has been proved by experiments on geese, the result of which showed more fat in the body than could be accounted for by that which existed in the food. Another proof is, that it has been found in the form of globules in the interior of the costal, laryngeal, and tracheal cartilage cells, and also in the muscular fibre cell of the uterus during involution. It also exists in the form of globules in the hepatic cells, sebaceous glands, corpus luteum, and uriniferous tubes of the carnivora. In the marrow of bones, it exists both in the form of oil globules and fat cells, forming adipose tissue. In some parts, it is formed from blastema supplied by the blood vessels, as in adipose tissue; in others it is formed as the result of a retrograde metamorphosis, as in the muscular fibre cell of the uterus.

It accumulates in excess in certain diseased conditions, as in fatty degeneration of the heart, liver, kidney. Its function in the form of adipose tissue is to give rotundity to the body, form a nidus for delicate organs, fill up spaces otherwise unoccupied, and from being a bad conductor to prevent the too rapid escape of the animal heat of the body. As an article of diet, it is necessary in the process of nutrition. It supplies animal heat, and is a store of food in case of emergency, as in the hybernating animals. Certain kinds of food favor the formation of fat; for example, Negroes employed in making

sugar grow fat from the quantity of sugar they eat. It is said to accumulate more rapidly when the animal is fattened in a darkened room. Fat is absorbed from the body in some diseases, and its place supplied with serum, as in consumption.

It is discharged by the sebaceous glands of the skin, and in the milk of the female during lactation.

PROXIMATE PRINCIPLES OF THE THIRD CLASS.

ALBUMEN, from "Albus," white, on account of its appearance when coagulated. It exists both in the fluid and solid state in the body—fluid in the blood, lymph, chyle, serous and synovial fluids, and milk,—solid in the brain, spinal cord and nerves. It is also found in mucous membranes, muscular tissue, and in the aqueous and vitreous humors of the eye. It exists in the white of the egg, and can be easily coagulated or made to assume a solid form.

COMPOSITION AND PROPERTIES.—It consists of $C_{54.8}$ $H_{7.1}$ $N_{15.9}$ $O_{21.3}$ $S_{.6}$ $P_{.3}$ in 100 parts. The sulphur and phosphorus are in small quantities. The presence of the former may be detected by the blackening of silver that has been in contact with it. It does not coagulate spontaneously, but may be coagulated by any of the following re-agents, viz., by heat at 160°F., alcohol, mineral acids, as nitric, sulphuric, &c., tannic acid, ferrocyanide of potassium in an acid solution, and the metallic salts. It is very readily coagulated by bichloride of mercury, and hence it is used in cases of poisoning from that salt. It unites with it to form the so-called albuminate of mercury. The white of one egg is sufficient to neutralize four grains of the bichloride. Albumen coagulates at the negative pole of the battery, if not too strong a current, and at both poles when a strong battery

is used. It is not coagulated by the vegetable acids (except tannic).

When albumen is evaporated at a temperature of 120°F., it becomes solid and brittle, but otherwise unchanged, and may be re-dissolved in water. When coagulated by heat or the mineral acids, &c., it cannot be re-dissolved or made to resume its original condition. It is held in solution in the body, by chloride of sodium, carbonate and phosphate of soda, which give it an alkaline reaction. It exists in a neutral state in diseased blood, the egg, renal, splenic and hepatic veins. It parts with some of the soda in passing through the spleen, kidney, and liver.

ORIGIN AND FUNCTION.—It is derived from the albuminoid elements of the food, by a catalytic process during digestion. It is the nutrient element of the blood, and the pabulum of all the tissues. When it is withheld from the food, or withdrawn from the body in disease, as in albuminuria, the nervous and muscular tissues suffer most. It is converted into fibrin through the agency of the blood-cells and oxygen; this is probably a chemico-vital process. There are some physiologists who hold the opinion that fibrin is not formed from albumen, but that it is effete matter formed from the worn-out elements of the blood and tissues. It is by no means a settled question; but it is not the object of this work to discuss questions of this kind.

Albumen is never discharged from the body in health (except during lactation). In a diseased state of the kidney it is found in the urine, as in albuminuria.

TESTS.—These depend on its property of coagulation.

First. Heat.—When a solution containing albumen is heated in a test tube to 167° F., a precipitate, more or less abundant, is formed. If, however, the liquid be

alkaline, the albumen will not coagulate; hence an acid should be used to neutralize it. The earthy phosphates of the urine, when in excess, are thrown down by heat; but these may be distinguished from albumen by the addition of a few drops of hydrochloric acid, which clears up the phosphates, but has no action on the albumen.

Secondly. Nitric Acid.—When this is added to a solution containing albumen, a precipitate is instantly formed. When the urates are abundant in the urine, nitric acid causes a deposition of uric acid, but this may be re-dissolved by an excess of nitric acid.

ALBUMINOSE.—This substance is found in the chyle and blood. It differs from albumen from the fact that it is not coagulated by heat, and only very imperfectly by nitric acid. It is coagulated by alcohol, acetic acid, and the metallic salts. When in solution in the gastric juice, it interferes with Trommer's test for grape sugar. It is found in the stomach only during digestion. When Trommer's test is applied to a saccharine liquid containing albuminose, a purple color is produced on the addition of the re-agents, and when boiled, the color changes from red to yellow, but no suboxide of copper is thrown down. This test may be made to apply, by evaporating the solution to dryness, and making an alcoholic extract, then a watery solution of the sugar contained in the extract will respond as usual. It also interferes with the mutual reaction of starch and iodine, no blue color being produced.

ORIGIN AND FUNCTION. — It is formed from the organic nitrogenized elements of the food, as fibrin, albumen, and casein, &c., by the action of the gastric juice during the process of digestion. It is absorbed in this state, and is converted into albumen in the blood. It is much more easily absorbed than albumen, on

account of its superior osmotic properties. It is the soluble principle of fibrin, albumen, casein, &c.

FIBRIN.—Fibrin ($C_{54.3}$ $H_{6.9}$ $N_{15.7}$ $O_{22.1}$ $S_{.3}$ $P_{.3}$) exists in the blood, lymph, and chyle as found in the lacteals. When blood is removed from the vessels, it soon separates into a solid portion, or clot, and a fluid portion, or serum. The clot consists of coagulated fibrin, containing red and white corpuscles entangled in its meshes. When inflammation is present, the corpuscles have a tendency to cohere, and sink to the bottom of the vessel, hence the fibrin is more abundant at the top, and from the peculiar color it presents, is called the "buffy coat." Fibrin is difficult to obtain free from corpuscles. It may be obtained nearly pure by switching freshly-drawn blood with a bundle of twigs. It coagulates on the twigs, and may be freed from impurities by washing. It is first washed with water, to remove the salts, then with alcohol, to remove the pigment, and ether, to remove fatty matters. Another mode is to filter frogs' blood, the corpuscles of which, being large, are kept back; but the liquor sanguinis passes through, and the fibrin coagulates, and may be washed as above. A little thin syrup, or a weak solution of an alkali, should be added to retard coagulation during filtration. It is sometimes found in a tolerably pure state in the cavities of the heart and large arteries, after death. It is also found arranged in laminæ in the sacs of aneurisms.

PHYSICAL APPEARANCE AND PROPERTIES.—Fibrin is a greyish-white, tough, elastic and stringy substance, composed of microscopic fibrils. It possesses the property of "spontaneous coagulation" (or fibrillation), and is a constituent of "*coagulable lymph*," which is deposited in the process of inflammation. This substance, which

is thrown out on some tissues of the body, as the pleura, forms fibrous bands, which unite the surfaces together. These are called "true membranes." In low forms of inflammation, however, it is liable to degenerate and form pus. This is also the case when it is thrown out on mucous surfaces, the epithelium and the elements of the mucus having the power of destroying the property of coagulation and subsequent organization. This is a wise provision of nature, to prevent the agglutination of those surfaces. The only apparent exception is the exudation in inflammatory croup and diptheria; but even in these cases it is so far deteriorated, as not to form a "true membrane."

Fibrin is insoluble in water, alcohol, and ether, but is soluble in the alkalies. Three-fourths of its weight is water. When treated with acetic acid, it swells out, becomes soft and gelatinous, and slightly soluble in water. It may be dissolved in cold concentrated hydrochloric acid, and after a time the solution acquires a blue color. When dissolved in the potash salts, it resembles albumen in its properties and reactions. When boiled in water, it forms binoxide and teroxide of protein. When boiled in hydrochloric acid, it yields "leucine" and "tyrosine." It is held in solution in the blood by the alkaline chlorides and carbonates. By some writers, it is said to be held in solution by ammonia, and that coagulation depends upon the evolution of that substance.

FIBRILLATION.—The coagulation of fibrin is a process of fibrillation. When the process of fibrillation in an organizable blastema, as in the repair of wounds, or in inflammation, is viewed with a microscope, the blastema at first appears as a homogeneous mass; then it assumes a distinctly granular appearance, some of the granules being developed into cell-nuclei, and others are arranged

in a linear manner, to form fibres, which extend in every direction between the cell-nuclei. These cell-nuclei seem to have the power of determining the arrangement and direction of the granules, which are subsequently developed into fibres. When fully organized, it is distinctly fibrous in structure, and presents a number of cell-nuclei, some of which remain and others disappear after a time. The completion of this process depends upon the previous elaboration of the fibrin, and the character of the tissue upon which it is deposited, whether serous or mucous, strong or flabby, dead or living.

In the coagulation of the blood under the microscope, a granular appearance is first noticed; some of the granules become star-shaped by the addition of other granules, the arms being directed towards the corpuscles, which are ultimately included in the meshes. It will be seen, therefore, that the blood corpuscles exercise the same influence over coagulation of the blood that the cell-nuclei do over the fibrillation of the blastema in the repair of wounds, &c. Coagulation of the fibrin will proceed, though more slowly, in the absence of the corpuscles, as in filtered blood. This is due to the vitality which it carried with it from the corpuscles.

ORIGIN AND FUNCTION.—Fibrin is a histogenetic substance. It is formed from albumen, by the influence of the corpuscles and oxygen; in other words, it is albumen in a higher state of organization. It gives to the blood its property of coagulation, and it is through this property that "natural hæmostasis" is effected. It builds up the fibrogelatinous or connective tissue, repairs wounds, and prevents the blood from exuding through the coats of the vessels.

A summary of the arguments in favour of the view

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that fibrin is effete matter, formed from the worn-out elements of blood and the tissues:

1st. It is too small in quantity to be of any great service in building up the tissues.

2nd. It is increased by repeated bleeding and starvation.

3rd. That in the improvement of the breed of animals it is diminished.

4th. That there is none found in the renal veins, it having been discharged by the kidneys, and in the hepatic veins it is considerably diminished.

5th. That there is less fibrin in the blood of the carnivora than the herbivora.

6th. Defrinated blood injected into the veins within twenty-four hours after death, will remove the cadaverous rigidity, and the blood returned by the vein is coagulable.

7th. That the blood of unborn infants contains less fibrin than that of adults.

8th. That there is very little fibrin in the blood of the fœtus, none in the egg, none in the chyle until it enters the lacteals, and then only as the result of the additions made to it from the blood or lymph.

CASEIN. — ($C_{55.1}$ $H_{6.9}$ $N_{15.9}$ $O_{21.6}$ $S_{.3}$) is the organic principle of the milk. It is held in solution by the alkaline carbonates, and may be coagulated by any of the acids. When any of the acids is added, the alkali is neutralized, and coagulation of the casein follows. It is also coagulated by rennet. This is obtained from the abomasus, or fourth stomach, of the young of ruminants. The pepsine contained in the stomach has the power of converting the sugar of the milk into lactic acid, which neutralizes the alkali, and causes a precipitate of casein. This is a catalytic

process. Casein is also coagulated during a thunder storm. A substance called ozone is developed in the atmosphere; this acts on the casein and decomposes it. The decaying casein acts as a ferment, and converts the sugar of milk into lactic acid, which precipitates the casein. Casein differs from albumen; it contains no phosphorus, is not coagulated by heat, and is precipitated by acetic acid. The precipitate of casein may be re-dissolved by a solution of caustic alkali. It is insoluble in water and alcohol.

ORIGIN AND FUNCTION.— It is formed from the albumen of the blood by a catalytic process in the mammary gland. It has been found in the blood of puerperal women. Casein may be obtained in nearly a pure state, by precipitating it with acetic acid, and then washing the precipitate with alcohol and water. It is the chief aliment of the young of the mammalia, and the substance from which all the tissues are formed.

GLOBULINE, $(C_{54.6} H_{6.9} N_{16.2} O_{21.9} S_{.3})$, in a semi-solid state, is found in the crystalline lens, in the blood globules, and in the structure of cells generally. It is coagulated by heat, alcohol, and the mineral acids. It is soluble in water, but not in the liquor sanguinis of the blood. The coagulum of globuline is partly soluble in hot alcohol; this distinguishes it from albumen. Acetic acid causes it to swell out and become transparent. The globuline of the crystalline lens is called by some "*Crystalline.*" It is more easily coagulated than globuline.

PANCREATINE.—This is the organic principle of the pancreatic juice. It is a viscid fluid, coagulable by heat, alcohol, and strong acids. It is coagulated by sulphate of magnesia; this distinguishes it from albumen. It has the property of emulsifying oils and fats, and of convert-

ing starch into sugar during the process of digestion.
It is formed from the albumen of the blood in the
pancreas.

PEPSINE.—This is the organic principle of the gastric
juice. It is coagulated by heat and alcohol, and is with
difficulty distinguished from albumen. It exists in the
gastric juice in the proportion of fifteen parts per
thousand. It may be precipitated and extracted from
the gastric juice by means of alcohol. The solvent power
·of the gastric juice depends on the presence of pepsine.
This will be discussed in the chapter on digestion.

MUCOSINE. — The organic substance of mucus is
termed mucosine. In some of its properties it resembles
albumen. It is coagulated by heat, strong acids, and the
metallic salts. It lubricates the free surface of mucous
membranes, being formed from the blood by the agency
of the cells, which line the free surface of the membrane
and its follicles. This substance, together with casein,
urrosacine, and biliverdine, are the only proximate prin-
ciples of this class that are discharged from the body in
health.

MUSCULINE is a semi-solid organic substance peculiar
to muscular tissue. It is insoluble in water, but is soluble
in a mixture of ten parts of water with one of hydro-
chloric acid, and may be precipitated again by neutral-
izing with an alkali.

It is a most important element of animal food, and
is the great source of albumen and fibrin.

CARTILAGINE is the organic ingredient of cartilage.
By prolonged boiling, it is transformed into a substance
called "chondrine." It is precipitated by acids and
some of the metallic salts; this distinguishes it from
"gelatine."

OSTEINE.—This substance, peculiar to bone, is natur-

ally solid. It constitutes the principal part of the animal matter. By prolonged boiling, it is converted into "gelatine" or "glue," and is then soluble in water.

ELASTICINE.—This is the organic principle of the yellow elastic tissue. It is soluble in nitric, sulphuric and hydrochloric acid, and these solutions are not precipitated by alkalies.

KERATINE.—This is an organic substance, found in the nails and hair. Unlike the other substances of this class, it is decomposed by potash.

The remaining substances of this group are the coloring matters of the body. They all contain iron in a molecular state. They are hematine, biliverdine, melanine and urrosacine.

HEMATINE (C_{44} H_{22} N_3 O_6 Fe.) is the coloring principle of the blood, and exists in the interior of the blood corpuscles. The presence of iron may be detected as follows:—Add a drop of nitric acid to a small quantity of blood in a watch glass, evaporate slowly over a lamp. The iron absorbs oxygen, and is converted into peroxide, and nitrous acid fumes are given off. Then add a drop of the sulphocyanide of potassium, and a red color will be produced characteristic of the sulphocyanide of iron. The color of hematine is supposed to be due to the *iron*. It exists in the blood in the proportion of one part of hematine to seventeen parts of globuline. When the red blood corpuscles are broken down from any cause, the hematine is set free, and the walls of the vessels and tissues are stained. This has been mistaken for arteritis. When the hematine is deficient in the blood, as in anemia, &c., it may be restored by the administration of iron. Hematine is soluble in ether and hot alcohol, but is insoluble in water and acids when removed from the blood.

BILIVERDINE is the greenish-yellow coloring matter
of the bile.   It contains iron in the same proportion as
hematine.   It is insoluble in water, but is soluble in
ether and alcohol.   No doubt it is formed from hematine.
It is discharged from the body in the fæces.

MELANINE is a brownish-colored substance, found in
those parts of the body where pigment exists, as in the
choroid coat of the eye, iris, epidermis and hair.   It is
very abundant in the epidermis of the negro.   It is
formed from hematine, but contains less iron.   The color-
ing matter is the same in all situations, the different
shades being produced by the arrangement of the pig-
ment cells among the fibres and capillaries of the tissue.
In some cases it is entirely absent, as in the "albino."
It is insoluble in water and dilute acids, but is soluble
in caustic potassa.

URROSACINE is a yellowish-red coloring matter pecu-
liar to the urine.   It is found, also, in urinary calculi.
It is probably the worn-out hematine of the blood, which
is being discharged by the kidney.   Urrosacine and
biliverdine are both discharged from the body, the one
in the urine, and the other in the fæces.

CHAPTER II.

ELEMENTARY OR PRIMARY FORMS OF TISSUE.

THE elementary or primary forms of tissue are cells, simple fibres, and simple or basement membranes. Of these, the cells are the most important, since they are the active agents in the performance of all the functions of the animal body, as digestion, absorption, selection, assimilation, respiration, secretion, excretion and reproduction. They also constitute the fundamental elements of all the tissues, and are the active agents in all the catalytic and chemico-vital changes which take place in, the animal economy. The agency of cells is not only exhibited in the healthy actions of the body, but may also be seen in the development of various morbid growths, as fibroid tumors, cancer, &c. Hence cellular physiology and pathology are the most important subjects which can engage the attention of the intelligent physician and surgeon.

HISTORY OF THE ANIMAL CELL.—The form which organic matter takes when it passes from the condition of a proximate principle to that of an organized structure, is that of a cell, a simple fibre, or a simple membrane.

DEFINITION.—A cell is a membranous sac enclosing a cavity, which contains matters of variable consistence, appearance and properties.

VARIATION IN SHAPE.—The cells are generally globular, but may assume various shapes, depending on internal and external circumstances, and the growth of

the cell; for example, cells which are originally rounded, as the fat cell, may become polygonal, as the result of mutual pressure. The specific gravity of the contents will also affect the shape to a considerable extent. When water is added, they have a tendency to swell out and finally burst. When evaporation or dessication takes place, they become flattened and hardened, as in the epidermis. The shape of the cell may also be changed by the absorption of gases and vapors, e.g., the blood corpuscle presents a distinctly biconcave disk under the influence of oxygen, and becomes rounded again when exposed to the influence of carbonic-acid gas. The vapor of ether, when inhaled, produces an irregular appearance of the blood corpuscles. Chloroform vapor causes a serrated outline, and alcohol renders them oval, with an indentation on one side. Cells may also assume different shapes, depending on their growth; for example, the pigment cell, which is at first spheroidal, throws out arms or projections in different directions, and becomes stellate during its growth. The nerve cell becomes caudate; nonstriated muscular cell, fusiform. Epithelial cells are either cylindrical (columnar), or squamous (tesselated or pavement).

This peculiarity of shape is due to the plastic power of the cell, which causes a molecular current of plasma to set to that part of the cell which is to be enlarged or prolonged. There is also, through the vital power of the cell, a condensation of the plasma at that particular part. In some instances, growths take place on the free surfaces or extremities of cells, as is seen in the ciliæ of epithelial cells.

VARIATION IN SIZE.—Cells vary in size from $\frac{1}{300}$ of an inch in diameter, the size of the largest fat cell, to $\frac{1}{20000}$ of an inch, the size of the fat globule. The aver-

age diameter of the blood corpuscle is about $\frac{1}{3200}$ of an inch. Nerve cells vary from $\frac{1}{300}$ to $\frac{1}{4000}$ of an inch in diameter. Muscular fibre cell $\frac{1}{4700}$ to $\frac{1}{1100}$ of an inch, &c. In order to facilitate the general description of a cell, it may be divided into a cell wall, nucleus, nucleolus and contents.

CELL WALL.—The cell wall is substantially the same in all cells. It is a simple homogeneous membrane, composed of globuline; and although no pores can be seen by the highest magnifying power, yet it possesses the property of osmosis. It has also the power of choosing and refusing from the particles of nutrient fluid or cytoblastema in its neighbourhood, incorporating some of them into the substance of its wall, and converting others into new substances in its interior. For example, the blood corpuscle has the power of forming globuline and hematine from the albumen and fibrin of the blood. It is contended by some physiologists that this power resides solely in the nucleus; but it must be borne in mind that this property belongs also to those cells which are entirely destitute of a nucleus, as the fat cell at maturity, blood corpuscle, germ cells of the vegetable kingdom, &c., &c.

When the cell-wall is acted on by acetic acid, it swells out and becomes transparent, so as to bring into view the nucleus, when that exists.

NUCLEUS.—In the interior of most animal cells is seen a collection of granular matter, which is called the nucleus. It exists in three forms: First, as a minute granular body; secondly, as a well-defined granule; and thirdly, as a small cell, containing a granular body or nucleolus.

The nucleus is generally situated in or near the centre of the cell; but may be attached to the wall, or

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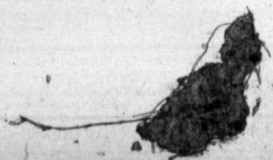
imbedded in it (as in the fat cell). It is generally rounded in form, but may be found elongated, as in the nonstriated muscular fibre cell. The size of the nucleus varies from $\frac{1}{4000}$ to $\frac{1}{8000}$ of an inch in diameter. It is more regular, both in shape and size, than the cell itself. When two or more nuclei are found in one cell, it is generally an evidence of rapid growth, as in fibro-cellular tumors, cancer, pus, &c., &c. They are, in these cases, formed by the subdivision of the original nucleus. Those cells which are not destined to reproduce their kind, do not possess a nucleus at maturity, as the blood corpuscle, fat cell, &c. The nucleus in substance is analogous to the cell-wall.

NUCLEOLUS.—When the cell-wall is acted upon by acetic acid, it swells out and finally bursts, and the acid coming into contact with the nucleus clears it up, and brings into view the nucleolus, when that is present. It is situated in the interior of the nucleus, and may consist of a single granule or a number united together. In some instances it is highly refracting and not readily acted upon by most chemical re-agents, as in the hepatic cell.

CONTENTS.—Every cell has the power of generating in its interior a substance peculiar to itself, which is the result of its own secretion; one secretes bile, another milk, another mucus, another gastric juice, &c., &c. The contents of the cell may be either solid, as in bone, nails, epidermis, &c., or fluid, as in blood, chyle, mucus, &c. The contents of all cells are originally fluid, but become hardened by secondary deposit, as in bone, dentine, &c. This takes place by the deposition of solid particles on the inside of the cell-wall, and the outside of the nucleus.

COLOR.—The color of the cell depends partly on its

refracting power, and partly on the hematine, melanine, &c., which it contains.

PABULUM, OR CYTOBLASTEMA.—This is derived either from the fluid in which the cell floats, as blood, chyle, &c., or from the capillaries near the seat of growth. When the cells are situated on a basement membrane, as the epithelium of mucous and serous membranes, it is found surrounding them; having passed through the basement membrane from the capillaries immediately beneath. In all these cases the cytoblastema contains material not only to supply the wants of the present brood of cells, but also for the development of the new brood which is destined to take the place of the old.

LAWS OF CYTOGENESIS. 1st Law.—In all tissues composed of cells, the new cells which are being developed must resemble the parent cells in all their distinctive features and properties. When the young cell deviates in its character from the parent cell, abnormal growth may be said to have commenced.

2nd Law.—Cell growth can only take place in or near its appropriate pabulum, and on living surfaces.

CYTOGENESIS.—(Κυτος, "cell," γενεσις, "generation.") Cells may be developed in two different modes;—either "de novo," in the midst of an organizable blastema, or from a pre-existing or parent cell.

Of the first mode, there are two varieties. First. The formation of the nucleolus from a collection of granules, and the subsequent development of the nucleus and cell-wall; and secondly, the formation first of the cell-wall, and subsequently the nucleus and nucleolus.

Of the second mode, there are also two varieties. First. Multiplication by subdivision of the original cell; and secondly, by the development of new cells within the parent cell.

FIRST MODE—THE DEVELOPMENT OF CELLS "DE NOVO"
IN THE MIDST OF AN ORGANIZABLE BLASTEMA.—In the
first variety, when examined under the microscope, the
blastema, when first effused, presents a homogeneous,
semi-fluid appearance. As it solidifies, a number of
molecules or minute granules show themselves. Some
of these cluster together, and form a well-defined granule.
This constitutes the future nucleolus. This nucleolus
seems to have the power of arranging the granules around
it at a certain radial distance, to form the nucleus; and
around the nucleus thus formed is arranged concentric-
ally a second series of granules, which constitutes the
cell wall. The growth of the cell wall and nucleus takes
place by the interstitial deposit of granules between
those already arranged, and by additions on the outside
and inside of their walls. In some instances this growth
is irregular, and gives rise to those peculiarities of shape
which have already been mentioned. This mode of
cytogenesis may be demonstrated by experimenting on
wounds.

In the *second* variety, the cell is formed by the ex-
pansion of granules. The molecules aggregate to form
a well-defined granule. This enlarges, and presents a
nebulous appearance; it then clears up in the centre, so
as to resemble a cell nucleus. This expands and forms
the cell wall, which allows the plasma to pass through
for the subsequent formation of the nucleus and nucleo-
lus. The nucleus is formed within the cell by a col-
lection of granular matter (developed from the plasma),
which clears up in the centre; and in the interior of the
nucleus a few granules collect to form the nucleolus.

This variety of cytogenesis may be observed in the
primary development of nerve tissue.

SECOND MODE—THE DEVELOPMENT OF CELLS FROM

A PRE-EXISTING OR PARENT CELL.—Of the first variety, viz., multiplication by subdivision, the development of the cartilage cells furnishes a good example. The cell is originally rounded; but when the process of subdivision commences, it becomes oval, and subsequently presents a sort of hour-glass contraction, or—first of the nucleus, and afterwards of the cell wall. This continues until there is a complete separation, first of the nucleus into two parts, and then the cell wall, each part of the nucleus drawing a portion of the cell wall around it. This process may be again repeated in each part, either in the same direction or transversely, so as to form four new cells, and so on until a large mass has been produced. At the point in which division of the original cell wall and nucleus is taking place, granular matter may be noticed, which is used in the process of reconstructing the new cells.

In the *second* variety the nucleus appears to separate at once into several parts, each of which is developed into a new cell, and in this way the parent cell may be filled by a whole brood of young cells.

This variety of cell development may be observed in structures of very rapid growth, as in cancerous tissue, &c. It is probable that these new cells may be formed by the expansion of granules.

A *compound cell* consists of a cell within a cell, as the graafian vesicle.

CONDITIONS NECESSARY TO CYTOGENESIS.—The conditions necessary to cytogenesis are the presence of pabulum upon a living surface, a certain degree of animal heat, a requisite amount of water, oxygen, light and electricity.

The dynamic agency of heat cannot be dispensed with; too much would be injurious. The mysterious

influence of light is necessary to healthy action, and a certain amount of water is required to preserve the integrity and promote the growth of the cell; but too much would destroy it.

CHANGES WHICH DEPRIVE A CELL OF ITS INDIVIDUALITY.—Cells may lose their individuality :

1st. By coalescence of the cell wall with the intercellular substance of temporary cartilage, as in the development of osseous tissue, the nuclei of the cells forming the lacunæ.　(See development of bone.)

2nd. By the process of multiplication by subdivision, which has already been described.

3rd. By the coalescence of cells, in a linear manner, to form a fibre, as in fibrous tissue.　The cells are originally round; but in the process of forming fibres they become, first oval, then elongated, and in some instances fusiform.　They are then arranged end to end, sometimes slightly overlapping each other, and by their fusion or coalescence a fibre is formed.

4th. By the coalescence of cells, in a linear manner, to form tubes.　In this instance the opposing walls of the cells, as they are arranged in a line, break down, the cavities of the cells communicate with each other, and in this way a continuous tube is formed, as in the development of nerve tissue, and in the formation of the vascular tract from the germinal vesicles.—See chapter on blood.

SPONTANEOUS CHANGE IN THE SHAPE OF CELLS.—Spontaneous changes in the shape of cells give rise to motion.　The cause of motion in the vegetable kingdom was for a long time a matter of speculation.　It was finally discovered that this phenomenon was due to the spontaneous change in the shape of the cells when irritated, as in the mimosa or sensitive plant, the fly-trap of the Dionœa, and the Berberis.

In the animal economy, muscular contraction is due to this spontaneous change. It occurs in both the striated and non-striated muscular tissue. In contraction of the fibrillæ the sarcos elements become shorter and broader; the same is true of the non-striated muscular fibre cells. Spontaneous changes in the shape of the cells take place in the uterus during gestation. The cells are largely developed during pregnancy, in order to give enlarged accommodation for the development of the fœtus, and increased power for the act of parturition. After birth the uterus undergoes the process of involution, by which the cells are diminished in size and number, and changed in their physical appearance. When examined by the microscope, oil globules may be seen in their interior at this stage.

The movements of the ciliæ are no doubt produced by the spontaneous change in the shape of the cells from which they spring. It is probably caused by the alternate contraction and relaxation of the opposite sides of the cell wall.

CAUSE OF ORGANIZATION, VITALITY, &c.—This is a purely speculative subject. Many theories have been advanced from time to time, to endeavour to explain the phenomena of organized bodies. Some suppose that it is due to an "animating principle" which pervades every organized structure and regulates its functions, and by which the new organism for the production of the species is moulded into shape, from materials furnished by the parent. This "principle" is supposed to be regulated and controlled by the Deity himself. This was the theory of Aristotle, and was afterwards advocated by Harvey.

Hunter attributes the organization of living beings, and the vital actions manifested by them, to a "materia

vitæ" diffused throughout the solids and fluids of the body. Abernethy supposes this materia vitæ to be a species of electricity.

Müller supposes that the cause of organization is due to an "organic force" which resides in the whole organism, and possesses the property of generating each part. This "organic force" exists already in the germ, and is creative, as is seen in the aggregation of granules by the primary germ to mark the different parts of the new organism. It is not under the influence of the mind, for instinct is as capable of reproducing the species as higher intelligence.

Prout advocates the existence of an "organic agent," which possesses extraordinary powers in controlling and directing the organization and development of the living being. This is very similar to the preceding hypothesis.

There can be no doubt, however, that organic matter derives its vital properties from a previously existing vital organism. While these organic matters retain a perfect organization, and are supplied with their proper stimuli, as light, heat, moisture, &c., vital actions go on perfectly: for example, the fecundated egg, "omne vivum ex ovo," acquires its vital properties while in the body of the mother; and when laid, if supplied with vital stimuli, and the organization remain perfect, it is developed into a new being. But as soon as the structure is destroyed, or the vital stimuli withheld or withdrawn, the organism dies, and its elements form new compounds, most of which are of an inorganic character.

Organic life is presided over by the cerebellum and spinal cord; intelligence by the cerebrum.

PHENOMENA OF CELLS.—The phenomena of cells are exhibited in the *plastic* and *metabolic*, or *vital* and *chemical* power of the cell. The *plastic* power of the cell is

seen in the preparation of material for the formation of new cells; in the organization of this material into granules; in the arrangement of these granules in a certain order, to form the nucleus, nucleolus and cell wall; and in the subsequent growth and development of the cell.

The *metabolic* power of the cell is shown in the property it has of chemically changing the plastema within and without the cell. It is confined to the conversion of special substances, as in the formation of globuline and hematine, by the blood corpuscle, bile by the hepatic cell, and pepsine by the epithelium of the stomach. The cell of the yeast plant has also the power of converting sugar into alcohol and carbonic acid.

These two forces (plastic and metabolic) may act together; in fact, it is difficult to separate them, and the change which they produce is called a *chemico-vital* change, as the formation of fibrin from albumen, &c.

Both these forces act together in harmony, and through their united action the different secretions and excretions are formed. These forces are affected by nervous impressions, as fear, joy, grief, anger, &c. For example, the character of the milk is changed by a fit of anger, and the secretion of the gastric juice is arrested by fear.

The *plastic* and *metabolic* power of the cell may be arrested by powerful chemical re-agents, as arsenic, corrosive sublimate, acids and alkalies. The latter will prevent the conversion of albumen into fibrin, and should be administered in cases of inflammation. It is also arrested by strong nervous shocks, as a stroke of lightning or a powerful battery, and by septic poisons.

MANIFESTATIONS OF CELL LIFE.—These are exhibited: *First.* In cell growth from the germ.

Second. Multiplication by subdivision.

Third. Chemical transformation of the blastema..

Fourth. Permanent change in the cell.

Fifth. Temporary change in the cell.

Sixth. Production of nervous force (vis nervosa.)

And Seventh. Vitalization of the pabulum.

A cell is a living organism, and like all living bodies, has its period of growth, maturity and decay. It has the power of selecting matters from the blastema—assimilating and organizing them into the new substances found in its interior. This property resides in the cell as a whole, and not exclusively in any single part of it. The granules from which the cell was originally developed are supposed to be a transition state between albumen and the substance which it is destined to form. The duration of the life of a cell depends on its activity—those of slow development are long-lived, and *vice versa.*

When a cell begins to decay, granular matter is first noticed in its interior; the cell wall finally gives way, and the granular matter escapes. "Granules thou art, and unto granules shalt thou return."

SIMPLE FIBRES.

A simple fibre is formed by the arrangement and coalescence of granules in a linear manner. They are found only in repair of tissue, as in wounds (and in inflammatory exudations), and are formed under the influence of *cell-nuclei* by the process of fibrillation.

Schwann maintains that "all the tissues of the body are formed from cells." All the tissues of the body were originally formed from cells; but in the course of reconstruction or repair of wounds, and in inflammation, the process of fibrillation takes place. The plastic matter thrown out to heal the wound, or upon the inflamed

surface, at first presents a homogeneous appearance, and as it solidifies it becomes granular.   Some of the granules are developed into cell-nuclei, by the process of cytogenesis, and the remaining granules are arranged in a linear manner, radiating from the cell-nuclei, so as to form a network, including the cell-nuclei in its meshes. The cell-nucleus consists of a thin-walled nucleus, and a well-defined granule in the centre—the nucleolus. They never proceed any further towards organization, and are therefore called *free cell-nuclei*.   They may be demonstrated by exposing a portion of the newly-formed tissue of a wound to the influence of acetic acid, which clears it up and brings into view the free cell-nuclei, and also the simple fibres which surround them.

SIMPLE OR BASEMENT MEMBRANES.

These are formed like the simple fibres already described, directly from the nutrient fluid or *blastema*, by a certain arrangement of granules peculiar to themselves. They exist under three different forms, which vary somewhat in microscopical appearance.

In the *first* variety, it is a simple pellicle of homogeneous appearance, and shows no sign of organization, as in the cell wall.   A good example may be seen in the lining membrane of a bivalve shell.

In the *second* variety, the membrane is not homogeneous in its character, but presents a number of minute granules irregularly scattered through the transparent substance.

In the *third* variety, the membrane presents a number of distinct spots or nuclei, and is capable of being torn up into portions of nearly equal size, each containing one of these spots or nuclei.   From this it would appear that the *first variety* is formed by the condensa-

tion of a thin layer of blastema, the *second* by the condensation of a thin layer of blastema in which granules had been formed, and the *third* by the condensation of a thin layer of blastema in which nuclei had been formed.

The last two varieties of membrane above described have been called by some *basement* membrane, because it is the foundation or resting place for the epithelial cells; by others *primary, germinal,* or *maternal* membrane, because it furnishes the germs of those cells.

The basement membrane is found on all the free surfaces of the body, giving support to the epithelial cells. It forms the outer layer of the true skin, and the inner layer of mucous, serous and synovial membranes, bloodvessels and lymphatics. It is prolonged into all the ducts, follicles and tubuli connected with the mucous membranes.

In all these examples its free surface is covered with cells, which receive their nutriment by osmosis, through the membrane, from the capillaries on its attached surface. Its *office* is to limit osmosis of the nutrient fluid, and to modify it in its passage. It also supports the cells, and probably furnishes the germs of all the cells which are developed on its surface. In all probability, the granules and spots, or nuclei, seen in the basement membrane are the germs of cells, which spring from them as from a centre.

CHAPTER III.

TISSUES.

WHITE FIBROUS TISSUE.

THIS tissue enters into the formation of ligaments, tendons, aponeuroses and membranes.

1st. As *ligaments*, it connects the bones together and preserves the integrity of the joints in their various movements. The ligaments assume three different forms: *Funicular*, which consists of rounded cords of fibrous tissues, as the ligamentum teres. *Fascicular*, which consists of flattened bands, as the ligaments of the ankle, knee, and elbow; and *Capsular*, which form tubular expansions, as in the shoulder and hip joints.

2nd. As *tendons*, it serves to connect the muscles to the bones and other structures to which they are occasionally attached; some of these are rounded—*Funicular*, as the tendon of the semi-tendinosus; others flattened—*Fascicular*, as the semi-membranosus. The tendons, at their insertion into the bones, blend with the periosteum.

3rd. As *aponeuroses*. These are tendinous expansions of considerable extent, as in the abdominal muscles. They serve to enclose cavities, and protect the contained organs.

4th. As *membranes*, it is used to cover, protect, and attach various organs, as the dura mater, sclerotic coat of the eye, pericardium, tunica albuginea testis, periosteum, perichondrium, fascia, lata, &c.

PHYSICAL APPEARANCE AND PROPERTIES.—It presents

a beautiful, silvery-white appearance, when freed from
extraneous substances, and is composed of bundles of
fibres, which are parallel to each other in some cases,
and cross or interlace in others. Examined under the
microscope, it is found to consist of wavy bands about
$\frac{1}{500}$ of an inch in diameter. They appear to be formed
of numerous fibrillæ, varying in size from $\frac{1}{15,000}$ to $\frac{1}{20,000}$
of an inch. This is not the case, however. The bands
are not capable of being separated into fibrillæ; but they
present parallel streaks, which have a tendency to slit
up in a longitudinal direction. When a portion is
exposed to the action of acetic acid, it swells out and
becomes semi-transparent, the streaks are entirely oblit-
erated, and a number of cell-nuclei make their appearance,
showing that it has been developed from cells. At the
same time some wavy transverse lines may be seen at
regular distances, which somewhat resemble striped
muscular fibre. These lines mark the junction of the
cells from which the tissue was originally formed. This
tissue is perfectly inelastic, and allows of a slight
degree of extension from long-continued force. It
possesses no contractility, and its force of cohesion is
very great. It is said that the tendo-achilles is capable
of supporting a weight of nearly 1,000 lbs. It contains
few vessels and nerves. The actual presence of nerves
has not, as yet, been satisfactorily demonstrated, and its
sensibility is very low. The division of a tendon is
attended with very little pain. It yields gelatine, on
boiling.

YELLOW FIBROUS OR ELASTIC TISSUE.

It is found in the ligamenta subflava, ligamentum
nuchæ of quadrupeds, internal lateral ligament of the
lower jaw, stylo hyoid and pterygo-maxillary ligaments,

chordæ vocales, cricothyroid and thyrohyoid membranes, posterior wall of the trachea, arteries, veins, thoracic duct, and in areolar tissue.

PHYSICAL APPEARANCE AND PROPERTIES.—This tissue, unlike the preceding, is of a yellowish color, highly elastic, and consists of long, single, brittle fibres, which show a disposition to curl upon themselves when broken. They vary in size from $\frac{1}{5000}$ to $\frac{1}{10000}$ of an inch, the average diameter being about $\frac{1}{7500}$ of an inch, and are round or flattened—depending on their situation or pressure. They anastomose with each other, and are mingled in various proportions with the white, to form areolar or filamentous tissue. It does not gelatinize on boiling, is not acted on by acetic acid, and is not readily dissolved by the gastric juice. It resists the approach of disease longer than any other tissue in the body; e. g., an artery will remain intact in the interior of an abscess after the other structures are destroyed, and when the artery gives way, the walls present a honeycomb appearance, on account of the destruction of the white fibrous and muscular tissues with which it is associated.

It consists of $C_{48} H_{36} N_6 O_{14} + 2$ Ho., or one part of protein and two parts of water (Scherer). Its elasticity is due to the presence of water. It is sparingly supplied with blood vessels and nerves. The fibres are marked by transverse lines, in the lower animals, which shows that it is developed from cells. Its elasticity is impaired by age.

MODE OF DEVELOPMENT.—This is nearly the same in both white and yellow. They were supposed by Henlé to be developed by the process of fibrillation. Their real mode of growth was first pointed out by Schwann, to be from cells. The cells are developed from the plasma in the ordinary way. (See chapter on

cells.) They are at first round, and possess a nucleus, nucleolus and granular contents. They then become oval, then elongated, and finally fusiform; and being applied or spliced end to end in a linear manner, coalescence takes place, and a fibre is formed. At the same time the cells clear up, the nuclei become elongated, and finally disappear, until brought into view by means of acetic acid. In the white fibrous tissue, the bands are formed by the juxtaposition of several rows of cells thus arranged.

AREOLAR TISSUE, (Syn., Cellular, connective or filamentous.)—This tissue is found in all parts of the body except the brain, compact tissue of bone, teeth, cartilage, hair, nails, epidermis, &c. It consists of a network formed by a combination of white fibrous and yellow elastic tissue. Where great strength is required, the white predominates; and where motion is required, the yellow, as in the tissue of the lungs. The proportion of each may be easily demonstrated by acting on it with acetic acid, which swells out the white, while it produces no change on the yellow. The interstices or meshes (improperly called cells) of areolar tissue communicate with each other. This tissue, therefore, may be inflated with air (the butchers take advantage of this circumstance in inflating their meat), or the meshes may be filled with fluid, as in anasarca. The interstices, especially in the subcutaneous areolar tissue, are partially filled with adipose tissue, and contain a small quantity of serous fluid of an alkaline reaction, composed of water, albumen and chloride of sodium. When the fat is absorbed by the demands of the system, its place is filled with serous fluid, as in phthisis, &c.

FUNCTION.—Its function is to surround and connect various organs, and retain them at certain distances; at

the same time allowing a certain amount of motion. It also forms a nidus for the vessels and nerves, fills up spaces between different organs, and when the meshes are filled with fat, gives rotundity to the body. In some parts of the body it is very dense, and has received the name of a fibrous membrane, as in the pharynx, sheaths of vessels, &c. It forms sheaths for the muscles, and the bundles and fasciculi of which they are formed. It also forms sheaths for the vessels and nerves. It attaches the membranous expansions, as the mucous, cutaneous, serous and synovial membranes, to the structures which they surround and embrace, and receives the name of submucous, subcutaneous, subserous and subsynovial areolar tissue, respectively.

ADIPOSE TISSUE.

This was formerly described as nothing more or less than areolar tissue, with fat cells imbedded in its meshes. This is not the case, however, for it exists in parts in which not the slighest trace of areolar tissue can be found, as, for example, in the cancelli of the bones. On the other hand, the areolar tissue in many parts of the body is entirely destitute of fat, as, *e. g.*, beneath mucous membranes, in the cutis vera, between the rectum and bladder, in the eyelids, epicranial aponeurosis, scrotum, penis, &c., but in other parts of the body they are associated together.

PHYSICAL APPEARANCE AND PROPERTIES. — It is composed of cells or vesicles containing fat, which vary in size from $\frac{1}{300}$ to $\frac{1}{800}$ of an inch. They are usually deposited in clusters, being held together by a mesh of capillaries, which surround them, and from which they derive their nutriment. This constitutes a lobule. When the adipose tissue exists in considerable quantity,

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the lobules are held together by areolar tissue, constitu-
ting a *mass* of fatty tissue. At an early period of its
formation, the cell or vesicle possesses a nucleus and
nucleolus, the nucleus being imbedded in the cell-wall;
but they disappear at maturity. The cells or vesicles
are round, when isolated, but become polyhedral from
the flattening of their walls against each other. They
are long-lived, and exosmosis of the fat is prevented by
the constant moistening of their walls by a thin, serous
fluid which surrounds them, on the same principle that
a moist bladder will retain fatty matter, while a dry oné
allows it to exude.

ORIGIN AND FUNCTION.—This tissue is formed partly
from the fat used as food, and also by a chemical trans-
formation from the starch and sugar present in the
different articles of diet. This process is accelerated by
an imperfect supply of oxygen, as is seen in the fattening
of animals which are closely penned up. It fills up
spaces otherwise unoccupied, gives rotundity to the
body, forms a delicate pad or cushion to facilitate
the action of movable parts, as at the base of the heart,
in the orbit, &c., &c., and from being a bad conductor of
heat, it prevents its too rapid escape from the animal
body. This is exemplified in those animals possessing
little hair on their skin, in which there is a large
quantity of adipose tissue beneath the integument, as in
the seal tribe, &c. In other instances it gives ease to
the gliding movements of parts, and protects them from
the ill effects of sudden changes of temperature, as in
the adipose tissue of the omentum. As fat, it supplies
combustible material for the maintenance of the animal
heat of the body. It is stored away in the body, to be
used, when necessary, to maintain animal heat, and as a
source of nourishment, as in the hybernating animals.
(See oils and fats).

CARTILAGE.

This is a very simple form of tissue, and is found in many parts of the body. In some of the lower animals, as fishes, the skeleton is formed entirely of this tissue, as the skate, shark, sturgeon, &c.

PHYSICAL APPEARANCE AND PROPERTIES.—Its color varies from pearly white to light yellow, and it is possessed of a considerable degree of elasticity, flexibility and cohesive power. It yields chondrine, when boiled. Cartilage consists of cells imbedded in a hyaline or inter-cellular substance, or matrix. The cells are contained in cavities or lacunæ in the intercellular substance These cavities are lined by a thin membrane, the cartilage capsule. The cells are round or oblong, and vary in size from $\frac{1}{450}$ to $\frac{1}{2000}$ of an inch. Each cell contains a nucleus and one or more nucleoli. The nucleus varies in size from $\frac{1}{2400}$ to $\frac{1}{4000}$ of an inch, and some-times contains fat globules, as a result of some peculiar metamorphosis of the contents. Cell growth takes place by the process of multiplication by subdivision, and parent cells are frequently seen containing two or more young cells.

The intercellular substance is either homogeneous, granular, or fibrous.

Cartilage is divided into two great classes: *Temporary* and *Permanent*.

TEMPORARY CARTILAGE is that form which constitutes the original framework of the body, and which becomes completely ossified during the development and growth of the animal. In this variety of cartilage the inter-cellular substance is homogeneous, and not very abundant; but the cells are numerous, and placed at nearly equal distances apart. They are rounded or oval, and vary in size from $\frac{1}{1500}$ to $\frac{1}{2000}$ of an inch, the nuclei being finely

granular.   Near the seat of ossification the cells are arranged in rows, running towards the ossifying part, and become hardened by interstitial or secondary deposit.

PERMANENT CARTILAGE is not liable to ossify, and is found in different parts of the animal frame.   It may be subdivided into four varieties,—*articular, costal cartilage, membraniform* and *fibro-cartilage.*

ARTICULAR CARTILAGE. — This variety is found in joints, covering the articular surfaces of bones.   The intercellular substance is more abundant than in temporary cartilage, and presents a finely granular appearance. The cells are rounded or oval, varying in size from $\frac{1}{1300}$ to $\frac{1}{900}$ of an inch.   Near the surface of the cartilage, the cells are numerous, and arranged in flattened groups, lying with their planes parallel to the surface.   This appearance has been mistaken by some physiologists for a layer of epithelium.   In the interior of the cartilage, the cells assume a linear direction, pointing towards the surface.   This serves to explain the disposition this form of cartilage has to split up in a direction perpendicular to the surface.

COSTAL CARTILAGE.—In the costal cartilages, the intercellular substance is very abundant, finely mottled, and, in some situations, distinctly fibrous.   The cells are larger than in any other cartilages of the body, being from $\frac{1}{550}$ to $\frac{1}{450}$ of an inch in diameter.   Some contain two or more nuclei, which are transparent, and others contain nuclei and fat globules.   The cells often assume a linear arrangement, the rows being turned in different directions — probably the result of the growth of the cells by subdivision from the parent cell, and their subsequent separation from each other in a linear manner.

MEMBRANIFORM CARTILAGE.—This variety is arranged in the form of plates or lamellæ of various thickness, which enter into the formation of the external ear, nose, eyelids, larynx, trachea, and eustachian tubes. These plates serve to maintain the shape of tubes or passages which require to be kept open, without the expenditure of vital force. It approaches in character to the fibro-cartilage. The intercellular substance is distinctly fibrous on the exterior part of these cartilages, and some fibres may be traced into the interior. The cells are very numerous, and vary in size from $\frac{1}{1300}$ to $\frac{1}{900}$ of an inch.

FIBRO-CARTILAGE.—Fibro-Cartilage consists of a mixture of white fibrous and cartilaginous tissue in various proportions. It exists in four forms, *Interarticular, Connecting, Circumferential* and *Stratiform.*

The *interarticular fibro-cartilages* are flattened lamellæ of different shapes, placed between the cartilages of the temporo-maxillary, sterno-clavicular, acromio-clavicular, wrist and knee-joints. They are free on both surfaces; thinner at the centre than at the circumference, and are held in position by the surrounding ligaments. Their use is to increase the depth of the articular surfaces; to moderate the effects of great pressure; as a cushion, to deaden the intensity of shocks; to give ease to the gliding movements of these joints; and to increase the extent of the synovial membrane for secretion.

The *connecting fibro-cartilages* are placed between the bony surfaces of those joints which possess very little mobility; as between the bodies of the vertebræ, and the symphysis of the pubis, and serve to connect them toge-ther. They are in the form of discs, composed of concentric rings of fibrous tissue and cartilaginous laminæ placed alternately; the former predominating towards the circumference; the latter, towards the centre.

The *circumferential variety* consists of a rim of fibro-cartilage which surrounds the margin of some of the articular surfaces, and serves to deepen the cavity; as, *e.g.*, the glenoid and colytoid cavities.

The *stratiform fibro-cartilage* lines the grooves through which the tendons of certain muscles pass; as, *e.g.*, the bicipital groove.

VASCULAR SUPPLY.—Cartilage is chiefly supplied by imbibition. Temporary, costal and membraniform cartilages, are covered by a layer of white fibrous tissue, containing vessels, called the perichondrium. This corresponds to the periosteum of bones. It is from this covering that the cartilage receives its nutriment. When the cartilage is thin no vessels penetrate it; but when it is more than $\frac{1}{8}$ of an inch in thickness it contains canals for their transmission.

Articular cartilage does not contain any vessels, its nutrition being derived by imbibition from the vessels of the synovial membrane which skirt the circumference of the cartilage, and also from those of the cancelli of the adjacent bone, which are separated from the cartilage by the articular lamella. The vessels of the synovial membrane pass forward to the margin of the cartilage, and then return in loops, and those of the cancellous tissue pass to the internal surface of the articular lamella, form arches, and return to the substance of the bone.

Fibro-cartilage is supplied by the vessels of the synovial membrane and perichondrium, with which it is invested.

BONE.

This constitutes the solid frame-work of the body. It forms organs of support, levers for motion, or it encloses cavities, and protects delicate organs, as the brain, heart, lungs, &c.

PHYSICAL APPEARANCE AND PROPERTIES.—It is a hard, dense, opaque substance, of a whitish color, and possesses a considerable degree of elasticity. It consists of an *organic or animal,* and an *inorganic or earthy* material, intimately blended together; the animal matter giving to the bone its elasticity and toughness; the earthy part its hardness and density. The animal matter may be separated from the earthy by steeping the bone in dilute nitric or muriatic acid. In this way the earthy matter is dissolved out, and the bone becomes quite pliable—so much so, that the fibula, if so treated, can be drawn into a knot. The earthy constituents may be obtained by burning the bone in an open fire. By this means the animal matter is entirely consumed, and the earthy part remains as a white brittle substance. The relative proportion of these two substances varies in different persons, and in the same person at different periods of life. In the child, the animal matter forms about half the weight of the bone, but it diminishes as age advances, while the earthy matter increases. In certain diseases of the bones, as rickets and mollites ossium, there is a deficiency of earthy matter. Bone, when boiled, yields *gelatine,* and from the earthy matter may be obtained granules, varying in size from $\frac{1}{5000}$ to $\frac{1}{14000}$ of an inch.

CHEMICAL CONSTITUENTS.—In 100 parts :—

Organic matter—Gelatine, Blood-vessels, Nerves and Fat		33.30
	Phosphate of Lime	51.04
Inorganic or Earthy matter.	Carbonate of Lime	11.30
	Fluoride of Calcium	2.00
	Phosphate of Magnesia	1.16
	Soda and Chloride of Sodium	1.20

100·00

STRUCTURE OF BONE.—Bone presents two varieties of osseous tissue. The one is dense, firm and compact,

and always situated on the exterior of the bone, called
the *compact tissue;* the other, loose and spongy, enclosing
cells or cancelli, and situated internally, is called the
cancellous tissue. In the extremities of the long bones,
the cancellous tissue is most abundant, while in the
shaft the compact tissue predominates. In short and
flat bones, the two varieties are more evenly distributed.
The external surface of the compact tissue (except the
articular lamella) is covered by a dense fibrous mem-
brane, the periosteum. The interior of the long bones
presents a cavity called the medullary canal. This is
lined by a delicate membrane, the endosteum, which is
also prolonged into the extremities, and lines the interior
of the cancelli. The periosteum and endosteum are
abundantly supplied with blood-vessels, and are inti-
mately attached to the bone; and if either of them be
detached to any great extent, the bone perishes. They
also send prolongations, accompanied with vessels, into
the canals of the compact tissue for its supply.

If a transverse section from the shaft of a long bone
be examined under the microscope, a number of aper-
tures, surrounded by a series of concentric rings, may be
seen. These apertures are sections of the Haversian
canals (named after the discoverer, Clopton Havers), and
the rings are sections of the lamellæ which surround
the canals. Surrounding the Haversian canals, in a
concentric manner, may be seen a series of dark spots or
centres, called lacunæ. These communicate with each
other, and with the Haversian canals, by minute tubes,
called canaliculi or pores. The whole constitutes an
Haversian system, and is a provision made for the supply
of the compact tissue.

The Haversian canals in the long bones run nearly
parallel to each other and to the long axis of the bone;

but in the irregular and flat bones, they are irregular in their direction. They vary in size from $\frac{1}{200}$ to $\frac{1}{2000}$ of an inch, and communicate freely with each other and with the outer and inner surfaces of the compact tissue, by means of transverse and oblique canals. Those near the surface are lined by a prolongation of the periosteum, and those near the medullary canal by the endosteum. They give passage to small arteries and nerves for the supply of the bone. The small arteries are derived from the nutrient artery, the vessels of the periosteum and endosteum. The laminæ which surround the Haversian canals vary in number from 8 to 15, and are called the Haversian lamellæ. Besides these, some appear to be arranged concentrically, around the medullary canal of the shaft; these are called circumferential, and others are situated between the Haversian systems, called interstitial lamellæ.

LACUNÆ.—The lacunæ are arranged in concentric circles around the Haversian canals. They are small cavities of a semi-lunar shape, the concavity being turned towards the Haversian canals, and they vary in size from $\frac{1}{1400}$ to $\frac{1}{2000}$ of an inch. They are reservoirs for the plasma of the blood, previous to its absorbtion by the tissue. These have been called bone corpuscles, by Virchow.

CANALICULI.—These are small tubes or pores which issue from all parts of the circumference of the lacunæ. They communicate with those from adjacent lacunæ, and some open on the free surface of the bone. By this arrangement the plasma of the blood is carried into every part. They vary in size from $\frac{1}{14000}$ to $\frac{1}{20000}$ of an inch in diameter.

In cancellous tissue, and in the *articular lamella* which supports the articular cartilage, there are no

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Haversian canals, and the lacunæ are larger than ordinary.

DEVELOPMENT.—Bone is formed from temporary cartilage. The cartilage is an exact representation of the bone which is to take its place.

Ossification commences in the cartilage at certain points, called points or centres of ossification.

In long bones there is usually a central point for the shaft, and one for each extremity. The central point is called the *dyaphysis*, the extremities the *epiphysis*. The point of ossification of a process, as, *e. g.*, the olecranon, is also called the epiphysis, and when finally joined to the shaft, an *apophysis*. The period at which ossification begins varies in different bones. The earliest is the clavicle, which begins about the fourth week of fœtal life; next, the lower jaw, then the ribs, vertebræ, femur, humerus, tibia, upper jaw, &c., in order of succession.

Temporary cartilage, from which bone is formed, consists of small, nucleated cells, uniformly scattered through a homogeneous, intercellular substance. The nuclei are large, and present a granular appearance. Near the seat of ossification, the cells are arranged in rows turned towards the ossifying part. The intercellular substance between the rows becomes ossified, so as to form lamellæ, so that each row of cells is enclosed in an areola or cancellus. The rows of cells then arrange themselves on the inner surface of the newly-formed areolæ or cancelli, and become ossified by secondary deposit—the nuclei remaining granular, and subsequently forming the lacunæ. At the same time, within the cancelli, granular blastema appears, from which new cells are formed, which are destined for the future growth of the bone. These, in their turn, become ossified in successive layers; hence the laminated

appearance of bone. When the cancelli are partly filled in this way, this process is arrested, and subsequently these cancelli communicate with others in the same line, and ultimately become the *Haversian canals.* The granular nuclei of the cartilage cells clear up, and constitute the *lacunæ.* Each nucleus throws out arms or projections in every direction, which meet others from adjacent nuclei, and in this way canaliculi or pores are formed. The lamellæ of bone, which were formed by the condensation of the intercellular substance, contain no lacunæ or canaliculi, and form a separating line between the Haversian systems.

GROWTH.—The growth of bone takes place by layers formed in succession on its external surface—*exogenous* —and also in an interstitial manner. Bones increase in length by additions between the points of ossification, and by accessions of osseous tissue to the extremities. This may be shown by inserting metallic substances in the shaft at certain distances apart, when it will be seen that, notwithstanding the increase in length of the bone, the distance between them remains the same.

Bones increase in diameter by additions of osseous tissue on their exterior. The osseous tissue thus added is not a mere lamina of bone, but consists of complete Haversian systems, the earlier systems being completely covered over by the more recent ones. This may be demonstrated by feeding animals with madder. The coloring principle is precipitated with the phosphate of lime, and on examination, beautiful crimson rings are seen encircling the Haversian canals. This appearance is confined chiefly to the external or vascular surface. When the madder has been given at intervals, colored and colorless portions alternate with each other. The color remains a long time, indicating a slow change of this tissue.

In early life there is no medullary canal in the shaft of the long bones, its place being filled with cancellous tissue. This tissue, however, becomes gradually absorbed as age advances, until about the twenty-fourth year, when the canal is completely formed. It is lined by the endosteum, and contains fat, blood vessels, areolar tissue and some fluid containing salts. This is commonly called the marrow.

REPAIR OF BONE.—Directly a fracture occurs, blood is of course effused round the broken ends. After a short time, lymph is thrown out from the vessels of the medullary canal, Haversian canals, and periosteum. This lymph is substantially the same as in other wounds. In the course of from ten days to a fortnight it becomes condensed into a substance resembling temporary cartilage. In the mean time the effused blood is absorbed and carried away. This cartilaginous substance becomes ossified towards the fourth or fifth week, and forms an investment for the exterior of the broken ends, serving to maintain them in apposition. A stem of this substance may also be seen in the medullary canal, when the shaft has been broken across. This exterior investment and the stem are called *provisional callus*—because it is subsequently absorbed; while that which is deposited directly between the broken extremities is called *permanent callus*, and possesses all the features of true bone. When any accident interferes with the reparative process, and prevents the development of osseous tissue, ligamentous union takes place, or a false joint is formed.

MUSCLE.

The muscles are those organs by which the various movements of the body are effected. They possess the

property of contractility, and consist chemically of fibrin. They are divided into two great classes, *Striated* and *Non-striated*. These two varieties may be distinguished from each other—1st. By their color; the striated are reddish in color, while the nonstriated are pale. 2nd. By the aid of a microscope; the striated muscular fibres are characterized by being marked with transverse, lines or striæ; other striæ pass longitudinally, indicating the direction of the fibrillæ. The nonstriated muscular tissue consists of pale-colored fusiform fibre cells. 3rd. By galvanism. The striated respond to galvanism instantly, by a clonic spasm, while the nonstriated respond slowly by a tonic spasm.

Muscular tissue is divided into *voluntary* and *involuntary*, according as it may happen to be under the express control of the will, or entirely independent of it.

STRIATED.—This variety of muscular tissue comprises the whole of the voluntary muscles, the muscles of the ear, tongue, larynx, pharynx, upper part of the œsophagus, heart, and the veins, at their entrance to the heart. When a transverse section of a muscle, as the sartorius, is examined by the microscope, it appears to be formed of a number of large bundles of muscular tissue, enclosed in a coat of areolar tissue, which constitutes the sheath of the muscle. Each larger bundle consists of numerous smaller ones, enclosed in a similar covering, derived from the sheath of the muscle. Each smaller bundle contains the *primitive fasciculi or fibres*, and each primitive fibre contains the *primitive fibrillæ*.

In the spaces between the bundles may be seen the vessels and nerves for the supply of the tissue.

THE PRIMITIVE FASCICULI OR FIBRES.—Each primitive fibre contains hundreds of primitive fibrillæ, and is

surrounded by a sheath of transparent homogeneous membrane, called the *myolemma* or *sarcolemma*. The primitive fibres are cylindrical or prismatic in shape, and vary in thickness from $\frac{1}{200}$ to $\frac{1}{500}$ of an inch; their length is not always co-equal with the length of the muscle, but depends on the arrangement of the tendons, and tendinous intersections. They are marked by fine, dark, wavy, or curled parallel lines or striæ, from $\frac{1}{10000}$ to $\frac{1}{12000}$ of an inch apart, which pass transversely around them; this is characteristic of this variety of muscular tissue. Other lines, less distinct, run longitudinally, indicating the direction of the fibrillæ of which the fibre is composed.

THE PRIMITIVE FIBRILLÆ.—These constitute the proper contractile tissue of the muscle. They are cylindrical or prismatic, sometimes flattened—depending on pressure—vary in thickness from $\frac{1}{10000}$ to $\frac{1}{18000}$ of an inch, and are marked by transverse striæ, with which those on the surface of the fasciculi correspond. Each fibrilla consists of a single row of minute particles, named "*sarcos elements*," connected together like a string of beads. Upon close inspection, these particles present a rectangular outline, and the fibrillæ appear to consist of light and dark spots placed alternately; hence their striated appearance. The transverse striæ vary from $\frac{1}{10000}$ to $\frac{1}{12000}$ of an inch apart in the human subject; in birds $\frac{1}{10400}$, in reptiles $\frac{1}{11500}$, in fish $\frac{1}{11100}$, and in insects $\frac{1}{9500}$ of an inch apart.

NONSTRIATED.—This variety consists of flattened bands, or elongated fusiform fibre-cells, of a pale color, from $\frac{1}{4700}$ to $\frac{1}{3100}$ of an inch broad, finely granular, and containing a rod-shaped nucleus, which sometimes appears as a dark streak. These fibre-cells may assume

different shapes; some are fusiform, others club-shaped, and others again are of a rectangular shape, with fringed extremities. The average length of these fibre-cells is about $\frac{1}{50}$ of an inch. They are held together by areolar tissue, and the bands are applied to each other in such a way as to encircle the organ into the formation of which they enter. This kind of tissue is found in the ducts of the salivary glands, trachea and bronchi, alimentary canal, from the lower part of the œsophagus to the internal sphincter, gall bladder and ducts, calyces and pelvis of the kidney, ureters and bladder, and in the urethra. In the female, in the vagina, uterus, fallopian tubes and round ligaments. In the male, in the scrotum, epididymus, vas deferens, vesiculæ seminales, prostate and cavernous bodies, in the coats of arteries, veins and lymphatics, in the iris and ciliary muscle, and in the integument called *arrectores pilorum.*

MODE OF DEVELOPMENT.—The myolemma or sarcolemma of the primitive fibre is first developed, being distinctly visible long before any trace of the fibrillæ can be seen. This is formed by the arrangement of a series of nucleated cells in a linear manner; the contiguous walls break down, and thus a tube is formed, the wall of which constitutes the sarcolemma. Some of the nuclei still remain within the tube, while others break down; granular matter is developed in the interior, a process of consolidation takes place, and the granules or *sarcos elements* are arranged in the utmost order according to the two directions already specified—longitudinally and transversely. The arrangement of the granules or *sarcos elements* in a linear manner constitutes a primitive fibrilla, and thus the whole mass within the tube or myolemma is converted into primitive fibrillæ. Some of the nuclei which still remain may be seen in the adult

fibre when treated with acetic acid. According to some authorities, the primitive fibrillæ are composed of a succession of small cells from $\frac{1}{10000}$ to $\frac{1}{18000}$ of an inch in diameter, filled with a transparent substance called musculine, and connected together by their flat surfaces. When a primitive fibrilla is examined under the microscope, there is seen a series of light and dark spots placed alternately. The light spots correspond with the centre of the sarcos elements (or cells of some), and the dark spots with the lines of junction of the pairs; but when the fibrillæ are examined collectively in the primitive fibre, this appearance is exactly reversed, the centre of the sarcos elements (or cells) being dark, and the lines of junction constitute the bright-bands, or striæ characteristic of this variety of tissue. The light and dark spots have each a quadrilateral, and generally a rectangular form. There is no difference in the early stage of development between the striated and nonstriated varieties of muscular tissue, both being developed from cells; but whilst the striated variety goes on to complete development into fibrillæ, the nonstriated retains permanently its cellular condition.

ATTACHMENT OF TENDONS.—Nearly every muscular fibre is attached by its extremity to fibrous tissue. The sarcolemma terminates abruptly at the end of the muscular fibre, and the fibrous tissue of the tendon is attached to its truncated extremity. The fibre generally ends by a perfect disc, to the whole surface of which the tendon is connected, and it also blends more or less with the sarcolemma. In other instances, when the muscle is attached obliquely to a tendinous or membranous surface, the muscular fibres are obliquely truncated at their extremities.

CHEMICAL CONSTITUENTS.—Muscular tissue consists as follows in 100 parts:

Water 77.17
Musculine... .... 15.80
Albumen and Hematine... 2.20
Gelatine 1.90
Extractive and Fatty Matter and Salts 2.93
                                                          ———
                                                          100.00

It swells out on the addition of acetic acid, and is partially dissolved. It is also soluble in hydrochloric acid, and is precipitated by ferrocyanide of iron. Muscular tissue is sometimes changed into a substance called *adipocere.* (See oils and fats.)

VASCULAR SUPPLY.—The arteries intended for the supply of the muscle pierce the sheath, and divide and subdivide, giving off small branches which pass between the bundles of which it is composed, until the ultimate twigs insinuate themselves between the primitive fasciculi or fibres, and terminate in the capillaries. Some of these, the longitudinal, course along the fibres, lying in the intervals between them, and others pass transversely across them. The length of the longitudinal capillaries is about $\frac{1}{20}$ of an inch; the transverse vary according to the size of the fibres. The fibrillæ are, therefore, supplied by imbibition through the sarcolemma.

NERVOUS SUPPLY.—The nerves are distributed similarly to the arteries until the filaments reach the fasciculi or fibres. They then form a series of loops, which either return to the same trunk, or join an adjacent one. It is stated by some Physiologists that the nerves pierce the sarcolemma. As they pierce the fibre, their covering becomes continuous with the sarcolemma, and the nerves pass into the interior, and are distributed among the fibrillæ, and terminate either in free extremities, loops, or nerve buds (as they are called).

PROPERTIES OF MUSCULAR TISSUE.—The distinguish-
ing characteristic of muscular tissue is its property of
contractility, irritability or *tonicity.* Some have endea-
vored to draw a distinction between these terms; but,
after all, it is a distinction without a difference. The
primitive fibrilla is the proper contractile tissue of the
muscle. Still, it is a disputed point as to whether or not
it possesses this property in itself, some maintaining
that nerve is necessary to charge it with contractility ;
others that nerve is only necessary to call it into action,
and that this property is inherent in the tissue itself. It
is caused by a change in the shape of the sarcos elements.
In contraction they become shorter and thicker; this
change travels rapidly from one end of the *fibrilla* to the
other, and the muscle is thus very much shortened.
Some vegetable structures possess an analogous property,
as *e. g.*, the mimosa or sensitive plant, and venus' fly-trap
(Dionœa). If touched ever so slightly, the irritation
causes a change in the shape of the cells, followed by a
change in the shape or position of the whole leaf, in
consequence of the change travelling from one cell to
another. The property, therefore, of contractility is
inherent in the muscular fibrilla itself, and may be called
into action by various kinds of stimuli, as by nervous
influence, by pinching or pricking the tissue, by the
action of an acid or an alkali, or by galvanism. The
effect of the application of any of these stimuli varies
according to the kind of muscular tissue to which it is
applied. If a portion of striated muscle be irritated,
those fibres which are touched will contract, and those
only, the motion not being communicated to any other,
and the contracted part soon becomes relaxed—the spasm
is clonic.

If, on the other hand, a portion of nonstriated muscle

be irritated, as the alimentary canal, the contraction takes place more slowly, the spasm is long continued, or tonic, and the movement is communicated to other fibre-cells, until a considerable part of the canal is affected. The muscular fibre is shortened and thickened during contraction, and sometimes thrown into a zigzag shape, and some Physiologists, mistaking the effect for the cause, concluded that the zigzags occasioned the shortening. Contractility continues for a short time after death. This may be demonstrated by applying to the muscular tissue any of the above-mentioned stimuli which are known to affect it during life. The duration of this property after death varies in different animals. In birds, only a few minutes after death; in quadrupeds much longer; while in reptiles it remains for many hours, owing to the nutritive changes being more sluggish in these than in warm-bloods, and the sarcos elements being slowly formed and sluggish in their action, are long-lived.

If irritation be continued, the contractility or irritability of the muscle is soon exhausted. The circulation of arterial or oxygenated blood is not only necessary for the purposes of nutrition, but also to the continuance of contractility. The muscles will preserve their contractility after death, and the action of the heart itself will continue for a long time, if the circulation be kept up by artificial respiration. If the blood be charged with carbonic acid, or chloroform, ether, sulphocyanide of potassium, or a narcotic poison, as opium, &c., the contractility of the muscles is speedily destroyed.

Every act of contraction involves the death of a certain amount of muscular tissue, and prolonged exertion causes fatigue, which is an evidence of an impaired condition. Rest is necessary to recovery, and recovery is due to the nutritive process; hence the more a muscle is

used, provided it receives a sufficient amount of rest and nutrition, the more vigorous and bulky does it become ; as *e. g.*, the arm of the smith, and the legs of the rope-walker. On the other hand, disease, as paralysis, or sedentary habits, cause them to become flabby and atrophied, but this may be remedied by exercise, and the use of friction and galvanism. In some constitutions they are liable to fatty degeneration.

Muscular contraction produces a *sound* resembling the distant rumbling of carriage wheels. This is caused by the movements of the fibres upon each other. For example, the sound caused by the contraction of the masseter and temporal muscles may be distinctly heard in the stillness of the night, by placing the side of the face and ear on the pillow, and clenching the teeth firmly together.

There is also an *elevation of temperature* of from 1° to 2° F. This depends partly on the chemical changes which take place in the muscle, as a result of its action, and partly upon the friction consequent on the movements of the fibres upon each other.

RIGOR MORTIS.—This is the stiffening of the muscles which takes place after death. This condition is rarely absent; but it may be very slight, and continue only a short time. Sometimes it comes on within 15 or 20 minutes after death, as in typhus fever. It commonly takes place within 7 or 8 hours after death; but in some cases it may be deferred for 20 or 30 hours. It continues for 24 or 36 hours; but it may pass off much more rapidly, or be continued for several days. This rigor mortis is a sort of tonic contraction of the muscles, and in some cases it may be very violent—as after death from cholera and yellow fever—and has given rise to many absurd superstitions among the uninitiated.

It is most remarkably manifested in the nonstriated muscular tissue, as in the arteries and alimentary canal. In consequence of this contraction, the bowels are not unfrequently moved after death; the arteries are found empty, and so contracted that they cannot be injected until the rigidity passes off. When the rigor mortis subsides, decomposition of the muscular tissue begins; hence we may regard it as the last act of life, and in this respect it corresponds to the coagulation of the blood, when drawn from the body. The same causes that interfere with the coagulation of the blood after death, interfere, also, with the rigor mortis of the muscles, as in animals hunted to death, or killed by lightning, in which both coagulation and rigor mortis are imperfect.

LEVERS.—In the action of most muscles, and especially those of the extremities, examples of the three orders of levers are afforded.

In the *first order* of levers the power is at one end, the weight at the other, and the fulcrum between the two.

In the *second order*, the power is at one end, the fulcrum at the other, and the weight between the two.

In the *third order*, the fulcrum is at one end, the weight at the other, and the power between the two.

The first order of levers, although the most powerful, is that least used in the animal economy, as its use is less productive of extensive motion. The action of the gastrocnemius muscle affords an example of this order, as when the foot is raised from the ground, and extended to raise the os calcis and depress the toes; here the moving power is the gastrocnemius attached to the os calcis, the weight is the anterior part of the foot, and the fulcrum is the ankle joint.

The same muscle affords an example of the second order of levers, as when the foot is placed on the ground and the body raised by the action of the muscle; here the moving power is the gastrocnemius, the fulcrum the anterior part of the foot- resting on the ground, and the weight or resistance the body resting on the ankle joint.

The ankle joint also affords an example of the third order of levers, as when the foot is raised from the ground and flexed on the ankle joint; here the moving power is the tibialis anticus and peroneus tertius, the fulcrum is the ankle joint, and the weight the anterior part of the foot.

The biceps of the arm also affords a good example of the third order, as when a ball or weight is placed in the hand; here the moving power is the biceps inserted into the tuberosity of the radius, the fulcrum is the elbow joint, and the weight is in the hand. In this position, power is sacrificed to extent of motion, as in raising the hand and weight these pass through the arc of a circle of considerable dimensions, while the extent of motion at the insertion of the power is extremely limited. This is still more obvious when we hold a rod in the hand, as a fishing-rod or whip, the extreme end of which is made to pass through a space of considerable magnitude compared with that of the part where the power is applied. The great advantage derived from this disposition of levers in the human body, whereby motion is gained at the expense of power, is seen in the various acts of walking, running, leaping, &c., &c.

CHAPTER IV.

MEMBRANOUS EXPANSIONS.

THESE are the *serous* and *synovial, mucous* and *integument*. The serous and synovial membranes form shut sacs, with the exception of the peritoneum, in the female, which communicates with the uterus through the fallopian tubes.

The mucous membrane lines cavities which communicate with the external surface, and is continuous with the integument. The integument covers the exterior of the body, and serves not only as a means of protection, but also as an organ of sensation. The mucous and integument are convertible membranes. The structure of these membranes is very nearly the same in each instance. They consist of a basement membrane, lined by epithelial cells on the free surface, and presenting vessels, nerves and lymphatics imbedded in areolar tissue, which connects it with the subjacent parts. They therefore consist of *three parts—basement membrane*, with *epithelial cells* on one side, and *blood-vessels, nerves* and *lymphatics*, imbedded in areolar tissue, on the other.

1st. BASEMENT MEMBRANE.—The different varieties of basement membrane have been already described in Chapter II. Its function is to support the cells, and probably influence their development; to limit osmosis of the nutrient fluid from the subjacent capillaries, and modify it in its passage.

2nd. EPITHELIUM.—The cells which line the free surface of the membranous expansions are called *epithelium.*

There are two principal varieties of epithelium, viz.:
1st. *Tesselated, pavement, squamous, laminated* or *scaly*.
2nd. *Columnar* or *cylindrical*. In the serous, synovial,
and mucous membranes there is generally a single layer
of cells, with a quantity of granular matter and a layer
of partially developed cells lying on the basement mem-
brane; but in the integument there are several, the outer
being flattened, scaly, and hardened by secondary
deposit. The cells which line the serous, synovial and
mucous membranes, secrete a fluid which is intended to
lubricate the surface, to prevent the ill effects of friction,
and to give ease to the gliding movements of the parts
over each other. This fluid is formed as a result of the
growth, maturity and decay of the cells.

1st. TESSELATED, PAVEMENT, SQUAMOUS, OR SCALY
EPITHELIUM.—The cells of this variety are flattened and
polygonal in shape, and vary in size from $\frac{1}{800}$ to $\frac{1}{2800}$ of
an inch broad. Each cell contains a nucleus, nucleolus,
and granular matter. They are, in general, not very
active, and are therefore long-lived. In health, they
secrete only a limited quantity of fluid. Those which
line the synovial membranes, mucous membrane of the
mouth, and parts of the body in which a greater supply
of fluid is requisite, are somewhat rounded in shape and
much more active. Tesselated or pavement epithelium
lines all the serous and synovial membranes, the mucous
membrane of the mouth, lower part of the pharynx,
œsophagus, upper part of the larynx, intercellular pas-
sages (so called), and air cells, lining membrane of the
ventricles of the brain, tympanum, anterior and posterior
chambers of the eye, conjunctiva and canaliculi, veins,
and lymphatics, lower part of the vagina, bladder, and
urinary passages, vesiculæ seminales, and vas deferens.
Those cells which line the bladder and urinary passages

are somewhat spheroidal in shape, and would seem to be an intermediate variety.

2nd. COLUMNAR OR CYLINDRICAL EPITHELIUM.—This variety is cylindrical in shape, as the name indicates, and placed side by side, one extremity of the cell resting on the basement membrane, and the other forming the free surface. They vary in size from $\frac{1}{2500}$ to $\frac{1}{3500}$ of an inch in thickness, and from $\frac{1}{300}$ to $\frac{1}{1100}$ of an inch in length. Each cell contains a nucleus and nucleolus. In some parts, as in the gastro-intestinal canal, there appears to be a double layer of cells; this depends on their rapid development in these parts, the lower layer being the new cells which are rising up to take the place of the old. These cells not only line the free surface of the membrane, but also dip into the follicles, at the bottom of which they become rounded or *glandular*. This is owing to their greater activity in the latter situation. In some instances their free extremities are club-shaped, in order to comport with their position, as when they stand on the angles formed by the dipping of the follicles.

This form of epithelium is found in the alimentary canal, commencing at the cardiac orifice of the stomach, in the ducts which communicate with it, the gall bladder, nose, nasal ducts and lachrymal sacs, frontal sinuses, and antra, posterior surface of the palate, upper part of the pharynx, eustachian tubes, larynx—below the superior vocal cords—trachea and bronchi, upper part of the vagina, uterus, and fallopian tubes.

CILIÆ.—Both varieties of epithelial cells occasionally present a number of minute, conical-shaped filaments or prolongations attached to their free extremities or surfaces, termed *ciliæ*. They are attached by their bases to the cells, their free extremities being tapered, and they vary in length from $\frac{1}{500}$ to $\frac{1}{13000}$ of an inch. From

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five to thirteen may be seen attached to each cell.   They
are in continual motion; each filament appears to bend
from its root to its point and return to its original state, so
as to resemble the waving of a wheat field in a gentle
breeze.   This motion is independent both of the will
and the life of the animal, as it is seen to continue after
death.   Epithelial cells of the nose may be seen to float
about in water by the agency of their ciliæ, several hours
after they have been removed from the mucous sur-
face; and the motion of the ciliæ has also been observed
in the body of the tortoise fifteen days after death.   The
object of the ciliary motion is to propel fluids over the
surface, in the direction which the secretion is destined
to take, whether external or internal, the movement
being generally towards the outlets.   In fishes, the
external surface of the gills is covered with ciliæ, which
serve to propel the water, and bring fresh portions in
contact, for the purpose of aërating the blood.   In many
of the lower animals, they serve not only to produce
currents for respiration, but also to draw into the mouth
minute particles which serve as food.

GROWTH AND MOTION OF THE CILIÆ.—The ciliæ
may be considered as prolongations of the cell itself.
They are not seen in the early stage of development of
the cell, but make their appearance as it arrives at
maturity.   Their growth depends on the accumulation
of the plasma or nutrient fluid of the cell at that parti-
cular part, determined by the plastic or vital power
inherent in the cell.   (See Chapter II.)

The motion is due to the vitality of the cell, and not
to the presence of a kind of delicate muscular tissue, or
to nervous force, as some have suggested.   It has already
been shown, in the preceding chapter, that the motion of
muscular tissue is due to a change in the shape of the

sarcos elements. Now, in the same way, the motion of the ciliæ may be produced by a change in the shape of the cells to which they belong, so that by an alternate contraction and relaxation of the opposite sides of the cell wall, the ciliæ would be made to wave as they are seen to do.

The epithelial cells are developed from the blastema supplied by the vascular layer beneath the basement membrane.

Ciliated epithelium of the tesselated or squamous variety is found in the lining membrane of the ventricles of the brain, tympanum, intercellular passages (so called), and in the air cells.

Ciliated epithelium of the columnar variety is found in the cavity of the nose (except the roof), nasal ducts, lachrymal sacs, frontal sinuses, maxillary antra, eustachian tubes, posterior surface of the palate, upper part of the pharynx, (extending as low down as the floor of the nares), larynx, below the superior vocal cords, and the anterior part above, upper part of the vagina, uterus, and fallopian tubes.

SEROUS MEMBRANES.

The serous membranes are the arachnoid, pleura, pericardium, peritoneum, tunica vaginalis, and the lining membrane of arteries, veins, and lymphatics. Each membrane, respectively, lines the cavity to which it belongs, being attached to the wall by means of areolar tissue. This is called the *parietal layer.* It is then reflected upon the contained organ forming the *visceral layer.* The free surface is lined by tesselated or squamous epithelium, which in health secretes a limited quantity of fluid for the purpose of moistening the surface, the process of secretion and absorption being exactly counterbalanced. If the secretion be morbidly

increased it is retained in the cavity, and gives rise to dropsies which receive different names in different parts of the body; in the cavity of the arachnoid, hydrocephalus; in the pleura, hydrothorax; in the pericardium, hydropericardium; in the peritoneum, ascites; in the tunica vaginalis, hydrocele. The secretion is called serous fluid, and is similar to the serum of the blood. It has an alkaline reaction, and consists of water, albumen, and salts. The quantity of albumen varies in different parts. In the serous fluid of the pleura there are 2.85 parts in a hundred; in the peritoneum, 1.13 parts; in the arachnoid, .6 to .8; in the subcutaneous areolar tissue, .36.

The amount of albumen seems to depend upon the activity of the part, the density of the membrane, and the pressure brought to bear upon the capillaries, so to speak.

SYNOVIAL MEMBRANES.

The synovial membranes are placed between the articular surfaces of the bones, and in the fœtus they are prolonged over the articular cartilage; but in the adult they cover merely the margin to the extent of a line or two, and are then reflected on the inner surface of the ligaments, to which they are attached by areolar tissue. In some instances they send prolongations into the interior of the joints, as for example, the (so called) alar ligaments of the knee joint. The free surface of the synovial membrane is smooth and moist, being lined by a layer of tesselated or squamous epithelium, which secretes the synovia, for the purpose of lubricating the joint, and preventing the ill effects of friction. If the secretion be morbidly excessive, the result would be *hydrops articuli.*

SYNOVIA is a transparent, viscid, oily-looking fluid, and resembles the white of an egg, hence its name (συν, cum; ωον, ovum.) It has an alkaline reaction, and contains water, albumen and salts. It contains more albumen than serous fluid, more being necessary on account of the greater amount of motion in the joints.

BURSÆ.—A reflection of synovial membrane in the form of a closed sac, is found beneath some of the tendons where they glide over bony surfaces. This is called a *synovial bursa.* When they are situated near a joint they sometimes communicate with its synovial cavity. When they surround a tendon in its passage, they are called synovial sheaths. There is another variety of bursæ situated between the integument and bony prominences, as between the integument and patella, olecranon, &c. These are called *bursæ mucosæ*, and are nothing more or less than an enlarged mesh in the areolar tissue, surrounded by condensed fibres, and presenting a partial or incomplete secreting surface.

Synovial membranes are more readily reproduced than serous membranes. It is doubtful whether the latter are reproduced at all or not; but new joints are formed and lined by synovial membrane, as is seen in old-standing dislocations of the hip, &c. Serous membranes, when inflamed, pour out a plastic substance, which has a tendency to organize and form bands; but in inflammation of synovial membranes there is a tendency to the formation of pus.

STRUCTURE OF SEROUS AND SYNOVIAL MEMBRANES.— They are very nearly alike. On their free surface is a layer of epithelium, of a polygonal shape, and more or less transparent. This rests on the basement membrane, which is also nearly transparent, and very thin. Beneath the basement membrane is a layer of areolar tissue, in

which are imbedded the vessels, nerves and lymphatics; this constitutes the chief thickness of the membrane, and gives it strength and elasticity. The areolar tissue is more condensed beneath the basement membrane, and becomes more lax near the subjacent tissue. The vessels are arranged in a plexiform manner, running parallel with the basement membrane. In parts of the body where there is much motion, and a greater supply of blood is necessary, as beneath the pleura and the synovial membranes, the vessels are tortuous.

MUCOUS MEMBRANES.

These resemble the serous and synovial in lining cavities, but they are not shut sacs. They line the interior of the alimentary canal from the mouth to the anus, the ducts, and interior of glands which communicate with it; the nose and the passages which open into it, the larynx, trachea, bronchi, and air cells, bladder and urinary passages, vagina, uterus and fallopian tubes. The free surface of the mucous membrane is lined by a layer of epithelium, generally of the columnar variety; the exceptions are the mouth, upper part of the larynx, lower part of the pharynx, œsophagus, tympanum, intercellular passages and air cells, lower part of the vagina, bladder and urinary passages. The cells secrete a fluid called *mucus*, which is intended to lubricate the surface, and protect it from the contact of air, and any irritating substance to which it may be exposed.

Mucus is a transparent, viscid, semi-fluid substance, of great tenacity, insoluble in water, but may be readily dissolved by any alkali, and precipitated again by an acid. A substance resembling mucus may be obtained from any fibrinous exudation, or even from pus, by treating it with liquor potassa and agitating it. Any

irritation to the mucous surface, from whatever cause, will increase the secretion of mucus, as for example the use of snuff, &c. It consists of about 95 to 95½ parts fluid, and from 4½ to 5 parts solid matter. The organic matter is termed *Mucine* or *Mucosine*. Mucus consists of

Water	95.5
Mucine	3.4
Fatty Matter	.3
Salts	.8
	100.00

The salts consist of chloride of sodium, .6 parts, phosphate, sulphate, and carbonate of soda and potassa, .2. The part of the body from which the mucus is obtained may be determined by the form of epithelium present in it.

STRUCTURE.—The mucous membrane, like the serous and synovial, consists essentially of three parts; the *epithelium*—the *basement membrane*—and the *areolar tissue*, in which the vessels, nerves, and lymphatics are imbedded, and which connects it with the subjacent parts. The latter gives the membrane its thickness, and is made up of white fibrous, and yellow elastic tissue, vessels, &c. In the mucous membrane of the erectile tissues, as in the organs of generation, some nucleated, fusiform, muscular fibre-cells are seen imbedded in the areolar tissue. The epithelium not only covers the free surface of the membrane, but also dips down to line the follicles, ducts, &c. It also covers the surface of the villi and valvulæ conniventes. The relative amount of vessels, nerves, and lymphatics, depends upon the activity of the parts, and these are also more tortuous where a large supply of mucus is requisite. Some parts of the mucous surface are not so sensitive as others; for example, the passage of food is not felt in the œsophagus, stomach,

and intestines, until the fæcal matter reaches the rectum, when a sensation is felt demanding its discharge. This depends on its nervous supply—the rectum being largely supplied by spinal nerves, while the rest of the intestines, stomach, and œsophagus, are more directly under the influence of the sympathetic system. Mucous surfaces are not disposed to form adhesions in inflammation, owing to the presence of the epithelium and mucus. These change the character of the plastic material, and cause it to degenerate into pus; but if the epithelium be entirely removed a partial organization takes place, as may be seen in fibrinous casts of the alimentary canal in dysentery, when not of a very low type.

APPENDAGES OF THE MUCOUS MEMBRANE.

In certain parts of the body, where a large amount of mucus is necessary, as in the alimentary canal, the mucous membrane is provided with papillæ, follicles, valvulæ conniventes, villi and glands. These are termed appendages.

PAPILLÆ. Of these there are two kinds, *spongy* or *vascular*, as found in the tongue, &c., and *rough* or *horny*, as found in the integuments of the palms of the hands and soles of the feet. In the integument they are the organs of touch or *tactile organs;* in the tongue, the organs of the special sense of *taste*, and also of touch; the former will be described with the integument.

A papilla is a slight elevation of the surface of the membrane of which it forms a part, consisting of the basement membrane, covered by one or more layers of epithelium, and containing within a reticula of capillaries, nerves forming loops, lymphatics, and in some instances nonstriated muscular fibre-cells, the latter causing it to contract and become prominent when any

irritation is applied. Some of the papillæ are cleft, as for example, those in the back part of the dorsum of the tongue and in the hands.

The principal varieties of papillæ of the tongue are—the *circumvallate*, *fungiform*, and *filiform*.

The *circumvallate* papillæ are of a large size, and vary in number from eight to ten. They are situated on the dorsum of the tongue, near its base, and consist of a row on each side, which runs obliquely backwards and inwards, to terminate in one large papilla situated in the median line, called the *foramen cæcum*. The two lines resemble the letter V inverted. Each papilla consists of a circular flattened projection of the mucous membrane, from $\frac{1}{20}$ to $\frac{1}{12}$ of an inch in diameter, surrounded by a narrow circular fissure, this fissure being again surrounded by a narrow circular elevation of the mucous membrane. The whole surface of these papillæ are studded with numerous smaller or secondary papillæ, and invested with epithelium, the deep layer being rounded, the superficial, scaly.

The *fungiform* papillæ are scattered irregularly among the filiform papillæ on the dorsum of the tongue, but chiefly at the sides and apex. They vary from $\frac{1}{25}$ to $\frac{1}{35}$ of an inch in diameter, generally narrower at the base than the summit, and studded with numerous smaller papillæ, like the preceding variety. They have a reddish color, owing to the thinness of the epithelial covering.

The *filiform papillæ* cover the anterior two-thirds of the tongue. They are conical in shape, and vary in thickness from $\frac{1}{50}$ to $\frac{1}{70}$ of an inch, and are about $\frac{1}{10}$ of an inch in length. They are pale in color, owing to the density of the epithelium, and are also covered with numerous secondary papillæ, some of which enclose

5*

minute hairs from $\frac{1}{2000}$ to $\frac{1}{3000}$ of an inch in thickness
and about $\frac{1}{10}$ of a line in length. Simple papillæ are
dispersed over the surface of the tongue among the com-
pound forms. Besides the papillæ, the mucous mem-
brane of the tongue is provided with a number of follicles
and glands.

FOLLICLES.—These are found in nearly all mucous
membranes. Those of the tongue are called lingual
follicles; those of the stomach, gastric follicles; those of
the intestines, simple follicles, or Lieberkühn's follicles;
those of the uterus, uterine follicles, &c. In structure
they are essentially the same. They consist of minute
tubular depressions of the mucous membrane, or inver-
sions, like the finger of a glove, arranged perpendicularly
to the surface, upon which they open by minute apertures.
Their walls consist of a basement membrane lined by
epithelium, which is generally columnar on the sides and
round in the bottom, and covered externally by the
vessels, nerves, &c. In some instances, as in the stomach
near the pylorus, the follicles subdivide into from two to
four tubular branches, or cæcal pouches, and are some-
times convoluted.

The *mucous membrane of the stomach* presents a pe-
culiar honey-comb appearance, consisting of shallow
polygonal depressions or alveoli; from $\frac{1}{100}$ to $\frac{1}{350}$ of an
inch in diameter, separated by slightly elevated ridges.
In the bottom of these depressions are seen the openings
of minute tubes, the gastric follicles. These are divided
into two varieties, *mucous follicles*, or those that secrete
mucus, and *peptic follicles*, or those that secrete the gas-
tric juice. These two varieties differ only in the charac-
ter of the epithelium which lines them. The mucous
follicles are lined by columnar epithelium on the sides
and rounded in the bottom. In the peptic follicles, the

deep part of each tube is filled with nuclei and granular matter; above these is a mass of nucleated cells, the upper fourth of the tube being lined by columnar epithelium.

The *follicles of Lieberkühn* are found throughout the whole course of the small and large intestines. They are essentially the same in structure and function as the simple follicles in other parts of the mucous membrane, simple involutions of the basement membrane, carrying with them the layer of epithelium.

In some parts of the body the mucous membrane is thrown into folds or *rugæ*. Some of these are of a *temporary* nature, such as are seen in the empty state of all hollow organs, as the stomach, bladder, &c., and others of a permanent nature are called *valvulæ conniventes*.

VALVULÆ CONNIVENTES.—The valvulæ conniventes are reduplications or foldings of the mucous membranes, containing between them vessels, nerves, and lacteals or lymphatics imbedded in areolar tissue. They pass transversely around the cylinder of the intestine for about ¾ or ⅔ of its circumference, being about two inches in length, and from ⅓ to ⅔ of an inch in depth. They begin below the pylorus, and increase in size and frequency, until they pass below the entrance of the ductus communis choledochus. They then diminish gradually towards the lower part of the ileum, where they entirely disappear. They are studded with villi and covered with a layer of epithelium. The valvulæ conniventes retard the passage of food along the intestines, and increase the extent of surface for absorption.

The permanent folds of the large intestines are the sacculi, the ileo-cæcal valve, and the folds of the rectum. The latter are three or four in number; the first is near the upper part of the rectum, on the right side; the

second is on the left, opposite the middle of the sacrum;
the third, which is the largest and most persistent, is in
front, opposite the base of the bladder.   When the fourth
is present, it is situated behind, about half an inch above
the anus.   Their function is to support and gently retard
the passage of fæcal matter towards the anus.

VILLI.—The villi are found throughout the whole
extent of the small intestines, from the pylorus to the
ileo-cæcal valve, covering the surface of the valves next
the ileum, and terminating at the free margin, being en-
tirely absent on the cæcal surface.   They are minute,
highly vascular prolongations, or eversions of the mucous
membrane, and give to its surface a velvety appearance.
They are conical or filiform in shape, and vary in length
from $\frac{1}{60}$ to $\frac{1}{45}$ of an inch, and from $\frac{1}{60}$ of an inch in
thickness at the base, to $\frac{1}{150}$ of an inch near the summit.
The villi are largest and most numerous in the duo-
denum and jejunum, there being about fifty to ninety
in a square line; but they become sparser in the ileum.
The total number for the whole intestine is about four
millions.

STRUCTURE.—Each villus consists of a basement
membrane covered with a layer of columnar epithelium,
externally, and contains in its interior a network of
capillaries, nerves, and lacteals, with nucleated cells and
fat globules in their interstices.   It also contains some
fusiform muscular fibre-cells, which probably assist in
the propulsion of the chyle after it enters the lacteals,
(see chapter on absorption).

DUODENAL OR "BRUNNER'S" GLANDS.—These are limi-
ted to the duodenum and commencement of the jejunum.
They are small, ovoid, granular bodies, imbedded in the
submucous areolar tissue, and open upon the surface of
the mucous membrane by minute excretory ducts.   These

glands are most numerous near the pylorus, and diminish from above downwards. In structure, function, and in the character of their secretion, they resemble the pancreas.

SOLITARY GLANDS. "PEYER'S" GLANDS.—These are small, round, whitish bodies, from half a line to a line in diameter, consisting of closed vesicles having no apparent excretory duct, and containing a whitish secretion consisting of nucleated cells, nuclei and granular matter. In the lower part of the intestines they are aggregated together in circular or oval patches, from twenty to thirty in number, called *Peyer's patches* or *glandulæ agminatæ*. These are more numerous in the lower part of the intestine, and are situated on that part of the tube most distant from the attachment of the mesentery. Their use is not very well known. By some they are supposed to pour out their secretion upon the mucous membrane by temporary communications; by others they are supposed to be connected with the lacteal system, in the process of absorption, since they are found larger and more developed during the digestive process than during fasting. Besides, in typhoid fever, these glands are liable to become inflamed and ulcerated. This is probably due to the irritation produced by the absorption of noxious matters from the intestines. Those who hold that these glands are organs of excretion, maintain that the ulceration is due to the irritation produced by the elimination of poisonous matter from the blood. In phthisis they may become the seat of tuberculous deposit, which softens and ulcerates, resulting in a troublesome form of diarrhœa.

INTEGUMENT.

It resembles the other membranous expansions in its general structure, and might be considered as an everted

mucous membrane. It covers and protects the body, allows of motion, and merges gradually into the mucous membrane at the outlets of the body.

It consists of three parts, the *epithelium, basement membrane,* and the vessels, nerves, lymphatics, &c., imbedded in areolar tissue, called the *corium* or true skin (cutis vera).

EPITHELIUM, (here called *epidermis*). This is not permeated by vessels, is much thicker than in any other membrane, and consists of several layers of cells. The first layer, or those which are next the basement membrane, are columnar or rounded, and nucleated, called the mucous layer (rete mucosum). Surrounding these, on the basement membrane, are seen nuclei and granules. The next series of cells are oval, sometimes polygonal from pressure; the next elongated, and the superficial layer flattened, hard and scaly, being hardened by dessication and secondary deposit, the nuclei remaining. The cells of the deep layer are about $\frac{1}{3000}$ of an inch in diameter; the superficial, $\frac{1}{500}$. The epidermis covers the whole surface, and is not very uniform in thickness, being very thin in the groin and axilla, and thick in the palms of the hands and soles of the feet. The thickness of the cuticle, in some parts of the feet, gives rise to corns. The development of the cells takes place at the basement membrane, and as they approach the surface they become changed in shape, and ultimately fall off by a gradual process of desquamation. In some of the exanthemata, as scarlet fever, measles, &c., a complete desquamation of the cuticle takes place during recovery. In the serpent tribe an exuviation occurs annually. The outer layers of cells, when exposed to the action of acetic acid, swell out and become rounded, showing their original shape. A solution of caustic

potash also makes them rounded, and completely destroys the deep or mucous layer, as it is called. The epidermis is pierced by the hair follicles, sudoriferous ducts and sebaceous follicles; these openings are called *pores*.

The chemical constituents of the epidermis are C_{48} H_{39} N_7 O_{17}. It resembles hair, horn, nails, &c.

In parts subjected to irritation, as the integument of the laborer's hand, and beneath corns, the vascular supply of the cutis is increased, in order to supply the cells more abundantly.

COLOR.—The color of the different races is due to the development of minute particles of pigment matter (from $\frac{1}{10000}$ to $\frac{1}{20000}$ of an inch in diameter) in the interior of some of the cells of the mucous layer. These cells are therefore called *pigment cells*, and are very numerous in the Ethiopian race. The coloring matter gradually diminishes towards the surface of the epidermis. The development of pigment is increased by the influence of light, as is seen in the change of color in warm climates, and in the new-born infants of the negro, which are not very dark-skinned till after the lapse of a few days.

Pigment cells are also found in the choroid coat of the eye, iris, hair, the areola of the nipple, and other parts of the body in pregnant women, nævi, freckles, &c. They may assume different shapes; some are rounded, as those of the epidermis; others polygonal, as the epithelium lining the inner surface of the choroid coat of the eye; while those imbedded in the substance of the choroid present a remarkably stellate appearance. Those which line the inner surface of the choroid contain a large quantity of pigment granules. Pigment granules, when viewed separately, are transparent; but when viewed collectively have a dark color, and are seen to move

about when set free from the cell, sometimes even when contained in it. In their chemical nature they resemble the cuttle-fish ink, which derives its color from the pigment cells lining the ink-bag. Pigment contains from forty to sixty per cent. of carbon. In some persons there is an entire absence of pigment, as in the *albino*. In these the hair and skin are unusually white, and the iris has a pinkish hue.

BASEMENT MEMBRANE.—The basement membrane covers the cutis, or corium, supports the cells of the epidermis, and regulates osmosis. It is distinctly seen in the integument of the fœtus, but is not perceptible in the adult.

CORIUM, OR CUTIS VERA.—The corium consists of vessels, nerves, lymphatics, a few nonstriated muscular fibre-cells, and some fat, imbedded in areolar tissue. The meshes of the areolar tissue are very small towards the surface, but are larger towards the subjacent tissue. In parts where strength is required, the white fibrous tissue predominates; where there is much motion, the yellow elastic. The yellow fibres usually take a horizontal course, and give off branches which enclose lozenge-shaped meshes, among which the white fibres twine in great profusion. The contraction of the integument is due to the presence of nonstriated muscular fibre-cells (termed the *arrectores pilorum*). They are found throughout the whole extent of the cutis; some of them surround the hair bulbs, and give rise to that peculiar roughness of the surface called *cutis anserina*, as is seen in the cold stage of intermittent fever. They are very abundant in the cutis of the scrotum (the dartos). Fat is found in the meshes of the deeper parts of the corium, forming a soft bed on which the skin rests, giving rotundity and symmetry to the body, and

from being a bad conductor, it prevents the too rapid escape of caloric from the body. The integument may be tanned by any substance which will precipitate the gelatine, as oak bark, &c., the tannic acid of which unites with the gelatine, and forms tannate of gelatine.

APPENDAGES OF THE INTEGUMENT.

These are the *papillæ, nails, hair, sebaceous* and *sudoriferous glands* and ducts.

PAPILLÆ.—The external surface of the corium is raised into papillary eminences, carrying with them the basement membrane. They are irregular in size and frequency, except in the palms of the hands, soles of the feet, and surrounding the nipple. The average size of the papillæ are $\frac{1}{100}$ of an inch in length, and $\frac{1}{250}$ of an inch in diameter at the base. The interior of the papillæ consists of capillaries, nerves, and lymphatics, in areolar tissue. The nerves, as in all finer divisions, are destitute of the white substance of Schwann, and therefore difficult of demonstration. In the general surface of the body they are few in number, especially on the back, but in the palms of the hands, and soles of the feet, they are numerous, and attain a large size; and are so arranged as to form ridges on the surface, which are generally more or less curved and separated by grooves. This appearance can be seen with the naked eye. Each ridge is produced by a single or double row of papillæ projecting from the surface of the cutis, and covered with the epidermis. The grooves are the spaces between the rows. The papillæ in each row are generally arranged in pairs side by side, each pair being separated from the next adjacent pair by transverse grooves which cross the ridges at right angles. In the centre of each transverse groove may be seen the orifice of a sweat

duct. In a square inch of the palm may be seen twenty ridges, or forty rows of papillæ, and rather more than sixty pair in each row.

The office of the papillæ is sensation or touch, and to increase the surface for cell development. They are covered and protected by the epidermis, which also fills in the spaces between them.

NAILS.—The nail is an extension of the epidermis, very much hardened, in order to form a protective covering for the dorsal surface of the terminal phalanges of the hands and feet. Each nail consists of a root, body, and extremity. The cutis is folded upon itself so as to form a groove, in which the root and body of the nail are imbedded; this is called the matrix, because it is the seat of growth. Near the root of the nail may be seen a semi-elliptical white spot, called the *lunula*. The structure of the nail is the same as the epidermis; it consists of several layers of cells, the deep one being columnar or rounded, the next oval, the next elongated, and the upper series flattened and very much hardened. The latter, when acted on by acetic acid or caustic potassa, become rounded like the mucous layer, and imperfect traces of the nuclei may be detected. This proves that they are mucous cells, changed in shape, and hardened by the deposit of horny matter. The nail is traversed longitudinally by ridges and grooves, which are apparent to the naked eye, for the purpose of increasing the cell-forming surface. The vascular and nervous supply is very abundant in the matrix. In long illness, particularly of the mucous surfaces, the nails are marked by a transverse groove, the size of which is an index of the length and severity of the disease. It is caused by the abridgment of the nutritive process for the time being. This peculiarity is taken advantage of by fortune-

tellers, gipsies, &c., &c., who, by examining the nail, are able to tell the person when he was sick, and the length of the illness, from the size of the groove and its distance from the root. The nail increases in length by the development of cells at the root, and on the under surface of the body, which push it onwards in its growth. The finger nails grow at the rate of about $\frac{1}{5}$ of a line per week, and the toe nails about $\frac{2}{5}$ of a line per month.

HAIR.—Hairs are found on all parts of the surface of the body, except the palms of the hands and the soles of the feet, and they vary in length, shape, and thickness. They are implanted in a saccular cavity called the hair follicle, which is formed by an involution or dipping of the basement membrane into the corium, carrying with it the epidermic cells, the superficial layers of which become rounded. This follicle is larger at the bottom than at the top, to correspond with the bulbous enlargement of the hair, and presents in the bottom a highly vascular papilla covered with cells, from which the hair grows. A hair consists of a *root*—or that part imbedded in the follicle; a *shaft*—the part which projects from the surface; and the *extremity*, which is sometimes split. The root is the thickest part, and presents a bulbous enlargement. The diameter of the shaft varies from $\frac{1}{250}$ to $\frac{1}{1500}$ of an inch in diameter, and is divided into two parts—the *cortical* and *medullary* portion; the former predominates in the human subject. In structure it resembles the epidermis. On a transverse section it is seen to consist entirely of cells. In the medullary portion they are rounded; but toward the circumference of the cortical portion, they become first oval, then elongated or fusiform, and finally flattened and hardened, and the latter are so arranged as to present an imbricated appearance. If the finger be passed along the hair from

the extremity to the root, a distinct roughness is felt,
owing to this peculiar arrangement of the cells. The
external surface presents fine, sinuous cross lines, and a
jagged boundary, caused by these imbrications. If a
longitudinal section be made, the cortical substance pre-
sents a fibrous appearance, caused by the arrangement
of the elongated cells in a linear manner. A few pig-
ment cells may be seen scattered irregularly among the
fibres of the cortex ; but they are more abundant in the
medulla. The color of the hair depends on their presence.
The coloring matter resembles hematine, and is readily
bleached by chlorine. It is stated that the hair has
grown white in a single night from the influence of some
depressing passion, as fear, &c. It must, however, be a
very rare occurrence, and can only be explained upon
the supposition that some peculiar fluid is secreted at
the papillæ, which percolates through the hair and de-
stroys the coloring.

The hair is increased in length by the development
of cells on the papilla at the bottom of the follicle, which
push it upwards. The cells which are developed in the
papilla are originally rounded, and those which grow on
the summit continue so throughout the medulla to the
extremity of the hair; while those which grow from the
sides soon become flattened and imbricated as they pass
upwards on the exterior of the hair. In some animals
the papillæ are large, and prolonged upwards in the
central part of the hair above the surface of the body,
and hence they bleed when cut or extracted. In the
disease of the hair called *plica Polonica*, the papillæ are
said to be elongated, and bleed when cut close to the
skin. The hair in these cases grows very fast, and becomes
matted together by a glutinous secretion. Some of the
sebaceous glands open into the hair follicle, and pour out

an oily secretion which keeps the hair smooth and glossy.

DEVELOPMENT OF THE HAIR FOLLICLE.—At about the sixth week of fœtal life there is first seen a slight depression or inversion of the basement membrane lined by the epidermis, forming the rudimentary follicle. It then becomes deeper, narrower, and flask-shaped, containing cells; those in the centre, fusiform in shape, are arranged in a line, and form the rudimentary hair. At this time also the papilla springs from the bottom of the follicle. The first brood of hairs are temporary, like the deciduous teeth. After birth the follicles deepen, and a new papilla is formed at the bottom of each, from which the permanent hair is developed, the old hairs being cast off. When a hair is plucked out the follicle fills with blood, which after a little disappears, and if the papilla is not destroyed a new hair will spring up. Anything that interferes with the vascular supply at the base of the hair will affect its growth and cause it to fall out. The growth of the hair may be promoted by the application of certain stimuli, as tincture of cantharides, bay-rum, &c.; these form the bases of hair restoratives.

SEBACEOUS GLANDS.—These glands are found in most parts of the integument except the palms of the hands and soles of the feet. They are very abundant on the scalp, face, axilla, groin, &c., and open either upon the general surface, as on the face; or into the hair follicles, as on the scalp. Each gland consists of an involution of the basement membrane, lined by the rounded layer of epithelium. Globules of sebaceous matter (sebatine) are secreted from the capillaries beneath the basement membrane by these cells, which at maturity break down, and throw out their secretion either on the surface of the body, or into the hair follicles. In some cases the gland

is lobulated or sacculated in order to increase the secreting surface. In the scalp there are two of these glands to each follicle, into which they pour their secretion, for the purpose of lubricating the hair. The excretory ducts are generally short and straight, and in some parts of the body, as the face, they become the habitat of a parasitic animal, the *Steatgzoon Folliculorum.* These are more common about the period of puberty, and in those possessing a torpid skin.

The development of the sebaceous gland is similar to that of the hair follicle. At about the sixth month there is seen a knob-like depression of the basement membrane of either the general surface or the hair follicle, as the case may be. This soon becomes deeper, and narrower at the mouth, until it assumes a flask-shaped appearance, and is lined by the rounded layer of epithelium. These cells secrete an oily material (sebatine), and increase in number until they fill the gland. As they approach the orifice they break down and pour out their secretion. The sebaceous matter which covers the fœtus is called the *vernix caseosa.*

CERUMINOUS AND ODORIFEROUS GLANDS are varieties of the *sebaceous.* The ceruminous secrete a waxy material which entangles particles of dust, insects &c., and prevents their access to the delicate membrane of the tympanum.

SUDORIFEROUS GLANDS.—They are situated in the deep part of the corium and subcutaneous areolar tissue, being surrounded by adipose, and open by a duct upon the surface of the epidermis. Each gland is formed by a simple involution of the basement membrane, carrying with it the deep layer of cells and terminating in a convoluted tube beneath the corium. Sometimes the tube is branched, the branches being rolled up in one clump,

and held together by areolar tissue. The duct, as it passes to the surface, takes a tortuous course through the corium, upon the surface of which it loses the basement membrane and is continued on through the epidermis in a spiral course, the calibre being larger, and the walls of the duct being wholly formed by the layers of cells. It opens on the surface obliquely, and is protected by a small valve formed by the scaly epithelium. The openings are called pores, and as many as 2,800 on an average exist on each square inch of surface. The number of square inches of surface in an ordinary-sized man is about 2,500. Therefore the number of pores will be about 7,000,000. Each duct is about one-fourth of an inch in length when unraveled, and the total length of tubing about twenty-eight miles. This is a very important and extensive excretory surface.

FUNCTION OF THE SKIN.—It serves as a protective covering for the body, and possesses toughness, flexibility and elasticity—due chiefly to the presence of areolar tissue in the corium. It possesses both the function of absorption and secretion. Absorption is carried on through the lymphatics and capillaries of the corium. This may be proved by immersing the body in a bath, when its weight is found to be increased, and not only water, but also substances dissolved in it, may be thus introduced. In severe cases of dysphagia, life may be prolonged by the use of nutritious enemata, and baths of milk and water, beef tea, &c. It is in this way that the *modus operandi* of liniments may be explained. A secretion of watery fluid or perspiration is continually going on from the extensive system of glands. It generally passes off in the form of vapour, forming *insensible* perspiration, but when considerably increased the fluid remains in the form of *sensible* perspiration on

the surface of the skin. The *perspiration* is a colorless
watery fluid of an acid reaction, and has a peculiar odor,
which varies in different parts of the body. It consists
as follows:

Water... 995.00
Animal matter and lime.. .10
Sulphates and substances soluble in water .... .05
Chlorides of sodium and potassium and spirit extracts   2.40
Acetic acid, acetates, loctates, and alcohol extracts...   2.45
                                                       ————
                                                        1000.00

The function of perspiration is to regulate the tem-
perature of the body. The natural temperature is about
98° to 100°F., and a variation of from 8° to 9°F. from
the natural standard proves fatal. When the surface is
exposed to a high degree of heat, the glands pour out an
increased amount of fluid. This is immediately con-
verted into vapor, and in passing from the liquid to the
gaseous state, so much heat becomes latent that the sur-
face is cooled down to the natural standard. So long as
the air is dry, so that evaporation is not interfered with,
a very high temperature—from 300° to 400°F. can be
borne with impunity; but if the air be saturated with
moisture, evaporation is retarded, and the body suffers;
and if the exposure be long continued, death is the result.
The amount of perspiration may be diminished by a
cold, damp atmosphere, and increased by heat, exercise,
or excitement. The quantity of fluid thrown off by the
skin varies very much, according to the state of the at-
mosphere and the action of the kidneys, the average
amount thrown off in the course of twenty-four hours
being about 1½lbs. In cold weather, when the skin is less
active, the kidneys take on an increased action in order
to compensate the deficiency. When the action of the
skin is interfered with, as in burns, scalds, covering with
large plasters, coating with varnish, or in scarlatina, there

is a determination of blood to the kidneys, and some of the albumen escapes. This accounts for albuminuria in the exanthemata.

An interchange of gases or process of aëration also takes place through the integument, carbonic acid being liberated and oxygen absorbed.

A most important function of the skin is the sense of touch. This varies greatly in different parts, being greatest at the extremities of the fingers, the lips, the tongue, and least in the trunk, arms and thighs. Thus the two points of a pair of compasses rendered blunt may be separately distinguished by the point of the finger when only one-third of a line apart; while they require to be thirty lines apart to be separately felt on the integument of the spine, arm, or thigh. This is owing to the unequal distribution of the papillæ of the corium. Parts that are sensitive to tickling, as the axilla and soles of the feet, are comparatively blunt in regard to the appreciation of distance. Impressions made on the integument continue perceptible for a considerable time after they have been removed, as e. g., the pressure of the ring, if long worn, is felt on the finger for some time after its removal, and is apt to deceive the individual.

The integument, when wounded, is not restored in all its integrity; the cicatrix presents no hair follicles or glands, and the sensation is abnormal.

6

CHAPTER V.

DIGESTION.

DIGESTION is that process by which the food is prepared for absorption and assimilation.

The digestive process consists of seven different stages, *prehension, mastication, insalivation, deglutition, chymification, chylification* and *defæcation.* It will be most convenient to treat of these different processes in their order, giving the mechanism and the changes which each is capable of effecting in the food. Before proceeding, it will be profitable to examine the various kinds of food suitable to the nourishment of the human body.

FOOD.—The *food* of man consists both of organic and inorganic substances. The best classification is that of Dr. Prout. He divides the different kinds of food into four groups:

1st. The *Aqueous Group.*—This forms part of the food of all animals, and enters largely into the composition of the body.

2nd. The *Saccharine Group.*—This group is derived chiefly from the vegetable kingdom, and comprehends sugars, starch, gums, vinegar, &c. They consist of carbon, hydrogen and oxygen, the two latter in the proportion to form water.

3rd. The *Oleaginous Group.*—It includes oils, fats and alcohol. They resemble, in elementary composition, the preceding group, except that the carbon and hydrogen exist in nearly equal proportions.

4th. The *Nitrogenous* or *Albuminous Group.* All substances belonging to this group contain nitrogen, as

fibrin, albumen, casein, gelatine, gluten, &c, They are chiefly derived from the animal kingdom. Gluten is the nitrogenous principle of wheat. These are sometimes called *histogenetic substances.*

Milk is found to contain nearly all the ingredients embraced in the preceding groups, and hence it is well adapted to the growth and development of the young. From the above it will be seen that the food of man is naturally subdivided into two great classes; the *non-nitrogenous* embraced in the 1st, 2nd and 3rd groups, and the *nitrogenous*, which embraces the last group; the former supplying a large amount of carbon.

Liebig styles the nitrogenous substances the *plastic elements of nutrition*, and the non-nitrogenous, the ~~plastic~~ *elements of respiration.* The latter term is objectionable, however, inasmuch as those substances are not actually required in the process of respiration. The terms *nutritive* for the nitrogenous, and *calorifacient* for the non-nitrogenous, as proposed by Dr. Thomson, are preferable, or the terms *histogenetic* and *calorific.*

In colder climates, a large quantity of the calorifacient elements are necessary to maintain the proper temperature of the body, and the natives instinctively feed on fats and oils; while the natives of warmer climates feed on fruit, which contains less carbon.

From the construction of the teeth, and digestive apparatus of man, a mixed diet would seem to be the most suitable. Both animal and vegetable food is necessary to the highest *mental* and *physical* development of man.

Certain diseases may arise from the want of a proper admixture of fresh vegetable diet, as scurvy. This is supposed to be due to the absence of the vegetable acids in the system, as citric and malic acid, and may be remedied by their administration alone.

If, on the other hand, the nitrogenous elements be deficient or absent, imperfect nutrition shows itself in the form of ulcers in certain parts of the body, as in the cornea and alimentary canal.

Magendie tried the experiment by feeding dogs for some time on sugar and water alone, and ulceration of the cornea ensued.

QUANTITY OF FOOD.—The absolute quantity of food required for the sustenance of the body in health varies with the age, sex, constitution, habit, and the circumstances in which the individual may be placed. It is of considerable importance to know the average amount of food required by each individual. In the diet scale of the British navy, each seaman gets from 31 to $35\frac{1}{2}$ ounces of dry nutritious food daily, 26 ounces of which is vegetable, and the rest animal, together with sugar and cocoa. This is found to be amply sufficient for the support of strength. The soldier is allowed one pound of bread, and one pound of meat, per diem. In the English hospitals, full diet, upon which convalescents are put, consists of half a pound of meat, twelve to fourteen ounces of bread, half a pound of potatoes, one pint of milk, and one pint of beer, or half a pint of porter.

In prisons, if the prisoners are idle, they receive about 25 ounces of solid food per diem, 5 or 6 ounces being meat.

Some persons consume large quantities of food. The wandering Cossacks of Siberia devour from 8 to 20 pounds of meat daily.

It has been ascertained that from 25 to 35 ounces of solid food, one-fourth of which should be animal, is sufficient to maintain health.

It is also important to determine the proper diet suitable to particular maladies. Thus, in disease of the

kidneys, liver or bowels, or in rheumatism, gout, dyspepsia, or fatty deposit, much good may be effected by a well regulated dietetic treatment. For example, in diabetes, a diet of animal food, and the avoidance of starch and sugar, are generally attended by good results. In disease of the liver, a well-regulated nitrogenized diet is more suitable than one abounding in carbon, which would increase the work of elimination in this organ. In diarrhœa and dysentery, bland unstimulating articles of food should be used, and substances containing very little excrementitious matter, and easily digested, as beef tea, mutton broth, &c.

Starch and sugar are bad for the gouty, rheumatic and dyspeptic, for they are transformed into fat, lactic acid, and other substances which disagree with the stomach. When there is a tendency to obesity, a well-regulated nitrogenized diet is the best adapted to obviate it.

QUALITY.—The food should be in a wholesome or undecomposed state. Those who are in the habit of eating decomposed food, or what is commonly called *haut goût*—(highly seasoned)—are liable to zymotic diseases and disorder of the digestive organs, as diarrhœa. These diseases are very prevalent among the inhabitants of the Färoe and Bird Islands, who are in the habit of eating what they call "*rast*," half-decomposed, maggoty flesh and fish.

Prize fighters, in training, adopt a very strict regimen, consisting of the lean of beef and mutton, and stale bread, together with about three and a half pints of fluid per day, fermented liquors being strictly prohibited. Two full meals, with a light supper daily, and plenty of vigorous exercise.

Fish is said to be a watery kind of food, and is used by Jockeys who wish to reduce their weight by sweating.

DRINK.—Water constitutes the natural drink of man, and no other liquid can properly supply its place; therefore its purity is a matter of great importance. Water conveyed in leaden pipes is dangerous to drink, in consequence of the formation of carbonate of lead which is held in solution by the free carbonic acid which the water contains. Salines in excess produce derangement of the digestive organs; and, as in the case of decomposed food, a small amount of putrescent matter in the water, insidiously introduced into the system, renders it liable to attacks of diarrhœa, and to the inception of zymotic diseases. The use of *alcohol* in combination with water, or with other substances in the form of fermented liquors, cannot serve as a substitute for water. It precipitates most of the organic compounds whose solution in water is necessary to their assimilation. It cannot supply anything which is essential to nutrition, as it is incapable of forming albuminous compounds.

Alcohol is merely useful as a calorific agent; but even for that purpose it is inferior to fats and oils. It is also a stimulus, increasing for the time the vital activity of the nervo-muscular parts of the body, and is followed by a corresponding depression of power. As a stimulus it is useful in low forms of disease, to increase the digestive process, to raise the flagging powers, and carry the patient safely through a perilous disease. Beer and porter may also be found useful in various forms of indigestion; the bitter principle which they contain is also slightly tonic in its action. The habitual use of alcoholic liquors is highly injurious. They are poisonous in large doses, and when used in excess, produce a morbid

condition of the nervo-muscular parts of the body, as is seen in delirium tremens, and in fatty degeneration of the muscular tissues of the body. Intemperate persons are also more obnoxious to epidemic diseases, as cholera, dysentery, fevers, &c., in consequence of the accumulation of effete materials in the blood, which render it more liable to "*fermentation*." The power of the body to endure fatigue, or to resist the extremes of heat and cold, is also diminished by the use of intoxicating liquors.

TEA, when used in moderation, limits the loss of weight when the diet is insufficient; prevents the loss of substance in the shape of urea; diminishes the amount of perspiration; and has no appreciable effect on respiration or circulation; but when used in excess, is stimulating and highly injurious to the nervous system.

COFFEE is more stimulating than tea. When used in moderate quantities, it prevents waste of the tissues, arouses nervous energy, and invigorates the circulation; but in excess is decidedly injurious.

TOBACCO, though not properly an article of diet, should be referred to in this connection, as in excess it interferes very much with the proper assimilation of the food. Smoking, chewing, and snuffing, are the most barbarous customs of our race. To those unaccustomed to the use of tobacco, it causes nausea, vomiting and purging. In habitual smokers and chewers, it creates thirst and increases the secretion of the saliva and buccal mucus, which, from being mixed with the juice, must be expelled from the mouth. To some people the fumes of tobacco are very disagreeable, and irritating to the lining membrane of the lungs. The application of it to abraded surfaces is very dangerous, and has been known to prove fatal. A substance called *nicotine* is obtained from tobacco, which is very poisonous, almost equalling in activity hydrocyanic acid.

HUNGER.—Hunger is the general want of nourishment in the system ascribed to the stomach. The introduction of food into the stomach alone will not allay the sensation; it must be partially absorbed, and enter the circulation. Hunger is not occasioned by mere emptiness of the stomach; neither can it be due to the secretion of gastric juice, as some have supposed; because that fluid is not secreted, except during digestion, or when some substance is introduced into the stomach. It is more probable that the sensation in the stomach is due to a congested condition of the capillaries, beneath the mucous membrane, excited by the influence of the sympathetic nerves, and communicated or telegraphed to the nervous centre. If the brain is actively engaged, the telegraphic message is not noticed, and thus the sensation may be dispelled for a time. Division of the pneumogastric nerve annihilates the sensation of satiety, but not of hunger.

THIRST.—Thirst is the general want of fluids in the system referred to the fauces. This sensation may be as effectually allayed by the introduction of liquids into the stomach as by swallowing in the ordinary way, as is seen in cases of cut throat, where the œsophagus is divided. It may also be relieved by injecting fluids into the veins, or by immersing the body in a bath.

STARVATION OR INANITION.—This is the result of an entire deficiency, or an inadequate supply of food. In starvation the body is greatly emaciated, and usually deprived of its adipose tissue. The most prominent symptoms of starvation are—First, hunger, which becomes painful, the pain being referred to the epigastric region, followed by a sinking sensation. Next, an insatiable thirst, which is most distressing; the countenance becomes pale and haggard, the eyes wild and glistening;

the body exhales a peculiar fetor, the secretions are of-
fensive; the bodily strength fails, and the voice gets
weak. The mental powers are at first blunted, and the
sleep consists of short naps, disturbed by dreams in
which the individual fancies that he is in sight of plenty
of food. Towards the close of the process, delirium
generally sets in, and death closes the scene, either from
sheer exhaustion or from the occurrence of convulsions.

Now, it will be observed that the above symptoms
are common to all low forms of disease; and the medical
practitioner should be careful in such cases to supply
nourishment and stimulants liberally; even the presence
of delirium should not deter him from administering
beef-tea and brandy.

Life may be supported under entire abstinence from
food or drink for a period of eight or ten days; but this
period may be prolonged by the occasional use of water.

PREHENSION.

The organs of prehension are the hands, lips, teeth,
and tongue. The tongue is used in the act of suction
somewhat like a piston, so as to produce a vacuum, and
allow the fluids to enter by atmospheric pressure. Suc-
tion cannot properly take place when the tongue is tied
down at the tip, as in tongue-tied children, it being ne-
cessary that the tip and sides of the tongue should be
brought in contact with the roof of the mouth. In
drinking a fluid by means of a suction tube, as a catheter,
it is found that suction will not take place if the tube is
passed too far back in the mouth, behind the floor of
the nares, because air enters through the nose, and no
vacuum can be produced. The tongue of the ant-eater
is covered with a slimy secretion, which entraps the
ants. Dogs and cats lap the water by means of the
tongue, and many other examples might be cited.

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MASTICATION.

This is the first process which the food undergoes, and is entirely a mechanical one. It consists in the cutting and trituration of the food by the teeth. The principal organs are the teeth, tongue, and muscles of mastication.

TEETH.—The teeth in all animals are suited to the kind of food which each is destined to use. In the graminivora, some of the teeth are formed for cutting or cropping the food, but the majority of them are broad and flat, for the purpose of grinding it. In the carnivora, the principal teeth are strong, sharp, and pointed, for tearing the food, while the remainder are broad and flat.

The teeth of man partake of the nature of both the graminivora and carnivora, as he is destined to feed on both animal and vegetable food. In some animals, as fish and reptiles, which swallow their food entire, the teeth are only organs of prehension, and are curved backwards to prevent the escape of their prey. Some of the lower animals, as the crustacea, are provided with teeth in the stomach.

STRUCTURE OF THE TEETH.—There are two sets of teeth with which the human subject is provided. The first set appears in childhood, and are called *temporary* or *deciduous* teeth. They are twenty in number,—four incisors, two canine, and four molars in each jaw. The second set are called *permanent*, and are thirty-two in number,—four incisors or front teeth, two cuspids (one on each side of the incisors), four bicuspids (two on each side), and six molars (three on each side), in each jaw. Each tooth consists of the *crown*, or exposed part, the *neck*, the constricted part beneath the gum, and the *fang* or root, imbedded in the jaw, and contains within it a pulp cavity.

The pulp is supplied with vessels and highly sensitive nerve tissue. The solid structure of the tooth is composed chiefly of *dentine*, covered with a thin layer of *enamel* on the crown, and bone tissue (crusta petrosa) on the fang.

Dentine consists of minute, wavy tubes, *dental tubuli*, which lie parallel to each other, and open into the pulp cavity, being arranged vertically on the summit, and horizontally on the sides. The tubuli are about $\frac{1}{10000}$ of an inch in diameter, and are imbedded in a dense, homogeneous substance—the intertubular tissue. They divide and subdivide dichotomously as they pass towards the surface, sometimes terminating in small lacunæ, and convey nourishment for the supply of the enamel. Its chemical composition is similar to bone, with a predominance of the earthy matter, in the proportion of seventy-two earthy to twenty-eight per cent. animal matter.

Enamel is the hardest tissue of the body, and forms a covering to the dentine of the crown of the tooth. It consists of a congeries of minute, solid, hexagonal rods, which are parallel to one another, resting on the dentine by one extremity, the other forming the free surface. They are arranged vertically on the summit, and horizontally on the sides, like the dental tubuli, and are about $\frac{1}{3500}$ of an inch in diameter. Small spaces are left between the rods at the dentinal surface to allow of the permeation of fluids from the dental tubuli, for the supply of the enamel. It consists of 96.5 parts earthy, and 3.5 parts animal matter.

The *bone* covering the fangs is called *crusta petrosa*. In structure and chemical composition it resembles true bone.

DEVELOPMENT OF THE TEETH.—About the sixth week of fetal life, the mucous membrane covering the

upper jaw presents a semicircular depression or groove.
This is the primitive dental groove, from the bottom of
which the germs of the teeth are developed. The germ
of each tooth consists of a conical elevation or papilla of
mucous membrane, bounded on each side by the margin
of the primitive dental groove. This is called the pap-
illary stage, and is completed about the eleventh week.
The primitive dental groove now becomes narrower
and deeper, the margins thicker and more prominent,
and is subdivided into ten compartments or follicles, by
the growth of transverse septa, for the reception of the
ten papillæ or germs of the deciduous teeth. These fol-
licles become the future alveoli, lined by periosteum, at
the bottom of which is the germ of the future tooth.
This constitutes the follicular stage, and is completed
about the fourteenth week. The papillæ now commence
to grow rapidly, and assume the shape of the future
teeth; the follicles deepen, and are covered by mem-
branous projections—the opercula—which unite and
form a lid to the now closed cavity. The follicles are
thus converted into *dental sacs*, and the papillæ become
the *pulps* of the future teeth. Then the margins of the
primitive dental groove approach each other, and finally
cover over the follicles. This completes the third or
saccular stage, which takes place about the fifteenth week.

During the fourteenth week may be seen a small
groove, between the margin of the primitive dental
groove and the opercula, on the outer side, called the
"*secondary dental groove*," from which the permanent
teeth are developed. In the bottom of the secondary
groove the follicles are formed, and as the groove closes
in, these follicles become cavities of reserve. These
cavities elongate and recede behind the sacs of the de-
ciduous teeth, and a papilla projects from the bottom of

each, which constitutes the germ of the permanent tooth. The margins of the secondary groove close over the cavity, and convert it into a dental sac, and the papilla becomes the pulp, the same as in the deciduous tooth.

The four temporary molars become the four bicuspids of the permanent set, and the six molars of the permanent set (three on each side), are developed successively—commencing behind the last temporary molar—by successive extensions backwards of the back part of the primitive dental groove.

DEVELOPMENT OF THE DENTINE.—The *dental sacs* formed by the closing of the follicles, are lined by a membrane, covered by columnar epithelium, which covers the papilla forming the visceral layer; it is then reflected upon the inner surface of the cavity constituting the parietal layer. The dental papilla (or pulp) resembles that of membranous expansions — already described—and is converted into dentine by a process of ossification, which takes place from without inwards. It at first consists of nucleated cells, held together by a network of delicate fibres, vessels, and nerves, the interspaces being occupied by a homogeneous plasma. When ossification commences, earthy matter is first deposited in the homogeneous membrane covering the dentinal pulp; then the vessels, fibres, &c., recede, and the cells enlarge and arrange themselves in a linear manner, perpendicularly to the coronal surface of the tooth. They then elongate, so that their extremities come in apposition, and the contiguous walls break down; the nuclei also elongate, and coalesce in such a manner as to form the cavities of the tubuli, which become hardened by earthy deposit. This takes place first on the surface, and gradually extends inwards, while the vessels, nerves,

and fibres still recede, until they come to occupy the central part, which is called the pulp cavity.

DEVELOPMENT OF THE ENAMEL.—The inner surface of the lining membrane of the dental sac secretes a thick semi-transparent pulpy tissue containing albumen, termed the *enamel pulp.* On the surface of this pulp, next the *dentinal pulp* or *papilla,* is seen a layer of columnar epithelium, while on the opposite side are seen the vessels of the membrane lining the walls of the sac, the parietal layer. This columnar epithelium is the matrix of the enamel, the calcification of which begins on the surface of the dentine. It at first consists of a single layer of nucleated cells, placed between the dentine and enamel pulp; but soon others are added on the surface towards the enamel pulp—arranged endwise on the preceding, which they resemble in all respects, so that the enamel rods grow by the superposition of nucleated cells, and the subsequent calcification of each in its turn. These cells are developed from the enamel pulp.

ERUPTION.—When the tooth is sufficiently hard to enable it to pass through the gum, the eruption takes place. The gum is absorbed by the pressure of the tooth against it, which is itself pressed up by the increasing size of the fang. The septa between the dental sacs, at first fibrous, soon ossify, and constitute the septa of the alveoli in which the fangs are lodged.

Periods of eruption of the temporary teeth.—The teeth of the lower jaw precede those of the upper.

Central Incisors	7th month.
Lateral "	7th to 10th "
Anterior Molars	12th to 14th "
Canines	14th to 20th "
Posterior Molars	18th to 36th "

Periods of eruption of the permanent teeth :

First Molars	6½ years.
Middle Incisors	7 "

Lateral   " ....   8 years.
First Bicuspid..............................   9   "
Second   "   10   "
Canine ....11 to 12   "
Second Molars...............................12 to 13   "
Wisdom Teeth (Dens Sapientæ) ....17 to 21   "

The teeth of the lower jaw also precede those of the upper, in the permanent set.

TONGUE.—The tongue is an important organ of mastication, and being the seat of taste, it receives accurate impressions of the kind and quality of the food. While the food is being triturated, the tongue is engaged in moving it from side to side, in collecting the scattered fragments from different parts of the mouth, and bringing them within the range of the teeth. This action is accomplished by the muscles which belong to this organ. The cheeks also assist more or less in moving the particles of food, and keeping them within the range of the teeth.

The *muscles of mastication* are the temporal, masseter, external and internal pterygoid, and digastric. They all act upon the lower jaw, which is capable of being moved in different directions, for the purpose of triturating the food,

The temporal, masseter and internal pterygoid, elevate the lower jaw, and close the mouth. The posterior fibres of the temporal and the deep part of the masseter carry it upwards and backwards. The internal pterygoid and superficial part of the masseter, draw it upwards and forwards. Both pterygoids draw it from side to side, and it is depressed by the action of the digastric muscle.

INSALIVATION.

During the process of mastication, the food is mixed with the saliva. This substance is a mixture of four distinct fluids which differ from each other in their che-

mical and physical properties, viz.: The secretion of the parotid gland, the submaxillary, the sublingual, and the buccal glands.

The parotid gland is situated beneath the ear, close to the temporo-maxillary articulation, and opens into the mouth by its excretory duct (Steno's), opposite the second molar tooth of the upper jaw.

The submaxillary gland is situated beneath the lower jaw, and communicates with the mouth through Wharton's duct, which opens on the side of the frænum linguæ. The sublingual gland is situated beneath the tongue, near the symphysis of the lower jaw, and opens into the mouth upon an elevated crest of mucous membrane, (which may be felt with the tip of the tongue), by fifteen or twenty openings (ductus Riviniani).

STRUCTURE OF THE SALIVARY GLANDS.—The salivary glands consist of numerous lobes made up of smaller lobules connected together by areolar tissue, vessels, nerves, &c. Each lobule consists of numerous vesicles which open into a common duct; these vesicles are lined by a layer of rounded or glandular epithelium, and surrounded by capillaries and nerves. The secretion of saliva is stimulated by the presence of food or other substances in the mouth; even the sight or idea of food causes the mouth to "water." At other times the secretion is very limited in quantity. The amount secreted in twenty-four hours is variously estimated at from about fourteen ounces to three pounds avoirdupois.

SALIVA.—Saliva is a slightly viscid, transparent fluid, depositing, on standing, a little flocculent sediment, consisting principally of scaly epithelium of the mouth, small nucleated cells from the glands or ducts, granular matter, and oil globules. Its specific gravity is about 1005, usually alkaline, but often neutral, and sometimes slightly acid in its reaction.

COMPOSITION OF SALIVA.—(Bidder & Schmidt):

Water... 995.16
Organic matter, (ptyalin or salivin)........................ 1.34
Sulphocyanide of potassium.............. .... .06
Phosphate of lime, soda, and magnesia .... .98
Chloride of sodium and potassium........................ .84
Epithelium and gland cells 1.62
                                                    _____
                                                    1000.00

It is also said to contain a trace of albumen, and some oil globules; it therefore becomes slightly turbid on boiling, or by the addition of nitric acid. The *ptyalin* gives the saliva its viscidity; it is coagulated by alcohol; but not by heat. Sulphocyanide of potassium may be detected by chloride of iron, which produces the characteristic red color of sulphocyanide of iron.

The saliva from the parotid gland is a clear, limpid, watery fluid, having a distinctly alkaline reaction. It may be readily obtained by introducing a silver canula, $\frac{1}{220}$ of an inch in diameter, into the orifice of Steno's duct. The quantity of organic matter in the parotid saliva is large, when compared with the mineral ingredients.

The submaxillary saliva differs from the parotid secretion in being somewhat viscid, and more strongly alkaline. It may be secured by inserting a canula into Wharton's duct. The saliva from the sublingual gland is also alkaline, and more viscid than the preceding.

The secretion from the buccal glands and mucous membrane is obtained by ligating the ducts of the parotid, submaxillary, and sublingual glands, to exclude their secretion, and then collecting the fluid subsequently secreted in the mouth. This fluid is small in quantity, and much more viscid than either of the preceding secretions.

FUNCTION OF SALIVA.—It possesses the property of converting boiled starch into sugar, if kept in contact

with it a short time, at the temperature of 100° F.
This is due to the presence of the organic substance
which exists in the saliva, and it sometimes takes place
with great rapidity. This, therefore, was formerly sup-
posed to be the true physiological use of saliva. viz.: to
dissolve or digest the starchy portions of the food. It
was very soon noticed, however, that in the ordinary
process of digestion the starchy matters do not remain
long enough in the mouth for this change to take place,
but pass at once into the stomach, where the further
conversion of starch into sugar is entirely suspended by
the presence of the gastric juice. The most important
use of the saliva is to moisten the food and facilitate its
mastication, to lubricate the mass or bolus, and to assist
in its passage during the process of deglutition. The
watery fluid of the parotid gland is useful in the process
of mastication; while the more viscid secretion of the
other glands, and buccal mucus, serve to lubricate the
triturated mass, and facilitate its passage down the
œsophagus. During mastication, the saliva is intimately
mingled with the mass, and may in this way mechanically
enable the gastric juice to penetrate more readily every
part, as it enters the stomach. It was observed by
Spallanzani that food enclosed in perforated tubes, and
introduced into the stomachs of living animals, was more
readily digested when previously mixed with saliva, than
when mixed with water.

DEGLUTITION.

The organs of deglutition are the mouth, tongue,
pharynx, and œsophagus. The food, when properly
masticated and formed into a bolus on the tongue, is
carried backwards by that organ and thrown into the
pharynx. This is done by the pressure of the tongue

against the root of the mouth—the pressure commencing at the apex, and ending near the base. During this time, the hyoid bone is carried upwards and slightly forwards by the anterior belly of the digastric mylo-hyoid and genio-hyoid, the pharynx is raised by the stylo-pharyngeus and palato-pharyngeus to receive the bolus, the epiglottis is pressed over the aperture of the larynx, by the elevation of the pharynx and larynx towards the base of the tongue, and the bolus glides past. This constitutes the first act of deglutition. The base of the tongue is now drawn slightly upwards and back-wards by the posterior belly of the digastric and stylo-hyoid, the palato-glossi (or constrictors of the fauces) contract, and prevent the return of the bolus into the mouth, the soft palate is raised by the levator palati, the palato-pharyngei contract and come nearly together, the uvula filling up the space between them, and in this way the food is prevented from passing into the pos-terior nares. The constrictors of the pharynx then contract upon the bolus from above downwards, and force it into the œsophagus, which, by virtue of its vermicular and peristaltic action, urges it onwards to the stomach.

VOMITING.—In the mechanism of vomiting, the pro-cess of deglutition is exactly reversed. This may be caused by the administration of direct or indirect emetics, by mental emotion, as the sight of a disgusting object, by any unusual motion, as sailing, swinging, &c., by nervous shock, as in the case of severe wounds, by derangement of the system, or the presence of irritating substances of any kind in the stomach, or obstruction to the passage of the food through the bowels. Its *rationale* may be explained by the theory of reflex action. The irritation or impression being applied to the periphery

of the nerves, is first conveyed to the nervous centres (medulla oblongata), and thence a motor impulse proceeds, by which an impression is made upon those parts concerned in the act of vomiting, through the nerves which are distributed to them. The medulla oblongata may be affected directly by the presence of particular substances in the blood, or causes acting directly on the centre itself. The motor nerves implanted in it are thus stimulated to action, and the abdominal muscles, diaphragm, muscles of the larynx and pharynx, as well as the muscular fibres of the stomach and œsophagus, are thrown into contraction.

First, a deep inspiration is taken; the aperture of the glottis is closed, and the lungs being filled with air, the diaphragm is fixed. The glottis is closed by the elevation of the larynx against the base of the tongue. The pharynx is raised, the palato-pharyngei contract and close the posterior nares, the uvula filling the small interval between them, and thus the fluids are prevented passing through the nose. This constitutes the first act. Then the stomach contracts and is compressed against the diaphragm by the contraction of the abdominal muscles; the pylorus is closed, and the contents are forcibly ejected, their passage being facilitated by the anti-peristaltic action of the stomach, œsophagus, and pharynx.

CHYMIFICATION.

This process takes place in the stomach, through the agency of the gastric juice. The mucous membrane of the stomach is lined by columnar epithelium, and when examined by a lens, it presents a peculiar honeycomb appearance, caused by a number of shallow depressions or alveoli of a polygonal or hexagonal form, which vary from $\frac{1}{100}$ to $\frac{1}{350}$ of an inch in diameter, separated by

slight ridges. In the bottom of each alveolus may be seen the orifices of minute tubes, the gastric follicles. They are arranged perpendicularly, side by side, short, and tubular in character towards the cardiac end; but near the pyloric extremity, they are more thickly set, convoluted, and terminate in dilated saccular extremities, or divide into from two to six branches, the object of which is to increase the extent of surface for secretion. The follicles consist of an involution of the basement membrane, lined with cells, and are divided into two varieties, which differ only in the character of the cells which line them, and the secretion which they produce, viz: the *mucous follicles* and *peptic follicles.* The former predominate towards the pylorus, and the latter towards the cardiac end. The mucous follicles are lined with columnar epithelium on the sides, and rounded in the bottom, and secrete the mucus. The deep part of the peptic follicles is filled with neuclei and granules; above this is a mass of nucleated cells, the upper part of the follicles being lined with columnar epithelium. These follicles are supposed to secrete the gastric juice.

GASTRIC JUICE.—Gastric juice was obtained by Spallanzani from the stomachs of animals, by causing them to swallow sponges, attached to the ends of cords, by which they were afterwards withdrawn and the fluid expressed. It has since been obtained and experimented upon by Dr. Beaumont, of the U. S. Army, from Alexis St. Martin, a Canadian boatman, who had a permanent gastric fistula, the result of a gun-shot wound. It may also be obtained from any of the lower animals, by making an artificial opening through the abdominal walls and inserting a canula.

PHYSICAL APPEARANCE AND PROPERTIES.—It is a clear, colorless fluid, of an acid reaction, secreted only

during digestion, or as the result of some irritation applied to the mucous coat of the stomach. Its specific gravity is 1010. It is not prone to decomposition, and may be kept for an indefinite length of time in an ordinary glass-stoppered bottle. After standing for two or three weeks, a confervoid vegetable growth shows itself in the fluid. This growth has a dendritic appearance, each branch or filament consisting of a single row of elongated cells. The total quantity of gastric juice secreted in twenty-four hours is about fourteen pounds. This would seem almost incredible, did we not remember that the gastric juice is in part reabsorbed, together with the alimentary substances which it holds in solution, after the process of digestion is completed. The secretion of gastric juice is much influenced by nervous conditions. It is diminished by irritation of temper, fear, joy, fatigue, mental exertion, or any febrile disturbance of the system. The gastric juice does not act on the mucous membrane of the stomach during life; but after death this membrane is generally found dissolved and disintegrated by its action. This depends upon the fact that the vital power of the tissues enables them to withstand the action of the gastric juice.

CHEMICAL COMPOSITION OF GASTRIC JUICE:

Water	975.00
Pepsine	15.00
Lactic acid, (free)	4.78
Chlorides(of sodium, potassium, calcium, and ammonium)	3.63
Phosphates (of lime, magnesia and iron)	1.59
	1000.00

It was formerly supposed that hydrochloric acid was the acidifying agent of the gastric juice, and in all probability a small quantity is sometimes present; but lactic acid is much the more abundant and important of the two. The presence of free acid is essential to its

physiological properties, for the gastric juice will not exert its solvent action upon the food after it has been neutralized by an alkali.

The organic matter, or *pepsine*, is next in importance. It is precipitated from its solution in the gastric juice by alcohol and various metallic salts; but is not affected by ferrocyanide of potassium. It may be coagulated by boiling. Gastric juice which has been boiled, or mixed with a small quantity of bile, loses its property of digesting substances.

FUNCTION.—It dissolves the albuminoid or organic substances of the food, but not starch, oils, fat or sugar. By its action the albuminoid matters of the food are converted into a substance called albuminose. (See albumen.)

The liquefying process which the food undergoes in the stomach is thought by some to be, not a simple solution, but a catalytic transformation produced in the albuminoid substances by the *pepsin*, which acts as a ferment. The gastric juice will exert its solvent action on the food outside the body, as well as in the stomach, if kept in glass phials upon a sand bath, at a temperature of 100° F.

RATE OF DIGESTION.—The time required for digestion varies in different animals. In the carnivora, fresh raw meat requires from nine to twelve hours. The average time required in the human subject varies from one hour to five and a half hours, according to the kind of food taken.

Dr. Beaumont's table, taken from Alexis St. Martin.

Pigs' Feet	1.00 hour.	Roast Beef	3.00 hours.
Tripe	1.00 "	Roast Mutton	3.15 "
Trout	1.30 "	Veal	4.00 "
Venison	1.35 "	Salt Beef	4.15 "
Milk	2.00 "	Roast Pork	5.15 "
Roast Turkey	2.30 "		

ARTIFICIAL DIGESTION.—An artificial digestive fluid
may be made by macerating a piece of the mucous
membrane of the stomach of a pig in distilled water for
twelve hours, at a temperature of from 98° to 100° F.,
and then adding lactic or hydrochloric acid. The fluid
thus formed will be found to possess full digestive powers,
and nearly all the properties of the gastric fluid. Such
a preparation is very useful in cases where deglutition
is impracticable, and in which the body is being nour-
ished by nutritive enemata. It is mixed with the nutri-
tive fluid, which is injected into the bowels. *Pepsine*
is administered with benefit in some forms of dyspepsia.

MOVEMENTS OF THE STOMACH.—The movements of
the stomach are effected by the alternate contraction of
the longitudinal and circular fibres of its muscular coat.
It was observed by Dr. Beaumont, by introducing the
bulb and stem of a thermometer. By this action the
food is first carried into the left side of the stomach, into
the pouch or cul de sac, and thence along the greater
curvature to the pylorus, and back again along the
lesser curvature to the cardiac extremity. This circuit
is repeated as long as there is any food in the stomach.
The duration of each circuit is about three minutes.
This action of the stomach produces a constant churning
of the food, and secures its thorough admixture with the
gastric juice, which penetrates every particle of food, and
converts it into a greyish pulpy mass of a homogeneous
appearance, called *chyme*, which then passes into the
duodenum.

CHYLIFICATION.

This process takes place in the small intestines, but
principally in the duodenum. For a description of the
mucous membrane of the small intestine, see "mucous
membrane." It has already been stated that only the

albuminoid substances are digested by the gastric juice. The starch, oils, fats and sugar, pass unchanged into the small intestines. Here they come in contact with the mixed intestinal juices, and are reduced to a state fit for absorption. The juices of the small intestines are the *intestinal juice proper*, or the fluid secreted by Brunner's glands, and Lieberkühn's follicles, the *pancreatic juice*, and the *bile*. These fluids, in contradistinction to the gastric juice, have an alkaline reaction.

INTESTINAL JUICE.—This may be obtained in a tolerably pure state by ligating the duodenum of some of the lower animals, as the dog or rabbit, just above the opening of the choledoc duct, and establishing a fistulous opening into the duodenum. It is small in quantity, and consists of the secretion from Brunner's glands, mixed with the fluid from the follicles of Lieberkühn, and some mucus.

PHYSICAL APPEARANCE AND PROPERTIES.—It is a colorless, viscid fluid, of an alkaline reaction, closely resembling, in its physical characters, the saliva and pancreatic juice. It possesses the property of converting starch into sugar. The quantity obtained by experimenters has rarely been sufficient for a thorough investigation of its properties.

FUNCTION.—It is supposed to aid in the digestion of the amylaceous portions of food. By its action the starch is converted into dextrin, and then into sugar (glucose), in which state it is soluble, and thus admits of direct absorption into the blood-vessels, or the sugar is converted into lactic acid, and in this condition passes into the circulation. The presence of free alkali is as necessary to these changes, as free acid to the solution of the albuminoids by the gastric juice. Boiled starch is

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more readily digested by all animals than raw; in fact, boiling is necessary to its perfect digestion.

PANCREATIC JUICE.—This substance is intended to assist in the conversion of starch into sugar, and also to digest the oily portions of the food. It may be obtained from the dog by inserting a canula in the pancreatic duct (major), through a fistulous opening in the abdomen. The pancreas is present in all the vertebrate animals, and its duct opens into the upper part of the small intestines. In the human subject, the pancreatic duct and choledoc duct open into the duodenum at the same place. In some of the vertebrata they open at some distance from each other, the pancreatic duct being always below the biliary.

PHYSICAL APPEARANCE AND PROPERTIES.—It is a clear, colorless, viscid fluid, of an alkaline reaction, somewhat resembling, in its physical character, the salivary fluid. It is coagulated completely by heat, not a drop of fluid being left. It is also coagulated by nitric acid, alcohol, and the metallic salts. The precipitate may be redissolved by the addition of an alkali. The average amount secreted by the human subject in the course of twenty-four hours, is about 1 lb. 13 ozs.

Chemical composition according to Bidder & Schmidt:

Water	900.76
Organic Matter (Pancreatine)	90.38
Chloride of Sodium	7.36
Soda (free)	.32
Phosphate of Soda	.45
Sulphate of Soda and Potassa	.12
Lime, Magnesia and Iron	.61
	1000.00

The most important ingredient is the organic matter, or *pancreatine*. It is coagulated by heat, nitric acid and alcohol. It is also precipitated by sulphate of magnesia, and this distinguishes it from albumen.

FUNCTION.—It acts upon the oily portions of the food and fats, disintegrating them, and reducing them to a state of complete emulsion, the mixture being converted into a whitish, opaque, creamy fluid, which is readily absorbed. It also assists in the conversion of starch into sugar, and in this way promotes the digestion and absorption of amylaceous food. In disease of the pancreas, which is exceedingly rare, the patient invariably suffers extreme emaciation, and in some cases fat appears in the fæces. It is supposed by some that pancreatic juice is intended solely for the conversion of starch into sugar, and they argue that the pancreas is present in the herbivora as well as the carnivora; but it must be borne in mind that oil exists in vegetable as well as in animal diet.

USE OF THE LIVER AND BILE.—Bile is secreted by the cells of the liver from the blood of the portal vein, and may be readily obtained from its reservoir, the gall-bladder. It is secreted by the hepatic cells, which are situated in the interior of the lobules. When the cells become filled with bile, they break down, and the fluid is then taken up by the minute hepatic ducts which originate in the interior of the lobules. These small ducts, by frequent successive junctions, form two large ducts, each somewhat larger than a crow-quill, which emerge at the transverse fissure of the liver, one from the right and the other from the left lobe. These two ducts, together with the hepatic artery, the portal vein, nerves, and lymphatics, are enclosed in a little areolar tissue called *Glisson's capsule;* and about an inch below their exit they unite to form the hepatic duct, which soon unites with the cystic duct from the gall-bladder, and the union of the two constitutes the ductus communis choledochus. This is about two or three inches

long, and passing down behind the first portion of the
duodenum, it opens into the second portion, on its inner
side, a little below the middle, in connection with the
pancreatic duct.   The gall-bladder is situated on the
under surface of the right lobe of the liver, and serves
as a reservoir for the accumulation of the bile.   During
fasting, the gall-bladder is found full, and it empties itself
when digestion is going on.   Its presence is not essential,
for in many animals it is entirely absent, as in some of
the fishes, mammals, &c.

PHYSICAL APPEARANCE AND PROPERTIES OF BILE.—
The bile is a thick, viscid fluid, of a greenish yellow
color, a bitter taste, and a nauseous smell.   Its specific
gravity is from 1018 to 1030, and it possesses either a
neutral or slightly alkaline reaction.   When agitated in
a test tube it presents a peculiar soap-like foam, the
bubbles adhering closely together and remaining for a
long time without breaking.   The amount of bile secre-
ted in twenty-four hours is about two and a half pounds
avoirdupois.   It possesses antiseptic properties, prevent-
ing substances with which it is mixed from putrefying.
When it is absent in the alimentary canal, as in cases of
complete biliary obstruction, the fæces are found to have
an intolerable fetor.   Bile is constantly secreted by the
liver, but more actively from one to two and a-half hours
after food is taken.

CHEMICAL CONSTITUENTS OF OX BILE.—Frerichs:

Water	880.00
Glykocholate and taurocholate of soda	90.00
Biliverdine, fats and cholesterin	
Oleates, margarates and stearates of soda and potassa	13.42
Phosphates of soda, lime and magnesia	
Chloride of sodium, and carbonate of soda and potassa	15.24
Mucus of the gall-bladder	1.34
	1000.00

BILIVERDINE.—The most important ingredient is the
Biliverdine, which is the coloring matter of the bile.   It

is an uncrystallizable substance, of organic origin, containing nitrogen and a small quantity of iron. It does not pre-exist in the blood, but is supposed to be formed in the liver. In cases of biliary obstruction it may be absorbed, and circulating with the blood, stain the tissues and fluids of the body of a geenish-yellow or saffron color, giving rise to a state called jaundice. It is scarcely soluble in water, very slightly in alcohol; its best solvent being a solution of soda or potassa. Such a solution becomes green on exposure to the air, and on the addition of an acid, deposits green flocculi resembling the *chlorophyl* of plants. This was called by Berzelius *Biliverdine*.

CHOLESTERIN.—This substance may be removed from bile by agitation with ether, in which it is soluble. It is distinguished from fats, with which it is closely associated, by not being saponified by alkalies. It has also been found in the fluid of hydrocele, ascites and in the interior of many encysted tumors. It is a crystallizable substance, the crystals having the form of thin transparent rhomboidal plates. Cholesterin is not formed in the liver, but is supposed to originate in the brain and nerve tissue, from which it may be extracted by alcohol or ether, and is discharged by the liver. It is also found in the tissue of the spleen. It is the principal constituent of gall stones; its formula is $C_{37} H_{32} O$.

BILIARY SALTS.—The most important of these are glykocholate and taurocholate of soda. They are soluble in water and alcohol, but not in ether. The taurocholate possesses the property, when in solution, of dissolving a certain quantity of fat. These substances may be obtained as follows: The bile is evaporated, and the dry residue treated with alcohol and filtered; this alcoholic solution contains glykocholate and taurocholate of soda,

coloring matter, and fats. Ether is now added until a
precipitate takes place, which has at first a resinous ap-
pearance.   After this precipitate has stood from twelve
to twenty-four hours, it presents, when examined by the
microscope, a number of acicular crystals of glykocho-
late of soda, and some drops or globules of taurocholate
of soda, which resemble oil globules, except in their
chemical properties.   The glykocholate may be separated
from the taurocholate of soda by the following means:
The fluid containing alcohol and ether previously used is
poured off, and the deposit in the bottom of the tube is
dissolved in water.   To this, acetate of lead is added,
which gives a precipitate of glykocholate of lead, leaving
acetate of soda in solution.   The precipitate is filtered
and decomposed by carbonate of soda, reproducing the
original glykocholate of soda.   The filtered fluid which
remains, containing the taurocholate of soda, is then
treated with subacetate of lead, which precipitates a
taurocholate of lead.   This is filtered and decomposed
by carbonate of soda as in the former instance.   The
glykocholates and taurocholates are formed in the liver,
being produced by the hepatic cells and discharged by
the ducts.   They are not found in the blood.   The biliary
matters of dog's bile differ from the ox bile, in being
both precipitated by subacetate, but not by acetate of
lead.

In *human bile* there is also a crystalline substance,
and an abundant deposit of resinous drops similar to
taurocholate of soda.   The crystals of glykocholate of
soda are of different shapes; some are feathery, with
secondary needle-shaped crystals growing from their
borders; others are octahedra or diamond-shaped.   These
substances may be both precipitated either by acetate or
subacetate of lead.   If the watery solution be precipi-

tated by acetate of lead, and filtered, the filtered fluid gives no precipitate afterwards with the subacetate, and *vice versa.* These biliary ingredients of human bile are therefore precipitated by both or either of the salts of lead.

FUNCTION OF THE LIVER.—The hepatic cells contain more or less fat in the form of globules, and this may be regarded as a part of their secretion. It is also found to be most abundant when fatty matters are withheld from the food. The fat is formed by the cells from certain elements of the food, as starch, sugar, &c., and is discharged into the duodenum to be reabsorbed by the villi, and carried to the lungs, where it is decomposed by the oxygen in the production of animal heat.

GLYCOGENIC FUNCTION OF THE LIVER.—The actual formation of sugar in the liver was first discovered by Bernard. The sugar is formed by the liver itself, and is a normal constituent of its tissue. Its presence may be determined in the substance of the liver, and in the hepatic veins, by means of Trommer's test, or by fermentation. It closely resembles "glucose," or sugar of starch. It has also been found in the portal vein, owing to the reflux which, in the absence of valves, may take place after death. The sugar thus formed, is carried to the right side of the heart, and thence to the lungs, where it is decomposed for the production of animal heat. When the glycogenic function of the liver is abnormally increased by the irritation of the eighth pair of nerves, or of the nervous centre from which it arises, sugar is produced so rapidly in the liver, that the lungs cannot decompose the whole of it, and therefore it is thrown off by the kidneys, producing what is known as diabetes mellitus. Sugar and fat are both formed in the liver, irrespective of the kind or quality of the food. When

fat is formed too rapidly, either by the process of digestion, or in the liver, it is stored away in the body in the form of adipose tissue, or is deposited as fatty tumors, &c.

FUNCTION OF BILE.—During fasting, the bile is stored up in the gall-bladder, but if the fast be prolonged beyond a reasonable time, the bile overflows into the intestine. The flow of bile into the duodenum is caused by the presence of food, or any irritating substance upon the mucous surface of the small intestines. The bile is poured into the duodenum above the opening of the pancreatic duct, never below it—a circumstance not very probable if bile were solely an excrementitious substance, since it would have been quite as convenient for nature to have effected its discharge into the hepatic flexure of the colon. When the bile duct is tied, and this fluid prevented from passing into the duodenum, the animal becomes greatly emaciated, and ultimately dies from inanition. There can be no doubt, therefore, that the bile contributes in some way to the complete digestion and assimilation of the food. Bile cannot readily be detected in the fæces, and therefore it is supposed to be entirely changed in its passage through the bowels, or reabsorbed with the chyle, and thrown back into the system, to be used in the generation of heat by contact with oxygen in the lungs. We may therefore conclude as follows:

1st. That the liver secretes a complex fluid, the *"bile,"* which is poured into the duodenum. Its coloring matter, *"biliverdine,"* and some of the salts, are carried off in the fæces forming the natural purgative of the body, and by virtue of its antiseptic properties, preventing decomposition of the fecal matters. Its fat is in great part reabsorbed; other elements assist in the complete digestion of those parts of the food which have escaped the action of the gastric juice; probably the azotized portions.

2nd. It forms sugar and fat in its circulation, independently of the substances in the food.

3rd. It eliminates carbonaceous matters; some directly, as *biliverdine;* others indirectly, as fat and sugar, which pass to the lungs, and are converted into carbonic acid and water by the oxygen of the air.

TESTS FOR BILE.—When a mixture containing bile is exposed to the air in an open glass vessel for a few hours, the upper part of the fluid assumes a greenish tinge. When nitric acid is added to a mixture of bile, and shaken, a dense precipitate of a bright grass-green color is produced. This does not indicate the presence of biliary substances proper, but only the biliverdine. Tincture of iodine produces the same change of color, when used in small quantity. In this way biliverdine has been detected in the urine and other fluids, in jaundice. These tests are, however, very inefficient, since they only determine the presence of biliverdine, and not of the biliary substances proper.

PETTENKOFER'S TEST.—This is the best test yet produced for the detection of the biliary substances. A watery solution of the bile is mixed with a little cane sugar, and sulphuric acid added, until a red, lake, or purple color is produced. The sugar must be used in small quantities, for when added in excess, it is liable to be acted on and discolored by the sulphuric acid. The solution of sugar should be about one part sugar to four parts water. If three or four volumes of water be added to the mixture, a precipitate falls down, and the color is destroyed. Foreign matters, not of a biliary nature, such as fats, oils, turpentine, &c., may produce a similar red or violet color. This may be overcome, however, by first extracting the suspected matters with alcohol, precipitating with ether, and dissolving the precipitate

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with water, before applying the test. In this way
all foreign substances which interfere with the test may
be removed.

We find, then, that the digestion of the food is not a
simple operation, but consists of several different pro-
cesses, which occur successively in different portions of
the alimentary canal. The food is first subjected to the
physical operation of mastication and insalivation in the
mouth. It then passes into the stomach, where it meets
with the gastric juice, which converts it into a pulpy mass
—the chyme. The food then passes into the duodenum, or
small intestine, where it meets with the intestinal juices,
and is converted into chyle. This is taken up by the
lacteals in the process of absorbtion, and the coarser
portions of the food, or excrementitious matters of the
body, are carried off by the large intestines.

LARGE INTESTINE.—Its office is mainly confined to
the separation and discharge of the fæces.

It is supposed by some that a certain amount of
digestion takes place in the cæcum. In some animals it
is very large, and would seem, without doubt, to exercise
some special function in the complete solution of the
food. But in man it is quite rudimentary, and has very
little action upon the fæces in their passage through. No
material change takes place in the fæces as they pass
through the intestine, excepting that they become drier
the longer they remain in the bowel, owing to the
absorbtion which takes place. Nutritive enemeta may
also be absorbed by the large intestine. The fæces are
urged onwards to the rectum by the vermicular action of
the bowel, where they accumulate, and are prevented
from escaping by the contraction of the sphincter. The
presence of the accumulated fæcal matter in the retcum,
causes a sensation demanding its discharge or defecation.

DEFECATION.

This is the expulsion of the fæces from the rectum, and it is effected by the contraction of the muscular fibres of the rectum, assisted by the contraction of the abdominal muscles and diaphragm, which diminish the size of the abdominal cavity, compress the intestines, and thus force onwards the fecal matter towards the anus. This force is at the same time quite sufficient to overcome the passive contraction of the sphincter. If the rectum be over-distended by fecal matter, its contractility will be diminished, and immense accumulations may take place. This is apt to occur in aged persons, and the fecal matter may require to be scooped out. On the the other hand, when the fæces do not accumulate in sufficient quantity to distend the rectum, the act of defecation may be attended with difficulty, and the straining may cause prolapsus ani. Under such circumstances enemata are of great service, by distending the bowel and stimulating it to proper action.

The quantity of fæces depends on the nature of the food and the state of the system. Vegetable food produces a greater amount of fæces than animal, because it contains much that is incapable of reduction in the stomach and duodenum. The quantity passed daily by men in health is about five or six ounces; so that if we assume thirty-five ounces to be the average quantity of food per diem, it may be inferred that about thirty ounces are appropriated for the support of the body.

ANALYSIS OF FÆCES—

Water			73.3
Matters soluble in water	Coloring of bile	0.9	
	Albumen	0.9	5.7
	Extractive	2.7	
	Salts	1.2	
Matters insoluble in water	Mucus		
	Resin		
	Fat	Excretine and	
	Animal matters	Stercorine	21.0
			100.0

EXCRETINE was discovered by Marcet. It is a crystallizable substance, insoluble in water, but soluble in ether and hot alcohol, and is slightly alkaline. The crystals are in the form of four-sided prismatic needles. It consists of $C_{78} H_{78} O_2 S$. It fuses at 204°F.

STERCORINE was discovered by Prof. Flint, Jr. It has the same crystalline form as excretine, is also soluble in ether and boiling alcohol, but fuses at a lower temperature. It is supposed to be formed from cholesterine.

ASHES OF FÆCES.—The ashes will yield, according to Berzelius, chloride of sodium, sulphate of soda, tribasic phosphate of soda, phosphate and sulphate of lime, phosphates of magnesia and iron, and silica.

The peculiar odor of the fæces is supposed to be caused by the secretion of Peyer's glands. Certain gases are also generated in the bowels. They consist of carbonic acid, hydrogen, carburetted hydrogen, sulphuretted hydrogen and nitrogen. They would seem to favor the passage of the fæcal matter by their distension of the bowel. In some diseases, as hysteria, puerperal fever, inflammation of the bowels, &c., large quantities of gas are accumulated, producing *tympanitis* or *meteorism*. The natural color of the fæces is yellow, but in biliary obstruction they become clay-colored and offensive. Again, when the bile is vitiated or secreted in large quantity, they vary from green to dark brown.

CHAPTER VI.

ABSORPTION.

ALL the tissues of the body are more or less porous, and capable of absorbing fluids brought into contact with them; but the special absorbents are the villi and lacteals, veins, lymphatic vessels and glands, and *probably* the glandulæ solitaire.

VILLI AND LACTEALS.—The structure of the villi has been already described among the appendages to the mucous membrane. (Chapter IV.) They are the agents concerned in the absorption of the chyle. In consequence of their number and form, they increase greatly the secreting surface of the intestine. They hang out in the nutritious semi-fluid mass contained in the intestinal cavity, like the roots of a tree in its soil, and rapidly imbibe the soluble portions of the food. The *lacteals* commence in the villi, and form a network with close meshes in the submucous areolar tissue. In structure they resemble the veins, having three coats; an *outer*, areolar and elastic; a *middle*, muscular and elastic; and an *inner*, epithelial and elastic. They commence near the apex of each villus, either by a blind extremity, or minute plexus. The precise manner in which they originate is not known. They then pass between the layers of the mesentery towards its root, anastomosing freely with each other, and traversing the mesenteric glands in their way to the right side of the aorta, opposite the second lumbar vertebra, where they empty themselves, together with the lymphatics from the lower extremity, into the receptaculum chyli, or commence-

ment of the thoracic duct. The thoracic duct, which is continued upwards, lies between the aorta and vena azygos major in the thorax; it then passes behind the arch of the aorta, and empties itself into the upper part of the subclavian vein, close to the internal jugular, its orifice being guarded by two valves. The lacteals are, however, not a special system of vessels by themselves, but may be considered as a part of the general lymphatic system. Their function is to absorb the chyle.

COMPOSITION OF CHYLE (of a donkey).—Rees:

Water	90.24
Albumen	3.52
Fibrin	0.37
Fat	3.60
Extractive	1.56
Salts	0.71
	100.00

As the chyle passes onwards towards the thoracic duct, it becomes more fully elaborated, the quantity of molecules or oil globules diminish, nucleated cells $\frac{1}{2800}$ to $\frac{1}{3000}$ of an inch in diameter, called chyle corpuscles, are formed in it, and by the development of fibrin, it acquires the property of coagulating spontaneously. The higher it ascends in the thoracic duct, the more fully is it elaborated, the chyle corpuscles are found more advanced towards their development into red blood corpuscles, so much so, that the fluid has a pinkish tinge from the number of red corpuscles it contains. (See chapter on blood.)

VEINS.—The structure and general function of the veins will be described in the chapter on circulation.

LYMPHATIC VESSELS AND GLANDS.—These constitute the chief system of absorbents of the body. They are found in nearly every part of the body, except the substance of the brain and spinal cord, eye-ball, cartilage,

tendons, membranes of the ovum, placenta, funis, hair, nails and cuticle. There are two sets, the *superficial* and *deep;* the former are situated in the superficial fascia, and the latter accompany the deep blood-vessels. The lymphatics of the lower extremities empty into the receptaculum chyli, which is continued upwards through the thoracic duct, to the left subclavian vein, and those of the upper extremities, head and neck, empty by a short trunk into the subclavian vein of the right side.

STRUCTURE.—The lymphatic vessels, like the arteries and veins, are composed of three coats. 1st, an inner, epithelial and elastic; 2nd, a middle, muscular and elastic, disposed tranversely; and 3rd, an external, areolar and elastic. They are also provided with valves, which prevent regurgitation, and assist in the onward flow of the fluid which the vessels contain. The valves are more numerous in the lymphatics than in the veins, and the walls of the vessels are thinner and more transparent. The lymphatic vessels may be readily brought into view by injecting them with mercury. The vessels, in their course, pass through certain glandular bodies— the "lymphatic" or "absorbent" glands.

LYMPHATIC GLANDS.—The lymphatic glands, among which may be included the *mesenteric glands,* consist of an external layer of fibrous tissue, and a pulpy substance within. From the inner surface of the external layer thin septa or laminæ are given off, which penetrate the interior of the gland in every direction, and unite with each other at various points, so that the substance of the gland is divided into numerous spaces, which communicate with each other by small openings. These spaces are filled with a soft, reddish, pulpy substance, which is penetrated, like the salivary glands, by a network of capillaries. Each lymphatic vessel, as it enters the

gland, divides into a number of small branches, called the *vasa afferentia;* these communicate in some way with other similar twigs forming the *vasa efferentia,* which leave the gland in the opposite direction. The lymphatic glands are arranged in chains, in various parts of the body, as in the groin, parallel to Poupart's ligament, and along the posterior border of the sterno-cleido-mastoid muscle, &c., &c. There are from 200 to 300 glands in the body, and they vary in size from a millet seed to an almond. The vessels and glands contain a fluid termed lymph.

LYMPH.—This is a colorless, or pale-yellow, transparent fluid, of a slightly alkaline reaction, and a saline taste. It also contains nucleated corpuscles, resembling those which are found in the chyle, but less numerous, which are supposed ulimately to form blood corpuscles. These two fluids—lymph and chyle—are nearly similar, as will be seen from the following table, when compared with the preceding one on chyle.

CHEMICAL CONSITUENTS.—(Lymph of a donkey). Rees.

Water	96.54
Albumen	1.20
Fibrin	0.12
Fat	A trace.
Extractive	1.56
	100.00

It is spontaneously coagulable when removed from the vessels, owing to the presence of fibrin, which is also more abundant in the large than in the small vessels. The albumen is smaller in quantity than in chyle, and there is scarcely any fatty matter. The ingredients of lymph are chiefly the products of the gradual wear and tear of the tissues.

MECHANISM OF ABSORBTION.

Imbibition or osmosis is a physico-chemical process, and occurs in inorganic as well as in dead or living organic

bodies. It depends on the force of adhesion between a fluid and a porous solid, by which the fluid is drawn into the interstitial passages of the solid. The fluid chiefly concerned in this process is water, and the various other substances which are taken up in a state of aqueous solution, as fibrin, albumen, salts, gases, &c. The process of osmosis in the living body is, however, regulated and controlled by the agency of cells, which have the power of choosing and refusing from the materials brought into contact or relation with them.

The *quality of the fluid* influences absorption. If water be brought in contact with the surface of the body or taken into the stomach, it is readily absorbed, especially in the latter case, because it is brought nearer the blood-vessels; or if a quantity of warm water is injected into the colon, it is rapidly absorbed and excreted by the kidney. But if the water contain a quantity of chloride of sodium, or any salt in solution, it will be absorbed more slowly, while if a saturated solution be used, the fluid portion of the blood will pass out of the blood-vessels to mingle with it. When the fluid passes from without inwards the process is termed *endosmose;* when from within outwards, *exosmose.* The term *osmose* or *osmosis* refers simply to the passage of a fluid in either direction, and is much more convenient. This property of endosmose and exosmose may be demonstrated by placing a membranous partition through a vessel of earthenware. and putting pure water on one side, and a solution of, salt and water on the other. It will be found that the water will pass more rapidly through the membrane to the side containing the salt and water, but that after a time both sides will be equally impregnated with salt. In this case the passage of the water to the salt is called "*endosmosis,*" and the more scanty passage of salt to the

water "*exosmosis.*"   The instrument used for measuring
the rapidity of endosmosis is called an *endosmometer.* A
very good one may be made from a common glass funnel
by tying a piece of bladder over the lower end, and fix-
ing a glass tube, open at both ends, in an upright position
within the funnel.   The instrument is then filled with a
solution of salt or sugar, and put in a vessel containing
pure water.   The water will then pass through the mem-
brane at the bottom of the funnel into the solution by
osmosis, and cause the fluid to ascend in the tube, which
may have been previously marked, or graduated, by a
common file.   The height to which the fluid rises in a
given time is a measure of the rapidity of endosmosis
over exosmosis.

The *character of the membrane* influences absorption.
It is necessary that the membrane should be fresh. If
it be in a state of decay, or if it has been dried, it will
not produce the desired effect.   The position of the
membrane causes a variation.   In some instances endos-
mosis is more rapid when the mucous surface is in con-
tact with the denser solution.   In other cases it is exactly
the reverse.   The density or laxity, and the thickness
or thinness of the membrane, also affect the result for
obvious reasons.

Pressure influences absorption.   Pressure promotes
the transmission of a fluid through a membrane, and the
rapidity of transmission will depend, "*cœteris paribus,*" on
the degree of pressure employed.   Since this promotes
the flow in one direction, it also tends to retard the pas-
sage of fluids in the opposite direction; for example,
when the blood-vessels are distended with blood, as in
plethora or inflammation, fluids enter with difficulty from
without, while if the tension is removed by venesection,
absorption takes place quite readily.

Motion of the fluid in the vessels influences absorption. The motion of the fluid within the vessels promotes absorption, by diminishing their pressure outwards on the walls and allowing the external pressure to predominate, and also by moving the particles onwards, to make room for those which are being removed by absorption.

ABSORPTION BY THE VILLI AND LACTEALS.—During the intervals of digestion, the lacteals contain a colorless transparent substance, similar to that which is obtained in other parts of the lymphatic system. If the food consists only of starchy and albuminous substances, very little change is noticed in the character of their contents. But if fat has been taken, the lacteals become filled with a white chyle or "*molecular base*," consisting of minute fat globules and a small quantity of fibrin, albumen, (or albuminose), &c. The presence of chyle in the lacteals is therefore not constant, but occurs during the process of digestion, or as soon as the fatty matters of the food have been disintegrated and emulsified by the intestinal fluids. The absorption of fat from the intestine is not performed exclusively by the lacteals, but some of it is taken up by the blood-vessels, for it has been found by Bernard in the blood of the mesenteric veins of the carnivora during digestion. It has also been found in the blood of the portal vein. Fat being a non-osmotic substance, especially when the membrane is moist, a difficulty has been experienced in accounting for its absorption. It has been found, however, that the presence of an alkaline fluid, mixed with the emulsified fat, will facilitate the process of osmosis, and secure the complete absorption of the fatty matter.

The chyle and other fluids are absorbed by the process of osmosis, which is regulated and controlled by the agency of cells. The epithelial cells covering the free

surface of the villi are the first active agents in this absorption, for during the process of digestion they are found filled with chyle. They then break down, and this fluid passes through the basement membrane by *osmosis* *(endosmosis)*, being regulated and controlled by those cells which are found in the interior of the villi, and in contact with the lacteals (see structure of villi). These cells, when filled with chyle, break down, and their contents come in direct contact with the lacteals, through the coats of which this fluid again passes by osmosis, the process being determined by the cells which line the interior of the lacteals. The fluid then passes to the receptaculum chyli, and thence through the thoracic duct to the left subclavian vein. Its onward flow is facilitated by the contractile tissue, which is found in the coats of the lacteals and thoracic duct, and is prevented from regurgitating by the valves which are found in these vessels.

ABSORPTION BY THE VEINS.—That the veins also absorb, has been proved by the experiments of Magendie and Panizza. The latter observer opened the abdomen of a horse, and drew out a portion of the small intestine, eight or nine inches in length, which he enclosed between two ligatures. He then ligated the mesenteric vein, and made an opening behind the ligature, in order to allow the blood brought by the artery to pass out. An opening was also made in the intestine, through which was introduced some hydrocyanic acid, and almost immediately afterwards, it was detected in the blood which flowed from the opening in the vein. The above experiment was varied by simply compressing the veins, and introducing hydrocyanic acid in the intestine. In this case no effect was produced on the animal while compression was maintained, but as soon as the pressure was

removed, symptoms of poisoning by hydrocyanic acid showed themselves. The veins not only perform an active part in the general absorption of fluids in various parts of the body, but are also specially engaged in the absorption of the alimentary fluids of the intestine. The albuminous and starchy portions of the food are absorbed by them from the mucous surface of the stomach and small intestines, in the form of albuminose and glucose. The substances taken up by the veins are thence conveyed by the portal system to the liver, where some of them are acted upon by that organ in the production of bile, sugar, fat, &c., some of which are carried back into the alimentary system, and others are thrown into the general circulation.

In the process of absorption, the substances pass through the basement membrane by osmosis, this process being regulated by the action of the cells, similar to that which takes place in the lacteals.

ABSORPTION BY THE LYMPHATICS.—That the lymphatics absorb is perhaps best shown by the phenomena of disease; for example, the virus of syphilis is frequently carried from the chancre on the penis, to the glands in the groin, giving rise to bubo, and the matter from the abscesses is capable of imparting the disease to other individuals. The glands of the axilla become enlarged and inflamed, in consequence of a poisoned wound of the hand or arm, or in erysipelas. Absorption takes place in the same way, and on the same principle, as in the lacteals and veins. The function of the lymphatic vessels is to absorb the ingredients of the lymph which are derived chiefly from the metamorphosis of the tissues, and returned into the general circulation, in order to subserve some further purpose in the animal economy, or to be eliminated by the process of excretion.

It is also quite possible that the superfluous parts of the material brought by the blood-vessels for the supply of the tissue may be carried away by the lymphatics. The effete matters are not all absorbed by these vessels, for carbonic acid seems to enter the capillaries in a direct manner through their walls, since it is found in greater quantity in venous than arterial blood.

The lymphatic glands are engaged in the process of elaborating the lymph, and they are also supposed to separate from the blood contained in the blood-vessels in their interior, a secretion which is ultimately thrown into the general circulation by the efferent vessels of the gland, which may be regarded as excretory ducts.

In the latter case, these glands may be looked upon as the "great internal glandular or secreting system."

GLANDULÆ SOLITAIRE.—These have been already described in the chapter on membranous expansions. Each gland contains in its interior a soft pulpy mass, pierced by a capillary plexus of vessels. They have no excretory ducts, and are supposed to be connected with the lacteals. By some they are regarded as the first row of mesenteric glands, situated in the walls of the intestinal canal.

CHAPTER VII.

BLOOD.

THIS fluid is prepared from the food by the process of digestion and assimilation, and is constantly circulating through the vessels, during life. It supplies the material from which the tissues are built up and nourished; it contains the substances used in the combustive process, and it also contains the effete particles which result from the disintegration of the tissues. The elements found in the blood may be divided into four classes, as follows:—

1st. The *elaborative* elements, as corpuscles and oxygen.

2nd. The *histogenetic* elements, as fibrin, albumen, and fat. (The fat is used to build up the adipose and nerve tissues.)

3rd. The *calorific* elements, as sugar (or glucose) and fats.

4th. The *depuritic* elements, as lactic acid, uric, hippuric, and carbonic acid, urea, creatine, creatinine, volatile fat acids, odorous substances, salts, and water.

QUANTITY.—It is very difficult to determine the exact quantity of blood in the human body; but from various experiments, it has been ascertained by approximation that the quantity of blood in a human body weighing 144 lbs. would be about 16 or 18 lbs., or as 1 to 8.

PHYSICAL CHARACTER OF THE BLOOD.

The blood, as it flows from the body, appears to be a homogeneous, red fluid, of a slightly alkaline reaction,

and heavier than water. The odor resembles the per-
spiration, or the breath of the animal.

The color of arterial blood is bright scarlet, and that
of venous blood dark purple; but disease of the lungs,
heart, or kidney, may cause the whole mass to assume a
venous hue, owing to the circulation of carbonic acid and
other impurities in it; or it may assume an arterial hue
when the animal breathes pure oxygen. It is also
stated by Dr. Davy that in warm climates the blood is
venous in its character. This is due to the high temper-
ature, which reduces the excretion of carbonic acid, and
is a fact of very great practical importance to the
physician. The inhalation of chloroform and ether pro-
duces a venous condition, by interfering with the function
of respiration.

SPECIFIC GRAVITY.—The *specific graity* of the blood
varies from 1050 to 1059, the average being about 1055.
Any substance which will modify the relation between
the solids and fluids will change the specific gravity.
For example, the specific gravity may be diminished by
the introduction of water, whilst, on the other hand, it
may be increased by the administration of drastic pur-
gatives. In anemia, the specific gravity may be increased
by good, liberal diet, and iron. The specific gravity of
the corpuscles (solids) is 1088, the liquor sanguinis
(fluids) 1028.

MICROSCOPICAL APPEARANCE OF THE BLOOD.

Blood, when examined by the microscope, when still
in the vessels, as in the frog's foot, or bat's wing, is seen
to consist of a solid and a liquid portion; the former
includes the *red and white corpuscles*, the latter, the
liquor sanguinis, or plasma. On the other hand, when
the blood has been drawn from the body, and allowed to

stand, it coagulates, or separates into two portions—the *crassamentum*, or clot, and the *serum*. This coagulation depends on the presence of fibrin, which coagulates spontaneously, and forms a network of fibres, in the meshes of which are included the red and white corpuscles. The clot then contracts, and squeezes out the serum. The crassamentum, or clot, therefore consists of the fibrin and corpuscles; and the serum contains the albumen, salts, and water.

BLOOD IN THE LIVING VESSELS.

SOLID.	LIQUID.	
Red and White Corpuscles.	Fibrin ... Albumen Salts and Water. ...	Liquor Sanguinis, or Plasma.

BLOOD OUT OF THE BODY.

SOLID.		LIQUID.	
Red and White Corpuscles Fibrin	Clot.	Albumen...... Salts........... Water.........	Serum.

BLOOD CORPUSCLES.—The *red* blood corpuscle is a simple rounded biconcave disc, in the centre of which is seen a bright or dark spot, according as the microscope is beyond or within focus. This spot, which has been mistaken for the nucleus (a structure which the corpuscle does not possess at maturity), is the result of the refraction of light. The form of the disc may be changed by any agent which modifies the specific gravity of the blood, or interferes with the circulation. For example, water is readily absorbed by the corpuscle, causing it to become oval, then rounded, and finally to burst. Gulliver mentions the case of oxen having died from drinking too much water; and from the bursting of the corpuscles, and the liberation of the hematine, the arteries were stained, so as to give rise to the supposition of arteritis. In anemia and Bright's disease they become oval, and

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in the latter case granular. When the amount of fluid is diminished, or solids increased, as in plethora, the corpuscles become strongly biconcave and ragged on the borders. The inhalation of gases also produces a marked change in their shape. When carbonic acid is inhaled they become rounded, and are again rendered biconcave by breathing pure air or oxygen gas. When chloroform is inhaled they become rounded and serrated. Ether produces an irregular outline, and the administration of alcohol renders them oval and indented on one side. The corpuscles may be changed in shape during circulation. In the capillaries, they sometimes become elongated, twisted, or bent, in order to accommodate themselves to the narrow, curved channels through which they have to pass.

The *size* of the red blood corpuscles varies in the human subject from $\frac{1}{4000}$ to $\frac{1}{2800}$ of an inch in diameter, the average being about $\frac{1}{3200}$ and the thickness about $\frac{1}{12000}$. The size of the corpuscle bears no relation to the size of the animal, *e. g.*, those of the mouse tribe are larger than those of the deer, as will be seen from the following table:

Man	$\frac{1}{3200}$	Mouse	$\frac{1}{3800}$
Ape	$\frac{1}{3400}$	Cat	$\frac{1}{4400}$
Horse	$\frac{1}{4600}$	Fox	$\frac{1}{4100}$
Ox	$\frac{1}{4200}$	Wolf	$\frac{1}{3600}$
Sheep	$\frac{1}{3600}$	Elephant	$\frac{1}{2700}$
Goat	$\frac{1}{6300}$	Red Deer	$\frac{1}{3000}$
Dog	$\frac{1}{3500}$	Musk Deer	$\frac{1}{12000}$
Rabbit	$\frac{1}{3600}$	Two-toed Sloth	$\frac{1}{2800}$

In all the above, the form and appearance of the corpuscles are the same, although they vary much in size. The elephant and sloth (*Bradypus didactylus*) are the only species in which the corpuscles are known to be larger than in man. In the camel tribe (camel, dromedary, lama) they are oval in shape, but do not possess a nucleus. In all the oviparous vertebrata, as birds, rep-

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tiles, and fishes, the corpuscles are of a large size, oval in shape, and contain granular nuclei. The nuclei may be distinctly seen on the addition of acetic acid, which clears up the cell-wall. The corpuscle of the frog is about $\frac{1}{1200}$ of an inch in diameter.

COLOR.—In a single stratum of red corpuscles no color is observed, but when two or three are superimposed upon one another, a deep red tint becomes apparent. The color depends partly on the shape of the corpuscle, and partly on the hematine it contains. They also have a tendency to adhere by their concave surfaces in the form of *ruleaux*. This is more peculiar to the red than the white, and is very much increased in inflammation. If any of the salines be added to the blood, this peculiar tendency is in a measure neutralized.

The red corpuscle of the mammalia, unlike the oviparous vertebrata (birds, fishes, reptiles), cannot be shown to consist of a cell and nucleus. If the nucleus be present, it must either be so large as to fill the cell, leaving no space between it and the wall, or so extremely small as not to be detected by our means of observation.

WHITE CORPUSCLES.—These are so named on account of their white, or colorless appearance. They have a circular outline, appear granular within, and are tolerably uniform in size, their diameter being about $\frac{1}{3000}$ of an inch in warm-bloods, and $\frac{1}{2500}$ in reptiles. In some of them a neucleus may be distinctly seen on the addition of acetic acid; in others the neucleus appears to be broken up, so as to give the cell a granular appearance. They are more highly refractive than the red under the microscope, and are generally observed on or near the margin of the field, while the red are grouped together in the central part. When examined in the circulating blood of a frog's foot, they are seen to occupy the ex-

terior of the current, and adhere more or less to the walls of the vessels, or appear to pass from the centre to the walls and back again, as if they were carriers of nourishment to the tissues. The proportion of white to red corpuscles in man is about one to fifty; but in inflammation it may be one to twelve. In certain diseases, as anemia, leucocythemia, &c., the white corpuscles are relatively increased. In the oviparous vertebrata the proportion is higher than in man, being about one to sixteen; while in one of the vertebrata (amphioxus) the red corpuscles are entirely absent. In the invertebrate series, on the other hand, the corpuscles are almost invariably white, and hence the so-called white blood of this class of animals.

ORIGIN OF THE CORPUSCLES.—The earliest blood corpuscles are formed from the primordial cells in the vascular tract. The embryonic heart and aorta are formed by the arrangement of masses of the primitive cells, or germinal vesicles, of the mucous or vegetative layer, in the position, form, and thickness of the developing vessels respectively. The external layer of cells is converted into the walls of the vessels, while those in the interior form the first brood of blood corpuscles. The primordial, or primitive vesicles, are large, colorless, spherical cells, each containing a nucleus, nucleolus, granular matter, fat globules, and stearine plates. These cells, gradually clear up, so as to bring into view the nucleus, become reduced in size, and develope the coloring matter (hematine) as they pass into the form of red corpuscles. The blood corpuscles of the human embryo thus formed are circular, disc-shaped, full-colored, and, on an average, about $\frac{1}{2500}$ of an inch in diameter. They each contain a nucleus (and in some cases two), about $\frac{1}{5000}$ of an inch in diameter, and slightly granular.

It is stated by some Physiologists that the primitive vessels (heart and aorta) are formed by the linear arrangement of a single row of these primitive cells, or germinal vesicles. Their contiguous walls then break down, and thus a continuous tube or canal is formed by the outer wall of the cells, while the *nuclei* clear up and form the first brood of blood corpuscles. During this time the granular matter, oil globules, and stearine plates, disappear, and hematine is developed in the interior of the newly-formed corpuscles.

During fœtal life, the blood corpuscles are reproduced by the process of multiplication by subdivision from the parent cell. According to some authorities, however, when the liver is fully formed this multiplication of blood corpuscles in the mass of blood ceases, and a new production of colorless nucleated cells takes place in the vessels of the liver. These nucleated cells undergo a gradual change into red corpuscles, similar to those of the first brood.

After birth, when the lymph and chyle corpuscles are thrown into the current of blood, they are developed into blood corpuscles, so as to supersede those formed as above described. This is evidenced—*First* by the formation of color, while the chyle and lymph are passing through the thoracic duct, due to the development of hematine. *Secondly*, by the presence of corpuscles, which appear to be intermediate stages of development between the lymph corpuscles, and the nucleated red corpuscles in the blood of oviparous vertebrata. *Thirdly*, by the progressive transition from lymph, or white blood, to red blood, which may be observed in the ascending scale of animal life.

MODE OF DEVELOPMENT FROM CHYLE CORPUSCLE.—Kölliker and Paget regard the red corpuscles as being

formed from the entire lymph and chyle corpuscles by a gradual progressive metamorphosis, while Wharton Jones maintains that they are formed from the nuclei alone of the lymph and chyle corpuscles, the cell-walls entirely disappearing in the change. The weight of authority, however, appears to favor the former opinion. The change from the chyle and lymph corpuscle to the red corpuscle, takes place as follows:—The chyle and lymph corpuscles are at first nucleated cells, the nuclei of which are generally more or less obscured by the granular matter which surrounds them. They vary in size from $\frac{1}{2800}$ to $\frac{1}{3000}$ of an inch in diameter. The granular matter next clears up, and the nucleus disappears either by deliquescence (Kölliker), or by expanding so as to become incorporated with the cell wall. They then become flattened or biconcave, contraction and consolidation of the cell-wall take place, which reduces the size of the cell to a certain extent, and hematine is developed within it. The consolidation and contraction are probably due to the increased vitality of the cell.

The origin of both red and white corpuscles is from the chyle and lymph corpuscles, and they are regarded by most Physiologists as two distinct and complete forms, neither being capable of metamorphosis into the other, and each having its own specific purpose to subserve in the animal economy; the greater number of chyle and lymph corpuscles proceeding to the formation of red corpuscles, while a few of them are developed into the white corpuscles of the blood. The argument in favor of this theory is, that the white corpuscles have been found in the blood in a state of decay, thus showing that they were not destined to proceed to a higher development.

By others the white corpuscles are regarded as an

early or embryonic condition of the red corpuscles, or an intermediate stage of metamorphosis between the chyle and lymph corpuscles, and the red corpuscles. The latter view is supported by the following arguments:

1st. The colorless corpuscles. are intermediate in shape and general appearance.

2nd. That they are increased under circumstances unfavorable to normal changes, as in inflammation, or in persons of weak health, as in anemia, leucocythemia, and in the tubercular diathesis.

3rd. That there is a difficulty in assigning to each their special function in the animal economy independently.

The red and white corpuscles are supposed by some to be developed directly from the plasma of the blood in which they float, by the ordinary process of cytogenesis. By others (Dalton) they are said to be simple rounded bodies floating in the blood, homogeneous in appearance, of the same color, consistence and composition throughout, and entirely destitute of a cell wall or membrane, and internal cavity.

Blood corpuscles, like other cells, have their period of growth, maturity and decay, and while some are undergoing the process of disintegration, others are rising up to take their places. They are, no doubt, formed very rapidly, as is evidenced after great hemorrhages, and their growth and development may be facilitated by the administration of iron, and a liberal diet. When the corpuscles are beginning to decay, they generally present at first a granular appearance; after a little the wall breaks down, and the contents escape. Many of them may be observed in a granular state in phthisis, albuminuria, and from the presence of septic poisons in the circulating fluid.

CHEMICAL AND STRUCTURAL CHARACTERS OF THE BLOOD.

CHEMICAL COMPOSITION OF THE BLOOD.—Becquerel and Rodier.

In 1000 Parts.	Men.	Women.
Water	779.0	791.0
Corpuscles	141.1	127.3
Albumen	69.3	70.5
Fibrin	2.2	2.2
Fatty Matter	1.6	1.6
Extractive Matter and Salts	6.8	7.4
	1000.0	1000.0

These proportions are subject to considerable variation, even in health, depending on diet, mode of living, &c., &c. The proportion of the various ingredients may be determined as follows: The blood, as it flows from the opening, is received into two vessels of equal size, the first and last portions of the whole amount into the first, and the second and third portions into the second vessel, in order that the two quantities may be nearly alike, and then weighed. The blood in the first vessel is allowed to coagulate; that in the second is whipped with a bundle of twigs, to separate the fibrin, which is then washed with water—to remove the salts, with alcohol—to remove any coloring matter, and with ether—to remove any fats. It is then weighed. The clot which has formed in the first vessel is then taken out, and after the serum has drained away, it should be weighed. From the weight of the clot subtract the weight of the fibrin obtained from the second vessel, and this will give the weight of the corpuscles. The amount of albumen may be obtained by precipitating it from the serum, filtering and weighing. In this way it may be ascertained that in 100 parts blood, about 78 parts are fluid, and 22 parts solid material. In the latter, there are 14 parts corpuscles, 7 parts albumen, $\frac{1}{4}$ part fibrin—

salts, &c., making up the balance. In ordinary analyses, the corpuscles are estimated at about 15 per cent., by weight, of the entire blood. This refers, of course, to the dry corpuscles, from which the water has been removed. But it is easily seen, by a microscopic examination, that the corpuscles, in their natural moist condition in the blood, are more abundant than this—constituting fully one-half of the entire mass. Hence the discrepancy in the analyses of different observers. Lehman and Schmidt put the *moist* corpuscles at 512 parts in 1000, or nearly four times the weight as obtained by Becquerel and Rodier.

RELATIVE CHEMICAL COMPOSITION OF CORPUSCLES AND LIQUOR SANGUINIS IN 1000 PARTS. Lehman.

CORPUSCLES.		LIQUOR SANGUINIS.	
Water	688.00	Water	902.90
Globuline	282.22	Albumen.	78.84
Hematine	16.75	Fibrin	4.05
Fat	2.31	Fat	1.72
Extractive and Salts..	10.72	Extractive and Salts..	12.49
	1000.00		1000.00

The most important ingredient of the corpuscles is the *globuline*. This forms the cell-wall, and is also mixed with the hematine in the contents. It is a semi-fluid organic substance, belongs to the "protean compounds," and is formed from albumen and fibrin. It is soluble in water, but not in the liquor sanguinis, owing to the presence of albumen and salts. It is readily acted upon by acetic acid, which causes the corpuscles to swell out and finally burst. It coagulates completely at 200° F.

Hematine is a kind of pigment matter which is found in the interior of the cell, being mixed with globuline and salts in solution. The proportion of hematine to globuline is about one to seventeen. It belongs to the "protean compounds," is developed from albumen and

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fibrin, and consists of (C_{44} H_{22} N_3 O_6 Fe), the latter of which is an essential ingredient. The iron is supposed by Liebig to exist in the form of a protoxide, and as it arrives at the lungs, it absorbs more oxygen, and becomes a peroxide, this being again reduced to a protoxide in the capillaries. Here it meets with carbonic acid, forming a carbonate which is returned to the lungs, where the carbonic acid is given off, and oxygen absorbed to again form the peroxide. Thus, the iron of the hematine is made the carrier of oxygen to the tissues on the one hand, and the deporter of carbonic acid to the lungs for elimination on the other. But it is now ascertained that the iron does not exist in the form of an oxide in the hematine, but is combined simply as an element with the others, as sulphur in albumen, fibrin, &c., and that carbonic acid and oxygen are carried to and from the lungs by the corpuscles simply as gases. Hematine is insoluble in water and acids, but is soluble in ether and hot alcohol. When from any cause the red corpuscles are broken down, the hematine is set free, and stains the coats of the vessels, so as to give rise to an appearance resembling arteritis. Rupture of the corpuscles may take place from drinking too much water, or in low forms of disease, as in typhoid fever, purpura hemorrhagica, &c.

DIFFERENCE BETWEEN ARTERIAL AND VENOUS BLOOD.

The analyses which have been already given are of venous blood. In arterial blood the quantity of solid constituents of the corpuscles is less, but relatively they contain more hematine and salts, and less fat. The liquor sanguinis is richer in fibrin, contains more water, and less albumen. The fatty matters of the serum are diminished, and the extractive matters increased. The

phosphorus which exists in the venous blood, united with the fat of the corpuscles, is converted at the lungs into phosphoric acid, which then unites with the alkalies of the serum, as lime, potassa, soda, magnesia, &c., forming phosphates. Phosphorus is supposed to be used in the building up of nerve tissue.

BLOOD OF THE GASTRIC, MESENTERIC, SPLENIC AND HEPATIC VEINS.—Blood drawn from different parts of the arterial system of the same animal is nearly always the same; but great variations exist in the composition of the blood of the different parts of the venous system. For example, during digestion, the blood of the *gastric* and *mesenteric* veins is much diluted, and contains the soluble alimentary substances taken up from the stomach and small intestines, as sugar (glucose), albuminose, &c. The fibrin also found in these vessels is less perfectly elaborated than in the blood in general. On the other hand, the blood of the *splenic* vein shows a diminution of the red corpuscles, and an increase of the albumen. The fibrin is also increased, but like that of the mesenteric vein, it is not fully elaborated, coagulates imperfectly, and liquefies in a few hours afterwards. The blood of the splenic vein is also remarkable for the large number of white corpuscles which it contains. The blood of the *hepatic* veins contains an increased amount of sugar and fat, which are formed during the passage of the blood through the liver. It also contains less water, and more corpuscles and extractive matter, than that of the portal vein.

GASES.—There is a remarkable difference in the amount of free *gases* which arterial and venous blood respectively contain. The former contains from ten to twelve and a half per cent., by volume, of oxygen, while the latter contains about half that quantity. The quantity of carbonic acid, on the other hand, is about twenty

per cent. in arterial, and twenty-five per cent. in venous blood. The quantity of nitrogen varies from 1.7 to 3.3 in arterial and venous blood respectively. The difference between the amount of oxygen and carbonic acid respectively in arterial and venous blood, confirms the idea that an exchange of oxygen for carbonic acid takes place in the system, and an exchange of carbonic acid for oxygen in the lungs. The corpuscles are supposed to carry oxygen from the lungs to the tissues, and return carbonic acid for elimination. The serum also possesses the property of absorbing or dissolving carbonic acid. A certain part of the oxygen is also used directly in the formation of the fibrin, from the albumen, this being a chemico-vital change. The proper development of fibrin does not take place when the due aëration of the blood is interfered with, as in double pneumonia, in which case it is very much diminished. The presence of oxygen seems to be essential to the production of fibrin, and it has been shown by experiments on rabbits, that when pure oxygen is breathed the quantity of fibrin is very much increased.

Dr. Gairdner examined the blood of six healthy rabbits, and found it to consist as follows, in 1,000 parts:

Fibrin 1.65
Corpuscles 82.35
Albumen 46.30

He also examined the blood of three of these which had been exposed to an atmosphere of pure oxygen for half an hour, and found it to contain as follows:

Fibrin................................ 2.40 in 1,000 parts.
Corpuscles .... 69.56   "   "
Albumen........................... 40.23   "   "

Another of these animals was exposed to the action of an electro-magnetic current passed between the chest and spine, which produced a great acceleration of the respiratory movements, and the blood was found to contain 2.9 parts of fibrin in a thousand. Although the

corpuscles appear to be very different in the two tables, yet their relative amount in proportion to the albumen is almost exactly the same in both cases.

COLOR.—The difference in *color* between arterial blood and venous, is due more to the change in the shape of the corpuscle, than the amount of hematine it contains. They are rounded in venous, and biconcave in arterial blood. The latter change is produced by the influence of oxygen; but it may also be occasioned by contact with some of the salts in solution, without any direct exposure to oxygen. Hence we find that the blood is darkened in color by whatever tends to expand the corpuscles, so as to render them rounded; whilst it is brightened by whatever tends to empty them, so as to render them biconcave. The difference of color, therefore, depends chiefly on the shape, and thickness or thinness of the wall of the corpuscle, and on its power of refracting or reflecting light; a thin distended wall transmitting light more readily than a thick one.

CONDITIONS WHICH INFLUENCE THE CHARACTER OF THE BLOOD.

INFLUENCE OF VENESECTION.—It has been found by experiment that, in bleeding, the corpuscles suffer most; the fibrin is increased, and the water taken away is soon replaced by transudation from the tissues, so that the specific gravity is diminished, as will be seen from the following table, the result of the analysis of the blood of ten patients. Becquerel and Rodier:

	1st Bleeding.	2nd Bleed'g.	3rd Bleed'g.
Specific gravity of defibrinated blood	1056.0	1053.0	1049.6
Specific gravity of Serum	1028.8	1026.3	1025.6
Water	793.0	807.7	823.1
Corpuscles	129.2	116.3	99.4
Albumen	65.0	63.7	64.6
Fibrin	3.5	3.8	3.4
Extractive and Salts	7.7	6.9	8.0
Fatty Matters	1.6	1.6	1.5
	1000.0	1000.0	1000.0

From the above it will be seen that the corpuscles are notably diminished, and that bleeding has no effect whatever in diminishing the amount of fibrin. Fibrin is increased in all inflammatory diseases, and the most copious venesection is unable to check it, but rather increases it. The following table gives the result of bleeding, in a case of rheumatism, from Christison:

Water... 844
Solids of Serum 93
Corpuscles... 57
Fibrin 4

This shows the absurdity of bleeding in order to reduce the amount of fibrin in inflammation, and prevent the effusion of plastic lymph, which, by its adhesions, ties down important organs. It has an effect the direct opposite of what was intended.

IRFLUENCE OF STARVATION ON THE BLOOD.—This is somewhat similar to prolonged venesection. The following tables show the result of bleeding upon a well-fed dog; and also the same, in a state of starvation. Todd and Bowman.

		NUMBER OF BLEEDINGS.			
		1st.	2nd.	3rd.	4th.
While being fed.	Water............	783.79	810.89	815.18	813.04
	Corpuscles......	142.85	113.54	110.58	106.95
	Solids of Serum	70.94	70.85	69.92	76.01
	Fibrin.............	2.42	4.72	4.34	3.99

After these bleedings, the animal was allowed to recover, and was well fed for about three weeks. He was then starved for about four days, being allowed nothing but water, and bled each day, with the following result:

		NUMBER OF BLEEDINGS.			
		1st.	2nd.	3rd.	4th.
While being starved.	Water............	804.40	805.44	838.30	849.84
	Corpuscles..	121.08	119.15	87.98	74.21
	Solids of Serum	72.61	71.46	68.46	71.62
	Fibrin	1.91	3.95	5.26	5.13

In the latter case, the diminution of the corpuscles is more marked than in the former; and it will be observed that the corpuscles had not entirely recovered from the effects of the first bleeding. It will also be observed that, in both cases, there is at first an increase in the fibrin, and afterwards a diminution—the latter being caused by the diminution of the red corpuscles, and consequent non-development of the fibrin.

INFLUENCE OF IRON AND FLESH DIET ON THE BLOOD.—The quantity of hematine and red corpuscles may be increased by the administration of iron and flesh diet. Fresh beef is the best diet for this purpose. It contains the most appropriate materials for nutrition, and is comparatively easy of digestion. .The essence of beef, or beef tea, is still better, especially when the patient is very feeble, and the stomach unable to digest solid food. In anemia, the corpuscles have been increased from forty to sixty, and even ninety in a thousand, in a few weeks, by this plan of treatment.

INFLUENCE OF AGE ON THE BLOOD.—During the latter part of fœtal life, the solids of the blood are increased, and remain high for a short time after birth. They then gradually diminish until puberty, when they are again increased, and remain so during the most vigorous period of adult life, after which they begin to decline, as old age advances. The object of these changes in the increase of solids is, to fit the blood more fully for the nourishment and growth of the body at these important periods, viz.: immediately after birth, at puberty, and during the period of ovulation in the female, and the corresponding period in the male.

INFLUENCE OF SEX ON THE BLOOD.—This will be seen at a glance, by reference to the table already given, from Becquerel and Rodier.

INFLUENCE OF DISEASE ON THE BLOOD.—It will be seen from the following table that the principal constituents of the blood may vary much, in health, in different persons; and in the same person, at different times This may be due to various causes, as the kind or quality of the food, habits, amount of exercise, &c., &c.

The amount of Fibrin may vary from	2	to	$3\frac{1}{2}$	parts in a thousand.
" " Corpuscles "	110	to	152	" "
" " Solids of Serum "	72	to	88	" "
" " Water "	760	to	815	" "
&c., &c.				

In estimating the quantity of fibrin in the blood in diseased conditions, it should always be borne in mind that it may contain a number of white corpuscles. These are very difficult to separate, and although not very numerous in a state of health, yet in many diseases, as inflammation, anemia, leucocythemia, &c., &c., they are so much increased as to add materially to the amount of fibrin. There is found to be an invariable increase of *fibrin* in all acute inflammatory affections of a sthenic kind. This augmentation is so constant, that if more than five parts of fibrin in a thousand be found in the course of any disease, it may be positively affirmed that some local inflammation is present. The maximum proportion of fibrin in inflammation may be stated at about 13.3 (acute rheumatism), the minimum 5, and the average about 7 parts in a thousand. Even in anemia and chlorosis it rises to 6 or 7 in inflammation. In phthisis also there is an increase, notwithstanding the deterioration of the blood. It is, no doubt, due to the local inflammation going on around the tubercles. In single pneumonia the fibrin has been found as high as 10.7; in acute rheumatism, 13.3. It is also slightly increased in all the exanthemata. In pregnancy it is said to be diminished during the first six months, and increased in the last three. This may be considered as

a provision of nature to favor the formation of clots in the mouths of the open vessels after parturition and the separation of the placenta. It is also increased in leucocythemia. The increase in the quantity of fibrin does not depend upon the febrile condition present in inflammation, but upon the inflammation itself. For example, in continued fever it is lower than in health, but if local inflammation arise in the course of the disease, the fibrin is at once increased. In simple continued fever it has been found as low as 1.6. In typhoid fever it may vary from 3.7 to 0.9, and in some cases the blood shows no disposition to coagulate, the fibrin either being entirely deficient, or very much lowered in vitality. In double pneumonia it is as low as 0.9, due to the imperfect aëration of the blood. In scurvy it is sometimes increased, and sometimes diminished. In cholera the serum is first diminished, next the albumen, and afterwards the fibrin. The vomited matters, and substances passed by the bowels are coagulable by heat and nitric acid. The fibrin is diminished in apoplexy, due probably to the arrest of nerve force. In purpura hemorrhagica it is 0.9, and sometimes entirely deficient. One of the effects of a diminution in the proportion of fibrin is a tendency to the occurrence of hemorrhages from slight causes, which is difficult to arrest.

The amount of *red corpuscles* is subject to greater variation within the limits of health than the fibrin. In plethora they may be increased to 180 or 190. Plethoric persons are not on that account more liable to inflammation; but they are very prone to congestion of the brain and apoplexy. This condition may be easily remedied by venesection. The number of corpuscles may be reduced from 180 to 144, or from 60 to 48 by one bleeding. In anemia, on the other hand, the cor-

puscles are diminished, in some cases as low as 27 in a thousand, but they may be rapidly increased by appropriate treatment. They have been increased in some instances from 40 to 60, and even 90, in three or four weeks. In diabetus mellitus, Bright's disease, disease of the heart, lead poisoning, tuberculosis, cancer, scurvy, leucocythemia, &c., they are materially diminished, and often assume a granular appearance.

The *colorless corpuscles* are said to be increased in inflammation, but it is by no means constant. In the disease first pointed out by Dr. John Hughes Bennett, of Edinburgh, and termed by him leucocythemia, they are largely increased. In this disease the specific gravity of the blood is low, and the fibrin is invariably increased.

The quantity of *albumen* seems to vary very little. It is reduced in cholera, albuminuria, &c., so that the entire solids of the serum have been found in some cases as low as 52 in a thousand. The diminution in the amount of the albumen in the serum, in albuminuria, is exactly proportioned to the quantity found in the urine.

The *fatty matters* are very much increased in some instances, so as to give the serum a milky appearance, as for example in tuberculosis, Bright's disease, hepatitis, dropsy, &c., and also during lactation in the female. Very little is known regarding the variations of the *alkaline salts* in disease.

The proportion of *water* varies according to the amount of solids, being increased when the solids are diminished, and. *vice versa*. In cholera, however, the drain is very great, and the reduction of the watery portion is most marked. In some cases the solids exceed the amount of water.

BLOOD POISONS. — Substances which should be excreted from the body, as carbonic acid, urea, bile, &c.,

may be retained in the circulating current, and be attended with serious and sometimes fatal results. The most serious cases of blood poisoning, however, are those in which the poison is introduced from without, producing fermentation of the mass of blood, and destroying its vitality, as the poison of malignant pustule, typhoid, glanders, &c., &c.

VITAL PROPERTIES OF THE BLOOD.

The blood is the pabulum of all the tissues of the body. It is a living fluid, which possesses the power of reproducing and maintaining itself, and contains all the elements necessary for the supply of the tissues, and nothing deleterious or poisonous; for the presence of pus, urea, venom of serpents, or septic poisons, would be alike destructive to the vitality of the blood, and also the tissues. It has a certain amount of viscidity, which seems necessary to its free circulation through the capillaries. Besides, it is observed that, when from any cause the albumen and fibrin are diminished, there is a strong tendency to transudation of the watery portions of the blood, resulting in dropsies in different parts of the body.

The Fibrin and Corpuscles are the only constituents of the blood which are endowed with vitality. To ascribe vital properties to a liquid like fibrin is looked upon by some Physiologists as an absurdity; but it must be borne in mind that it possesses the property of spontaneously forming an organized texture, which cannot be considered in any other light than as a vital property, however low it may be. It is to this property that the coagulation of the blood is due.

COAGULATION OF THE BLOOD.

This consists in a new arrangement of its constituents, which occurs when the blood is removed from the vessels,

or when the body itself dies. It depends upon the spon-
taneous coagulability of the fibrin, or its change from
the fluid to the solid state, during which it forms a net-
work of fibres, in the meshes of which, are included the
corpuscles, in groups, like small piles of money. These
are somewhat more numerous near the bottom of the clot.
This crassamentum, or clot, then contracts, and squeezes
out the serum, which contains the water, albumen, and salts.
The corpuscles exercise a certain influence in the coagula-
tion of the blood, but their immediate presence is not abso-
lutely necessary to its performance. This may be shown
by filtering frog's blood (diluted with thin syrup) on a fine
paper filter, by which the corpuscles are kept back on
the filter, and the liquor sanguinis, which passes through,
will afterwards coagulate. This is due to the vitality
which it carries with it from the blood corpuscles.

When coagulation is observed under the microscope,
there are first seen minute granules which aggregate to
form star-shaped spots; these send out arms or projections
in different directions, which are formed by the addition
of granules in a linear manner. In this way the whole
mass is converted into a fibrous net-work, enclosing the
corpuscles in its meshes. This is somewhat similar to
the process of fibrillation in wounds. Hence it appears
that the blood corpuscle exercises the same influence
over coagulation of the *fibrin* of the blood that the cell
nucleus does over the organization or fibrillation of the
blastema in repair of wounds. (See fibrin.)

THE PERIOD REQUIRED FOR COAGULATION varies
much. It commences about two minutes after the blood
is drawn, and is completed in from half an hour to two
hours afterwards; but continues to contract for many
hours. The coagulation of the blood is a vital process,
and not a proof of its death, as maintained by some

Physiologists. Generally speaking, the fibrin of the blood possesses sufficient vital power to coagulate, or assume an incipient form of organization, no matter on what tissue it is thrown. If deposited on the living tissue in parts of the body favorable to its development, it will be supplied with vessels, &c., and proceed to complete organization. On the other hand, if deposited on the mucous membrane, integument, or parts unfavorable to its development, or upon any inanimate tissue or substance, death takes place as soon as the process of coagulation is completed. Hence the coagulation of the blood is said to be an *expenditure of the vital force.* At all events, it seems absurd to maintain that the fibrin of the blood dies in order to assume an organized form.

The degree of regularity and the completeness of the process of fibrillation, depends,—First, upon the previous elaboration of the fibrin. Secondly, on the character of the surface on which it takes place, whether serous or mucous, strong or flabby, dead or living, &c.

In the living body, the blood itself, when not deposited in too large quantities, may organize. This may be seen in ordinary wounds; when small in quantity it does not interfere with the healing process; but, when in excess, it degenerates, and is removed by the process of suppuration. It has also been observed by Paget, Zwichy, &c., in the clots which form in blood-vessels above the point where they are tied. When the clot of blood is large, it is found that the superficial part, or that immediately in contact with the living tissue, becomes organized, while the central part remains soft, and is liable to degenerate.

CUPPED AND BUFFED CONDITION OF THE BLOOD.— This condition of the blood generally occurs in inflammation, but is not exclusively confined to it, for it has

been found to occur in anemia and in the blood of preg-
nant women during the last three months of gestation.
It is occasioned by the increased tendency of the red
corpuscles in these cases to run together and sink to the
bottom of the vessel, and thus leave the fibrin in the
upper part. The fibrin then contracts very firmly (a
circumstance which is favored by the comparative ab-
sence of the corpuscles), and in consequence of this con-
traction taking place, first on the surface and sides of the
clot, and thence extending internally, it causes it to assume
a concave, or cupped appearance, both on the surface and
sides. The "*buffed*" appearance is due to the predomin-
ance of the fibrin in the upper part of the clot, the
characteristic color of which is light yellow or *buff*. The
clot also contains some white corpuscles in its meshes,
and these are said to be increased in inflammation. The
formation of the *cupped* and *buffed* coat, though favored
by slow coagulation, is often observed in cases where the
coagulation is more rapid than usual.

This condition of the blood is due, either to an abso-
lute increase of fibrin, the corpuscles remaining the same,
or to a diminution of the corpuscles, the quantity of fibrin
remaining the same as in health. It has also been ob-
served that, although the clot is firmer in inflammation,
each single fibril is weaker and more easily broken down
than that of a healthy clot. This is supposed to be due
to the comparative absence of the corpuscles, from their
having sunk to the bottom of the vessel during the pro-
cess of coagulation.

CIRCUMSTANCES WHICH RETARD COAGULATION.—In
some instances it would appear that the blood does not co-
agulate after death; for example, it was stated by Hunter,
that in animals hunted to death, killed by lightning, by
electric shocks, or by blows on the epigastrium, the blood

did not coagulate; but it is probable that, even in these cases, it is only retarded, and ultimately coagulates, though imperfectly. It is further stated, by Polli, that the blood invariably coagulates before putrefaction sets in. Nevertheless, in cases of poisoning by hydrocyanic acid, and in death from asphyxia, coagulation may not take place, in consequence of the complete paralysis of the corpuscles and fibrin. In *inflammatory conditions* the blood drawn is usually slow in coagulating, in consequence of the sinking of the corpuscles; but the clot is preternaturally firm, especially at the upper part, where the buffy coat contracts, and produces the "cup," which generally indicates a high state of inflammation. The coagulation of the blood is also retarded, or altogether destroyed, by keeping it at a *temperature of* 150°F., while the natural heat of the body (98°F.) promotes it. It is also retarded by *cold*, but is not destroyed, even by freezing; for, if frozen as soon as it is drawn from the vessels, it will coagulate on being thawed. Gulliver considers this fact as conclusive against the vital character of coagulation; but it is a well-known fact that seeds, eggs, lizards, &c., may be frozen or kept in a state of dormant vitality for an unlimited period. *Continued agitation* will retard the coagulation for a time; but it ultimately takes place in the form of shreds, or strings. Blood while still *contained in the living vessels*, or effused in the *living tissues*, may continue in a fluid condition for a long period. Gulliver states that the blood included between two ligatures in a living vessel remained fluid three, four, or five hours. He also mentions one remarkable case, in which blood effused in the tissue of the loin, was found fluid when let out twenty-eight days afterwards. In all these cases it coagulated in from fifteen to thirty minutes when withdrawn from the living

parts. *Exclusion from the air* retards coagulation, as may be seen by covering the blood with a stratum of oil so as to exclude the air.

The *neutral salts*, added to fresh blood, have a tendency to retard, and sometimes to prevent coagulation; and the same effect is produced by many vegetable substances, especially those of the narcotic and sedative class, as opium, hyoscyamus, belladonna, aconite, digitalis, &c. Gulliver mentions that he has kept horses' blood in a fluid state for fifty-seven weeks, with solution of nitrate of potash, and that it still coagulated, when diluted with water. It is for this, among other reasons, that physicians administer the potash salts in inflammation. The *presence of bile* retards the coagulation of the blood; and *animal poisons*, as the virus of serpents, may retard or entirely destroy its coagulating power.

CIRCUMSTANCES WHICH PROMOTE COAGULATION.

The natural temperature of the body, from which the blood is taken (in man 98° to 100° F.) is most favorable to coagulation. *Rest* favors coagulation, but is not the cause, as some have supposed; for, although at rest, if *air be excluded*, as when it is within the living vessels, or covered with oil, coagulation is retarded for a considerable time.

Exposure to air accelerates the process of coagulation; also, the *multiplicity of points;* as in a lacerated, ragged wound, coagula are more readily formed than in clean, incised wounds.

A low state of vitality of the vessels, from whatever cause, favors the formation of clots, or embolia, as they are called. These are, no doubt, frequently formed during life, as grooves, marked out by the current of blood, may be observed in clots found in the heart after death.

The contact of a dead substance promotes coagulation, even in the living vessels. Simon carried a single thread, by means of a fine needle, through a contiguous artery and vein, and allowed it to remain from twelve to twenty-four hours. A coagulum was formed in both artery and vein; that in the artery being pyramidal in shape, the base directed towards the heart, while that in the vein was larger and more irregular, the clot being chiefly collected on that side of the thread most remote from the heart.

The contact of dead animal matter accelerates coagulation in a remarkable degree, either within or without the living vessels. The presence of pus will produce coagulation in healthy blood, in from two to five minutes, and when injected into the veins, it produces instantaneous death. When an artery gives way in the interior of an abscess, the hemorrhage is restrained, to a certain extent, by the presence of the pus which surrounds it.

FUNCTION OF THE ELEMENTS OF THE BLOOD.

FUNCTION OF FIBRIN.—It was formerly supposed that fibrin was that element of the blood which was directly drawn upon in the process of nutrition. This opinion was based on the then current theory that fibrin and muscle were identical in chemical composition; but it has since been shown, by Liebig, that, so far from this being the case, the evidence is precisely the other way. On the other hand, there are both structural and chemical indications that fibrin is in a state of transition towards the fibro-gelatinous, or connective tissues, and may be regarded, therefore, as their special pabulum. Besides, there is no evidence whatever that fibrin is used in the formation of the cellulo-albuminous tissues; while,

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on the other hand, there are negative evidences that their formation and growth do not depend upon its presence. *Firstly*, the general purposes of nutrition may be served by a fluid which does not possess the property of coagulating spontaneously. *Secondly*, in nearly all exudations in which inflammation is absent, the fluid is albuminous. *Thirdly*, the small amount of fibrin found in the chyle is simply the result of elaboration in the lymphatics. *Fourthly*, the vegetable cell, which is essentially the same as the animal cell, is formed from an albuminous fluid, there being no fibrin in the juices of the plant. The plant is also deficient in the fibro-gelatinous tissues.

Hematine and globuline are also formed from fibrin and albumen. As a component of the blood, fibrin is of importance in giving it its proper degree of plasticity, and in this way facilitating its passage through the vessels. It also prevents the blood from exuding through the coats of the vessels, and arrests hemorrhages by plugging up the mouths of the open vessels. The want of the coagulating power of the blood is strikingly seen in cases of purpura hemorrhagica, in which the blood is not able to form a clot sufficient to close the mouth of the smallest vessel, or to form a barrier to surround abscesses, and prevent the infiltration of pus in the tissues. The same thing may be seen in the hemorrhagic diathesis, in which there is almost an entire absence of coagulable material.

Again, the consequence of the excess of fibrin in the blood is seen in inflammatory diseases, in which it is poured out and forms bands and false membranes, which, in some cases, by their adhesions, tie down and inter-fere with the functions of important organs; but this, though injurious in some cases, may be highly beneficial

in others—by securing perfect rest in the affected part, as, for example, in penetrating wounds of the intestines, &c., &c. The fibrin is also the material of the blood which is used in the healing of wounds, and this would appear to be one of its most important functions.

Some physiologists and pathologists, among whom are Zimmerman, Simon, Jones, and Sieveking, &c., have advanced the idea that fibrin should not be regarded as an ingredient prepared for the nourishment of certain tissues, but as among those substances which have arisen from the decay of the blood, or the effete matter thrown into it from the tissues. In support of this view, they advance the following arguments. *First*, that fibrin is increased in bleeding, starvation, anemia, and other states of exhaustion, while, at the same time, the red corpuscles are rapidly reduced by the same means. This view is also favored by the fact that in improvement of the breed of animals the red corpuscles are increased, and the fibrin diminished. *Secondly*, there is also a small quantity of fibrin in fœtal blood, none in the egg, or the chyle, until it enters the lacteals, and it is also smaller in quantity in the blood of the carnivora than in the herbivora. (See Fibrin.)

FUNCTION OF THE RED CORPUSCLES.—One great function of the red corpuscles is to elaborate the materials of the blood which are to be used in the nutrition of the tissues, more especially those which supply the muscular and nerve tissues. They also assist in converting the albumen into fibrin, and in forming globuline and hematine from the albumen and fibrin of the blood. They are also carriers of oxygen to the tissues, and deporters of carbonic acid from the tissues to the lungs, where it is eliminated. This is due to the power the corpuscles have of absorbing gases, and not, as was

formerly supposed, to the presence of iron in the hema-
tine, which was supposed to be converted into a perox-
ide, as it passed from the lungs to the tissues, and then
into a protoxide, or carbonate of the protoxide, as it
returned to the lungs.

The amount of red corpuscles bears a close relation to
the amount of respiratory power in the different classes
of vertebrata : both of these are also found to be greatest
in birds, less in mammals, and very low in most reptiles
and fishes.

The proportion of the corpuscles is greater among
the carnivora than the herbivora. The want of red cor-
puscles in the invertebrata is compensated by the
introduction of air through their tracheal apparatus,
directly to the tissues themselves.

FUNCTION OF THE WHITE CORPUSCLES.—These are,
no doubt, also concerned in the elaboration of nutrient
material for the tissues of the body, more especially in
the invertebrate classes of animals. These corpuscles,
which are oat-shaped in the larvæ of insects, are found
more numerous just before each change of skin, at which
time a larger supply of nourishment is required. After
these changes have taken place, they are again dimin-
ished. The white corpuscles also contain a small
quantity of iron, thus showing that the characteristic
color of the red corpuscles is not due to this substance.
In the vertebrata, on the other hand, the excess of color-
less corpuscles is an evidence of unhealthy action; for
example, they are very abundant in the blood of frogs
that are young, sickly, or ill-fed. In the human subject,
they are increased in the disease called leucocythemia,
in anemia, and also in inflammation according to some,
although, in all probability, this only occurs in sickly,
scrofulous, or tuberculous patients. When the circula-

tion of the blood is examined in a bat's wing, or frog's foot, under the microscope, the white corpuscles may be observed running outwards and inwards, from the centre of the current to the circumference, and back again, occasionally adhering to the sides of the vessels. They are therefore looked upon, in the present state of our knowledge, as carriers of nourishment to the tissues. It has already been stated that they are considered by some physiologists as intermediate in development, between the chyle and red corpuscles.

FUNCTION OF ALBUMEN.—This substance is the original pabulum, from which all the tisssues of the body are formed. It is also used in the formation of the fibrin, globuline, and hematine of the blood itself. Albumen by itself, however, is incapable of organization, and its conversion into the various tissues must depend on their own power of appropriation. It also assists in holding in solution in the bood many of the metallic salts which exist in that fluid, or which enter the system. The albumen is derived from the food, and when any excess is taken into the system, it undergoes a retrograde change, and is eliminated by the liver and kidney. It is not excreted in health, but may be found in the urine in certain diseased conditions, as morbus Brightii, scarlatina, &c., &c. Its presence in the urine may be detected by heat and nitric acid, which cause a precipitate in the form of flakes. It may also be found in the *vomita* and *dejecta*, in cholera and yellow fever.

FATS.—The fatty matters taken into the system are intended, in part, for the supply of the nerve tissue, and fat cells; but their chief use, however, is to afford material for that combustive process which is necessary for the maintenance of animal heat. That which is stored up in the body may be looked upon as the surplus. Fat

is often detected in the fæces, and such cases indicate a diseased condition of the liver or pancreas.

The other organic compounds which have been found in the blood, as sugar, lactic acid, urea, uric and hippuric acid, creatine, creatinine, fatty acids and odorous substances, but which do not properly form a part of it, are the result of a retrograde metamorphosis, either of the alimentary substances or of the tissues themselves, and are rapidly eliminated by the lungs, kidneys, liver, skin, &c.

The uses of inorganic salts are not positively known; but such as have been investigated were referred to in the chapter on the proximate principles of the first class. The alkaline salts, as carbonate and phosphate of soda and potassa, are necessary to give the blood its alkalinity, to hold in solution the albumen, and to facilitate the passage of the blood through the capillaries. The salts of potash are necessary also for the proper nutrition of the muscular tissue. Phosphate of lime, carbonate of lime, fluoride of calcium, silica, &c., are required to build up the solid tissues, as bone, teeth, &c. The phosphate of lime, in particular, may be regarded almost as a *histogenetic substance*, as it seems to be almost invariably present in newly-forming tissues, but more especially in the bone and teeth. Iron is an essential ingredient of the blood itself, entering into the formation of the hematine. Water exists in large quantities, and is liable to considerable variation.

RELATION OF THE BLOOD TO THE LIVING ORGANISM.

The normal proportions of all the substances found in the blood are maintained partly by the selective power of the tissues in the process of nutrition and growth, and partly by means of the excretory apparatus, which

removes the surplus materials. Each part of the body takes from the blood the peculiar substance which it requires for its nutrition, aud thereby acts as an excretory organ, by removing that which, if allowed to remain in the blood, would act injuriously in the nutrition of the body generally; for example, the phosphates and carbonates which are deposited in the bones are as effectually removed from the blood as those which are thrown off by the urinary organs. Again, the rudimental organs, as the hair in the fœtus, the mamma in the male, &c., may be looked upon as excretions serving a useful purpose in the animal economy, by removing certain materials from the blood which might interfere with the proper nutrition of other parts of the body.

Although the blood may vary slightly in its composition and properties at different periods of life, yet we find that, taken as a whole, it presents such a constancy in its leading features, that we cannot fail to recognize in it some capacity for self-development, similar to that which the solid tissues possess. It retains its identity through life, just as a leg, an arm, or an eye. It has the power of maintaining itself from the new materials supplied to it from the food, and goes through the successive phases of growth, maturity, and decay, similar to all vital organisms. The self-maintaining power of the blood is forcibly exhibited in the phenomena of disease, especially those of a febrile class, as the exanthemata, typhus, typhoid, &c. In all these cases the "morbid poison" would be eliminated by nature, if time were allowed to do so, the blood replenished, and the patient would resume his wonted health. In some instances, when a poisonous substance has entered the blood, the life may be saved by keeping up artificial respiration until nature has time to eliminate the poison from the system. In

nearly all the toxic diseases of the zymotic class, there is a natural tendency to the self-elimination of the poison, and of the products of its action on the blood, either by the agency of the excretory organs, or by the local lesions which occur in these cases; and this occurs with such regularity that we are able to predict with certainty when the changes may be expected to take place. From the very nature of the action of these poisons on the blood, it is evident that no reliance whatever can be placed on the action of antidotes in checking its course—the objects of treatment lie wholly in promoting the elimination of the morbid poison, in subduing local action, and supporting the vital powers of the patient during the continuance of the disease.

CHAPTER VIII.

CIRCULATION.

THE object of the circulation of the blood is to carry to every part of the body the materials for its nutrition and growth, together with the supply of oxygen necessary for its vital actions; and also to carry away the effete substances which are formed as a result of the waste of the tissues.

The organs concerned in this process are the *heart, arteries, veins,* and *capillaries.*

THE HEART.

The *heart* is the great central organ of circulation, situated in the middle mediastinum of the thorax, being placed obliquely, the base upwards and to the right side, on a level with the upper border of the third costal cartilage, and corresponding to the interval between the fifth and eighth dorsal vertebræ; the apex corresponding to the interspace between the cartilages of the fifth and sixth ribs, one inch to the inner side, and two inches below the left nipple. The heart is a hollow, muscular organ, which, like a forcing pump, drives the blood through the vascular system. It varies in size and shape, in different classes of animals, from a simple, muscular tube, as in insects, to the complex double heart of man. In all animals the organs of circulation are adapted and modified in structure to correspond with the organs of respiration. In the lower order of animals, as insects, the heart consists of a simple muscular tube, provided with certain valves at short distances apart.

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Corresponding to the situation of these valves, there are distinct constrictions in the tube, so that it has the appearance of a series or chain of hearts. As we ascend the scale, we first observe the subdivision of the heart into two cavities, the auricles and ventricles, in the acephalous mollusks. In fishes, also, the heart consists only of two cavities, the auricle, into which the blood is received from the veins, and a ventricle, which drives the blood into the main artery which supplies the gills. In reptiles, there are two auricles and one ventricle. One of the auricles receives the blood from the lungs, the *pulmonic;* and the other, the blood from the veins of the body, the *systemic auricle.* They both open into a single ventricle, which propels the blood throughout the body, and also to the lungs.

In birds and mammals (including the human species) the heart consists of two auricles and two ventricles, separated by a complete septum, each auricle communicating with its corresponding ventricle, and each ventricle communicating with an arterial trunk.

The course of the circulation is as follows:—The venous blood is returned from the body by the superior and inferior venæ cavæ, and poured into the right auricle; thence it passes into the right ventricle, being prevented from returning by the closure of the tricuspid valves; from the right ventricle it passes to the lungs, through the pulmonary artery, the opening being closed behind it by the coaptation of the pulmonary semilunar valves. The blood being aërated in the lungs, is returned to the left auricle through the pulmonary veins; this constitutes the *pulmonic* circulation. It then passes through the auriculo-ventricular opening into the left ventricle, being prevented from returning by the closure of the mitral valves; it is then propelled with consider-

able force into the aorta, the opening being closed behind it by the coaptation of the aortic semilunar valves, and is thence distributed to the various parts of the body, to be again returned by the veins to the right side of the heart. The latter constitutes the *systemic* circulation. (For the anatomy of the heart, see *Descriptive Anatomy.*)

MUSCULAR STRUCTURE OF THE HEART.—The heart consists of striated, muscular fibres, and fibrous rings, which serve for their attachment. The fibres interlace with each other in an intricate manner, and adhere closely together, there being little or none of that areolar tissue which exists in the external muscles. The disposition of the fibres of the heart may be best demonstrated by prolonged boiling, which hardens the fibres and facilitates their separation. The fibrous rings are *four* in number; the *right* and *left auriculo-ventricular*, the *aortic* and *pulmonary*. The former serve for the attachment of the muscular fibres of the auricles and ventricles, and also for the tricuspid and mitral valves; the latter for the attachment of the arterial vessels, semilunar valves, and muscular fibres of the ventricles.

THE FIBRES OF THE AURICLES.—These are divided into two sets or layers, a *superficial,* common to both, and a *deep* layer, proper to each. The *superficial* fibres run in a *transverse* direction across the bases of the auricles, and are most distinct on the anterior surface. The *deep* fibres consist of two sets, *looped* and *annular.* The *looped* fibres commence at the ariculo-ventricular rings in front, pass upwards over the auricle, and return to the rings on the posterior part. The *annular* fibres surround the auricles in a circular manner, and are continuous with the circular fibres of the veins which open into them.

THE FIBRES OF THE VENTRICLES.—These are also divided into two sets, *superficial* and *deep*. The superficial fibres are, in some parts, longitudinal; in others, oblique or spiral; the deep fibres are circular, and in some parts oblique. In front the *superficial fibres* run obliquely, from right to left, and from above downwards, coil inwards at the apex of the heart, around which they are arranged in a whorl-like form, called the vortex; they then pass upwards, interlacing with those of the opposite ventricle in the intermuscular septum, and ascend on the right side as far as its base. If these fibres are carefully uncoiled in a heart previously boiled, the cavity of the left, and then that of the right ventricle, will be exposed at the vortex. On the back of the ventricles, the superficial fibres are directed nearly vertically. All of the superficial fibres are reflected inwards at the apex, pass upwards, and spread out to form the inner walls of the ventricles, the septum and columnæ carneæ, and some of them are finally inserted directly into the auriculo-ventricular and arterial rings; while others are inserted indirectly through the *chordæ tendineæ*. The *deep* or *circular fibres* are situated deeply in the structure of the heart, between the superficial and deep, or reflected portion of the superficial fibres; these fibres pass around each ventricle in a circular direction, some at right angles to its axis, and others obliquely. They form a sort of hollow conical cylinder for each ventricle, which is attached by its base to the fibrous zone of the auricles, and is open below towards the apex. Some of the fibres pass across the septum, and surround both ventricles.

VESSELS AND NERVES.—The heart is supplied by the anterior and posterior coronary arteries; the nerves are derived from the superficial and deep cardiac plexuses,

which are formed partly by the spinal, and partly by the sympathetic system.

ACTION OF THE HEART.—The blood is propelled in its course by the alternate contraction and dilatation of the muscular walls of the auricles and ventricles of the heart. The two auricles contract together, and afterwards the two ventricles; and in each case the contraction is immediately followed by a relaxation. The contraction is called *systole*, the dilatation, *diastole*.

During contraction the heart appears to become longer and narrower, although, in reality, it becomes shorter and narrower, owing to the simultaneous contraction of the longitudinal and circular fibres of the ventricles. This may be demonstrated by placing the heart of a recently killed animal, as a frog or rabbit, on the table, and transfixing the base by means of a large needle, and inserting another at the apex, so as merely to touch it. If the organ is then stimulated to contraction by pricking it, the apex will be observed to recede from the needle, while the heart at the same time becomes narrower and shorter.

SOUNDS OF THE HEART.—The action of the heart is accompanied by sounds. These are two in number; the *first*, or *systolic*, and the *second*, or *diastolic*. They follow each other in quick succession, and are succeeded by a pause, or period of silence, after which the first sound again recurs. The duration of the first sound is double that of the second, and the second is equal to the pause. Thus, if the whole period be divided into four parts, the first two would be occupied by the first sound, the third by the second sound, and the fourth by the pause, thus:

2 parts occupied by the first sound.................. ⎫
1 part occupied by the second sound.............. ⎬ *Rythm.*
1 part occupied by the pause........................ ⎭

A very short pause must also exist between the first and second sound, otherwise the distinct sounds could not be heard. This order of succession is called the *rythm* of the heart, which, in a state of health, is remarkable for its regularity. The first sound of the heart is a heavy, prolonged sound, synchronous with the impulse of the heart, and is most distinctly heard over the apex; the second is a short, distinct sound, best heard over the base. These sounds somewhat resemble the sounds of the words *"come" "up,"* whispered in rapid succession, the former representing the first sound, the latter the second.

CAUSES OF THE SOUNDS.—The *first* sound is, in all probability, a compound sound, chiefly produced by the closure of the tricuspid and mitral valves, and the collision of the blood against the walls of the ventricles. It is also partly attributed to the contraction of the ventricles, and the impulse of the heart against the walls of the chest.

The *second* sound is undoubtedly due to the closure of the aortic and pulmonary semilunar valves. They are forced back by the recoil of the blood, as one unfurls an umbrella—with an audible click as they tighten. This may be demonstrated by fastening one of the valves, by means of a hook or ligature, to the side of the aortic and pulmonary arteries respectively, in some animal, as a calf, so as to allow regurgitation to take place: when it will be observed that a bellows murmur takes the place of the second sound; but as soon as the valve is allowed to resume its play, the natural sound returns. It is thought by some that both sounds of the heart are produced by the same cause, viz; the tension of the valves. Disease of the valves gives rise to murmurs which interfere with the distinctness of the sounds.

IMPULSE OF THE HEART.—The impulse of the heart is produced by the contraction of the spiral muscular fibres of the ventricles, which produces a tilting of the apex against the walls of the chest. In its movement the apex describes a spiral curve from left to right, and from behind forwards. That the impulse of the heart is not due to the tendency of the arch of the aorta to straighten itself when distended with blood, and the elastic recoil of the parts about the base of the heart, is shown by the fact that the tilting movement of the heart will take place even when the apex has been cut off. Dr. Stille maintains that the impulse is due to the dilatation or diastole of the ventricles. The force of the impulse varies in different individuals, and in the same individual at different times, and is most distinctly felt in the space between the fifth and sixth ribs. It is very distinct in emaciated persons, and especially in hypertrophy of the heart, The impulse of the heart corresponds with the pulse in the arteries, consequently the actions of the heart may be counted by the pulse, at the wrist, or in any of the arteries.

FREQUENCY OF THE HEART'S ACTION.—In a healthy adult, the pulsations vary from seventy to seventy-five times per minute. The frequency of the heart's action diminishes from the commencement to the end of life, as will be seen from the following table, which represents

THE AVERAGE NUMBER OF BEATS IN A MINUTE:—

In the fœtus	150
At birth	140
In infancy	120
In youth	90
Adult age	75
Old age	60 to 65

Posture exercises a remarkable influence on the frequency of the heart's action. It is most frequent in the

erect posture, next to that, in the sitting, and least in
the recumbent position. The pulse is also most fre-
quent in the morning, becomes slower towards evening,
and is very much diminished during the night. In health
there is a nearly uniform relation between the frequency
of the heart's action and the respirations, the proportion
being about four of the former to one of the latter.

FORCE OF THE HEART'S ACTION.—A certain rate of
movement must be maintained in the circulation, and
the impediment produced by friction must be overcome
by the muscular force of the heart; and, since the left
ventricle propels the blood through the whole system,
while the right sends it only to the lungs, the walls of
the former are twice as thick as the latter, and the force
of the one is double the force of the other.

The force of the heart's action may be estimated either
by ascertaining the height of the column of blood which
its action will support (Hales' method), or by causing
the blood to act on a column of mercury (the method of
Poisseuille and Völkman). Hales introduced a long
pipe into the carotid artery of a horse, and found that
the blood rose to the height of ten feet. From this and
other experiments, on the lower animals, he concluded
that the human heart would sustain a column of blood
seven and a half feet high, the weight of which would
be about $4\frac{1}{2}$ lbs. Poisseuille's experiments were made
with a glass tube, bent so as to form a horizontal and
two perpendicular portions, the latter being shaped like
the letter U. It is called the *hæmadynamometer*. The
horizontal portion is adapted by a tube to the arteries or
veins, and the perpendicular branches are partly filled
with mercury, the rise and fall of which can be measured
on scales placed behind them, and as the rise and fall are
equal, the double of either will give the weight of the

column which the force of the stream is able to maintain. The results corresponded closely with Hales' estimate, being about $4\frac{1}{4}$ lbs.

Völkman passed a solution of carbonate of soda into the horizontal branch to prevent the blood from coagulating on the sides of the vessel. From his experiments it appears that the force of the stream is capable of supporting a column of mercury about eight inches in height, or a column of blood about nine feet. But the force which the walls of the heart must exert in order to impart such a pressure to the blood which it propels, is equal to a weight of about 13 lbs.

ARTERIES.

The arteries are cylindrical tubes which convey the blood to the different parts of the body. They are found in nearly every part of the body, except the hair, nails, epidermis, cartilages and cornea. They were formerly supposed to contain air, because they were found empty after death, hence the name *arteries.*

STRUCTURE.—They consist of three coats, *internal, middle,* and *external.* The *internal* is the thinnest, and consists of two layers, the inner or *epithelial,* and outer, or *elastic.* The former consists of a single layer of tesselated epithelium, with round or oval nuclei; the latter is a delicate, transparent, fenestrated membrane, which in medium-sized arteries is strengthened by several laminæ of elastic tissue.

The *middle coat* is thicker than the preceding, and consists of *muscular* (nonstriated) and *elastic* tissue, disposed chiefly in the transverse direction. In the largest arteries the muscular tissue forms only about one-third or one-fourth of the thickness of the middle coat, while in the medium-sized arteries it predominates, and in the smaller arteries it is purely muscular.

The *external coat* is the thickest, and consists of *areo-lar* and *elastic* tissue. In arteries of medium-size, this coat is composed of two distinct layers, an inner or elastic, and an outer or areolar. In the large arteries both these coats are very thin, and in very small arteries the elastic coat is entirely absent.

The arteries are supplied with blood-vessels like the other organs of the body. They are called the *"vasa vasorum."* They are derived from some of the smaller arterial branches, ramify in the loose areolar tissue, connecting the artery with its sheath, and are distributed to the external and middle coats, probably also to the internal. They are also supplied with nerves, derived chiefly from the sympathetic system, but partly from the cerebro-spinal.

FUNCTION OF ELASTIC TISSUE IN ARTERIES.—It protects them from the suddenly exerted pressure to which they are subjected at each contraction of the ventricle. Under this force, which might burst a brittle tube, their elastic walls dilate, and by thus yielding, break the shock of the force impelling the blood, and exhaust it before they are in danger of bursting, from being over-stretched. Again, by their recoil, which occurs during the diastole of the heart, they exert a pressure which in some degree replaces the action of the heart. This pressure is equally diffused in every direction, and tends to drive the blood either onwards, or backwards to the heart; but the latter is prevented by the closure of the aortic valves; hence they *equalize the current* of blood by maintaining pressure upon the stream during the diastole of the ventricles, and also *moderate the jetting movements* given to the blood by the systole of the ventricles. In this we cannot but admire the beautiful simplicity and harmony in the laws of nature. There is no loss of the

force of the ventricles, for that part of their force which is expended in dilating the arteries is restored in full, according to the law of action of elastic bodies, by which they return to the state of rest with a force equal to that by which they were moved.

The elasticity of the arteries also gives them a *capacity* for receiving, under certain circumstances, more than the average quantity of blood, and it enables them to adapt themselves to the various movements of the different parts of the body. In consequence of their elasticity, the arteries are not only dilated, but also elongated. This is most apparent in arteries which are curved.

FUNCTION OF MUSCULAR TISSUE IN ARTERIES.—When an artery is cut across, its divided ends contract, and the orifices may be partially or completely closed, owing to the contraction of the muscular tissue. This contraction is greater in the young than in the aged, and in animals than in man, and continues many hours after death. It is also increased by the application of cold, styptics, galvanism, irritation, or by twisting the cut ends of the artery. Owing to their contraction after death, the vessels cannot be injected until the rigor mortis passes off.

The muscular tissue of the arteries can in no way assist in propelling the onward current of the blood. The manner in which the arterial trunks taper towards their distal extremities, renders it mechanically impossible that the contraction of circular fibres would drive the blood onward; in fact, the tendency would be in the opposite direction. The principal use of the muscular tissue is to *regulate the supply* to different parts of the body, according to the activity of the function of each part at different times; for example, the brain does not require so much blood during sleep as during mental

labor; the stomach does not require so much blood during fasting as during digestion, &c., &c. It is evident that the heart cannot regulate the supply to each part at particular periods; but it may be regulated by the contraction of the muscular coat of the arteries, or their passive dilatation, so as to *diminish* or *increase* the supply of blood according to the demand. Again, the contraction of the muscular coat of a wounded artery, first *limits* and then *arrests the escape of the blood*, when assisted by the formation of a clot of fibrin in the mouth of the wounded vessel. This is nature's mode of arresting hemorrhage (natural hemostatics).

The contraction of the arteries is determined chiefly by the influence of the great sympathetic system.

FUNCTION OF THE ARTERIES.—From what has been already stated, we may infer that the function of the arteries is—*first*, to convey and distribute the blood to the different parts of the body ; *second*, to equalize the current, and moderate the jetting movements given to the blood by the ventricles; *third*, to regulate the supply to the different parts of the organism according to the demand.

ANASTOMOSES OF ARTERIES.—The arteries have a remarkable tendency to communicate with each other in their course, in order more fully to supply the organs to which they are distributed. These are called *anastomoses*. One of the simplest modes is the union of two arteries to form one, as the union of the vertebral to form the basilar. Another mode is, where two branches unite to form an arch from the convexity of which other branches are given off, which may in their turn form arches, and this may be repeated until the resulting branches are reduced to a very small size, when they terminate in the capillaries, as for example, the mesen-

teric arteries. A third mode, which is the most remarkable, is, where two adjacent vessels communicate by a distinct vessel passing from one to the other, as in the *circle of Willis.* Here the anterior cerebral arteries are united by a short cross branch, the anterior communicating, and the carotid on each side is united to the posterior cerebral by the posterior communicating. In this way the brain is protected in all its parts against loss of blood, if the circulation in any of the main channels should be arrested.

The most common form is found in the limbs, where the main trunk usually divides into two branches, from which smaller branches are given off, which communicate with each other at various points, especially around the joints. These branches also communicate with others from adjacent arteries, as for example, the deep femoral with the sciatic, &c. By such an arrangement, the proper nutrition of the limb is secured by collateral circulation in the event of the main trunk being ligatured, or otherwise occluded. In the application of a ligature, the surgeon should always make allowance for the anastomoses in the vicinity of the wound. In consequence of the free anastomoses between the adjacent branches, it is always necessary, when the artery is wounded, to apply a ligature both above and below the wound, in order to prevent the recurrence of secondary hemorrhage.

PULSE.—When the finger is applied to the wrist, or any of the arteries of the body, it is felt to beat or pulsate in correspondence with the systole of the heart. The sensation communicated to the finger is due to the dilatation and elongation of the part, caused by the jetting movements of the current of blood in the vessel. Each jet of blood creates a wave, which moves along the

whole arterial system. A certain time will be required for the wave to travel from the heart to distant arteries, so that although the wave corresponds with the systole of the heart, yet it is not in exact synchronism with it; the difference varying according to the distance from the heart. The longest interval is about one-sixth to one-seventh of a second.

The *character of the pulse* will depend—1st, upon the force of the heart; 2nd, upon the integrity of its valves and orifices: 3rd, upon the quantity and quality of the blood in the system; and 4th, upon the condition of the walls of the arteries, whether rigid or yielding, tense or flabby, &c. The qualities of softness or fulness, of hardness or wiryness, of compressibility or incompressibility, &c., which are familiar to the practical physician, are determined by the yielding or the resisting condition of the arterial walls.

RAPIDITY OF THE CIRCULATION IN ARTERIES.—The velocity of the circulation in the arteries may be ascertained by an instrument similar to that used for measuring the force of the heart. Völkman estimates the velocity with which the blood moves in the carotid arteries of warm-blooded animals, at about twelve inches per second.

VEINS.

The veins return the blood from the various tissues and organs to the right side of the heart. They are more numerous, and, with the exception of the pulmonic veins, more capacious than the arteries. They commence in the capillaries, and uniting form trunks, some of which are superficial, and others deep, accompanying their corresponding arteries.

STRUCTURE.—In structure they consist of three coats. These resemble the coats of the arteries, with the excep-

tion of the outer, which contains some muscular tissue. Muscular tissue is, however, entirely absent in the sinuses of the dura mater, uterus, and corpora cavernosa, cerebral veins, retinal veins, and the veins of the cancellous tissue of bones. Most veins have valves which prevent the reflux of blood. They are more numerous in the superficial than in the deep veins, and in those of the lower than the upper extremity. The valves are formed by reduplications of the lining membrane, are semilunar in form, and are attached by their convex margins to the walls of the veins. They are generally arranged in pairs, occasionally there are three, but sometimes only one. In very small veins they are absent; also in the venæ cavæ, pulmonary veins, hepatic veins, portal vein, renal, uterine and ovarian, the cerebral and spinal veins, veins of the cancelli of bones, and in the umbilical vein. The veins are supplied, like the arteries, by little vessels (vasa vasorum); but the nerves are not so easily detected upon them.

CIRCULATION IN THE VEINS.—In the veins, the blood moves in a continuous stream, and the velocity of the venous current is considerably less than the arterial. The circulation in the veins is produced by the *vis à tergo of the heart*, the *action of the capillaries*, the *contraction of the voluntary muscles*, the *inspiratory movements of the thorax*, and *the vis à fronte or suction power of the heart* (Mulder); the latter, however, is extremely small.

The *vis à tergo* of the heart may produce, in certain conditions of the system, a distinct *venous pulse*, corresponding with the impulse of the heart, the wave having passed through the capillaries. This may be called the *communicated* or *systolic* venous pulse, and must be carefully distinguished from the *regurgitant* venous pulse,

which is caused by the regurgitation which takes place, in some persons, into the venous trunks, during the systole of the right auricle. In health, the regurgitation is very small and indistinct; but when the right cavities of the heart are dilated, a large quantity of blood is regurgitated, and a distinct venous pulse is visible in the superficial and deep veins of the neck.

The *inspiratory movements of the thorax*, by enlarging the capacity of the chest, tend to create a vacuum, which is chiefly filled by the rush of air into the chest; but partly by the afflux of blood, which must be principally venous, since the closure of the aortic valves would oppose any reflux in the aorta. This may be demonstrated by introducing a bent glass tube into the jugular vein of an animal, the vein being tied above the point where the tube is inserted, and the other end of the tube immersed in some colored fluid. It will be observed that at each inspiration the colored fluid will ascend in the tube, while during expiration it will either remain stationary or sink. Or it may be shown by the *hæmadynamometer*. The effect of inspiration on the veins is only observable in the larger ones. Forced expiratory movements, on the other hand, retard venous circulation, as may be seen by holding the breath for a few seconds, or by straining, when the veins about the face and neck swell up, and become distended, but immediately return to their former size when the breathing is restored.

The *contraction of the voluntary muscles* has a most marked effect in favouring the circulation of the blood in the veins, as may be seen in cases of venesection, when the patient is directed to move his fingers freely. During muscular action a portion of the veins is compressed, and the blood is prevented, by the valves in the

veins, from passing backwards in the small vessels; it is necessarily forced onwards towards the heart. As the muscles are relaxed the veins again swell out, to be re-compressed by the renewal of the muscular force, and so on. This force is an important agent in maintaining the circulation, since the voluntary muscles are more or less active in nearly every position of the body, and the veins liable to be compressed by them.

The *vis à fronte or suction power of the heart*, (Mulder), if there is such a thing, can exert very little influence in the general circulation. It is regarded by some as extremely small, by others as impossible.

RAPIDITY OF THE CIRCULATION IN VEINS.—The velocity of the venous current is to that of the arterial as two to three, or about eight inches per second, as near as can be ascertained by approximation.

CAPILLARIES.

They are so named on account of their small size. They are the connecting link between the arteries and veins, and are found in all parts of the body except the uterine placenta, corpora cavernosa of the penis, nails, epidermis, hair, &c., &c. In structure they appear, under the microscope, to consist of a homogeneous membrane with cell nuclei which adhere to or are imbedded in their walls, at certain distances apart. It is quite likely, however, that the capillaries consist of all the coats which belong to the arteries, but are very much attenuated. The capillaries vary in diameter, from $\frac{1}{1000}$ to $\frac{1}{4700}$, the average being about $\frac{1}{3000}$ of an inch, and their length is about $\frac{1}{30}$ of an inch. The smallest are those of the brain and mucous membrane of the intestines; the largest are those of the skin and marrow of bones. They form meshes, which vary in different

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tissues; for example, they are *rounded* in the lungs, *elongated* in muscles and nerves, and *looped* in the papillæ of the tongue and skin. The closest network is formed in the lungs and choroid coat of the eye. As a rule, the more active the function of an organ, the closer is its capillary net-work, and the larger its supply of blood. In the compound tissues the capillaries do not ramify among the ultimate particles of the tissues; thus in muscle the vessels lie between the fibres, but do not pierce the sarcolemma. In nerves, in the same way, they are separated from the nervous matter by the tubular membrane. In mucous and serous membranes they are imbedded in the sub-areolar tissue, which forms a nidus for them.

CIRCULATION IN THE CAPILLARIES.—The current of blood flows through the capillaries with a constant equable motion, as may be seen under the microscope in the frog's foot or bat's wing. In the central part of the current in the larger vessels, may be seen the red corpuscles; while near the edges of the vessel there is a transparent stratum of clear plasma, in which may be seen some white corpuscles. In the smaller vessels the corpuscles pass along in a single file, and sometimes become bent and otherwise distorted in order to accommodate themselves to the curvatures of the capillaries. Whenever the current is obstructed or retarded in any way, the white corpuscles accumulate in the affected part, and become more numerous in proportion to the red.

The circulation of the blood in the capillaries is partly due to the *vis à tergo of the heart,* and recoil of the arteries, and partly also *to the attractive or selective power of the tissues.* The former has been already referred to in connection with the heart and arteries. With

regard to the latter, it is in the capillaries that those chemical and physical changes between the blood and the tissues take place, in which the phenomena of nutrition essentially consist. A certain force is generated by this interchange, which promotes the circulation of the blood through the capillaries. It is termed the *attractive or selective power* of the tissues *(or by Carpenter capillary force.)* It may be explained as follows:—As the blood charged with oxygen and nutritious substances for the supply of the tissues approaches the capillaries, a rapid imbibition takes place with such energy, that it pushes before it, into the veins, the blood from which the nutritious elements had been previously removed, and which also contains the effete matter. This force resembles that by which the circulation is maintained in plants, and in some of the lower order of animals.

The *capillaries are under the influence of the nerves.* Their contraction on the application of certain irritating substances, and from fear, and their dilatation during blushing, may be referred to the influence of the nerves, for in these cases the changes are so rapid that the heart has not time to effect them. Under one kind of nervous emotion the vessels contract, and empty themselves, and the countenance becomes deadly pale, as in anger, fear, &c. Under another kind of nervous emotion the vessels dilate, become filled with blood, and the cheek is suffused, as in blushing.

RAPIDITY OF THE CIRCULATION IN THE CAPILLARIES.— The rate of movement of the blood in the capillaries may be determined by the microscope. It is slower than in either the arteries or veins, being, on an average, about $1\frac{3}{4}$ inches per minute.

The combined forces by which the blood is propelled throughout the body, are, first and *chiefly,* the muscular

force of the heart; second, the recoil of the elastic walls
of the arteries; third, the attractive or selective power of
the tissues; fourth, the pressure of the muscles among
which some of the veins lie; fifth, the inspiratory move-
ments of the chest.

RAPIDITY OF THE CIRCULATION IN THE BODY.—It is
estimated that the ventricles and auricles are each capa-
ble of holding about three ounces of blood, and that this
quantity is propelled by either ventricle at each systole,
and that the whole amount of blood in the system is
about eighteen pounds. This would require ninety-six
pulsations for its passage through either side of the
heart, and allowing seventy-two pulsations to a minute,
the time occupied in transmitting the whole would be
$1\frac{1}{3}$ minutes. But it has been ascertained by experiments
on animals, as the horse, that substances in solution, such
as prussiate of potash, nitrate of baryta, &c., may be
detected in the blood drawn from the carotid artery
within fifteen to twenty seconds after it had been intro-
duced into the jugular vein of the opposite side. In the
dog, the heart's action may be arrested in eleven or
twelve seconds, by the introduction of a solution of
nitrate of potash in the jugular vein; in the rabbit in
about four seconds, and in fowls, in about six. Hence,
it appears that the rapidity of the circulation is under-
rated in the estimate founded upon the capacity of the
heart, and the number of pulsations in a minute. It has
been estimated by Völkman, that in man the whole cir-
cuit is completed in considerably less than one minute.

PECULIARITIES OF THE CIRCULATION.—These are
observed in the *lungs, liver, brain* and *erectile organs.*
The chief peculiarity in the pulmonic circulation is, that
the artery carries venous blood to the lungs, and the
veins return arterial. The portal circulation is peculiar

CIRCULATION.

in being a kind of offset from the general circulation. The peculiarity of the circulation in the brain is, that it is provided with a uniform supply of blood. This is secured by the number and tortuosity of the vessels, and their large anastomoses in the formation of the circula- tion of Willis. It is also stated by Dr. Kellie, that in bleeding animals to death, the brain does not become exsanguine, owing to atmospheric pressure, unless an opening is made in the cranium. But this is disputed by Dr. Burrows, who concludes, from careful experiments, that the brain may become exsanguine without any apparent aperture in the cranium, and that, in health, slight variations may occur in the quantity of blood sent to the brain.

The *erectile tissues* are the *penis*, the *clitoris*, the *erectile tissues of the vagina*, and the *nipple* in both sexes. The venous plexuses of the erectile tissue become filled with blood, which swells and distends the organ, causing it to assume an erect condition. This influx of blood may be caused by local irritation, or by certain emotions of the mind communicated through the great sympathetic system. Erectile tissue consists of a plexus of veins with varicose enlargements enclosed in a fibrous envelope, with trabecular partitions. There are also some nonstriated muscular fibres, which are connected in some way with the process of erection. They may either by their con- traction prevent the due return of blood from the parts, or by their relaxation allow the plexuses to fill with blood, and remain so until the stimulus to erection subsides, when they contract and gradually expel the excess of blood.

FŒTAL CIRCULATION.—In the fœtus the course of the circulation is modified in consequence of the inaction of the lungs. The aëration of the blood is effected by

the placenta, through which also the fœtus is nourished,
so that the placenta serves the double purpose of a
respiratory and nutritive organ, or in other words, it per-
forms the office of the lungs and stomach in the fœtus.
The course of the circulation in the fœtus is as follows:—
The arterial blood is carried from the placenta to the
fœtus, along the umbilical cord, by the umbilical vein. It
then enters the umbilicus, and passes upwards along the
free margin of the longitudinal ligament of the liver to
its under surface, where it gives off two or three branches
to the left lobe, and others to the lobus quadratus and
spigelii. At the transverse fissure it divides into two
branches; the larger is joined by the portal vein and
enters the right lobe; the smaller passes onwards, under
the name of the ductus venosus, which joins the left
hepatic vein, where the latter empties into the inferior
vena cava. Hence the blood reaches the vena cava
in three different ways; most of it passes through the
liver with the portal venous blood, and is returned to the
vena cava by the hepatic veins; some passes through the
liver directly, to be returned also by the hepatic veins;
and the smallest quantity is carried on by the ductus
venosus to the vena cava. In the inferior vena cava the
blood is joined by that which is being returned from the
lower extremities and viscera of the abdomen, it then
enters the right auricle, and guided by the eustachian
valve, passes through the foramen ovale into the left
auricle, where it is mixed with a small quantity return-
ing from the lungs. From the left auricle it passes into
the left ventricle, from the left ventricle into the aorta,
to be distributed chiefly to the head and upper extremi-
ties—a small quantity passing into the descending aorta.
From the head and upper extremities the blood is re-
turned by the superior vena cava to the right auricle,

where it is mixed with some from the inferior vena cava. It then passes into the right ventricle, and from the right ventricle into the pulmonary artery, but the lungs of the fœtus being almost impervious, only a small quantity is distributed to them by the pulmonary arteries, and is returned to the left auricle by the pulmonary veins; the greater part of the blood from the right ventricle passes through the ductus arteriosus into the descending aorta, where it is mixed with a small quantity of blood transmitted by the left ventricle into the aorta. It then descends along this vessel to supply the viscera of the abdomen, pelvis, and lower extremities—the greater portion, however, being conveyed by the umbilical arteries to the placenta.

When the child is born, and respiration established, an increased amount of blood is sent to the lungs, and the placental circulation is cut off. The foramen ovale gradually closes up, being completed about the tenth day. The ductus arteriosus contracts as soon as respiration is established, and is completely closed from the fourth to the tenth day.

The umbilical arteries, between the umbilicus and the fundus of the bladder, become obliterated between the second and fifth days.

The umbilical vein and ductus venosus also become obliterated between the second and fifth days.

In some instances the foramen ovale does not close readily, and the blood continues to pass through into the left auricle after birth, giving rise to a bluish color of the surface of the body. This condition is called *cyanosis* or *morbus cœruleus*, and may be remedied by keeping the child on its *right side* for a few days.

CHAPTER IX.

RESPIRATION.

As the blood circulates through the different parts of the body, it is deprived of its nutritive elements and oxygen, and becomes loaded with impurities, resulting from the wear and tear of the tissues; hence it becomes necessary, not only that fresh supplies of nutriment and oxygen should be continually added to the blood, but also that provision should be made for the removal of the impurities. One of the most important and abundant of the impurities is carbonic acid, the removal of which, and the introduction of fresh quantities of oxygen, constitute the chief purpose of respiration.

THE LUNGS.

The organs of respiration are the *lungs*. They are two in number, situated one in each of the lateral cavities of the chest, separated from each other by the mediastinal space. They are provided with a single air tube, the *trachea*, which is divided into two branches, the right and left bronchus, one for each lung. (See Descriptive Anatomy).

MINUTE STRUCTURE.—The lungs are surrounded by a serous membrane, the pleura-pulmonalis, which is connected to the lung tissue by the subserous areolar tissue. The parenchyma, or lung tissue, is composed of lobules, which are held together by areolar or connective tissue. They vary in size and shape; those on the surface are large, of a pyramidal form, the base turned towards the surface; those in the interior are smaller, and of various

forms. Each lobule is a miniature representation of the whole organ of which it forms a part—being composed of one of the smaller bronchial tubes and its corresponding air cells, vessels, nerves, and lymphatics, all of these being held together by areolar tissue. The bronchus, on entering the hilus of the lung, divides and subdivides dichotomously throughout the entire organ until the branches terminate in the lobular bronchial tubes. Each lobular bronchial tube, on entering the substance of the lobule, divides into from four to nine branches, according to the size of the lobule, diminishing in size until they reach a diameter of $\frac{1}{50}$ to $\frac{1}{30}$ of an inch. They are then continued onwards, their sides and extremities being closely covered by numerous saccular dilatations—the air cells —in consequence of which the tubes lose their identity, as cylindrical tubes, and present the character of irregular canals or passages (these are the so-called intercellular passages).

The *air cells* are small, alveolar recesses, which vary from $\frac{1}{70}$ to $\frac{1}{200}$ of an inch in diameter, and are separated from each other by their septa. They communicate with the terminal bronchial tubes, which they surround, by large circular openings; but do not communicate with each other except through the tubes. In the terminal bronchial tubes and air cells, the cartilaginous and muscular tissues are absent, and the mucous membrane is lined by squamous epithelium, while the trachea and bronchii are lined by columnar or ciliated epithelium.

VESSELS AND NERVES.—The *pulmonary artery* conveys the venous blood to the lungs for aëration. It divides into branches, which accompany the bronchial tubes, and terminates in a dense capillary plexus beneath the mucous membrane of the terminal bronchial tubes and air cells. The blood, purified during its passage through

the capillaries, is returned by the pulmonary veins to the left auricle of the heart. The *bronchial arteries* supply the blood for the nutrition of the lung. They arise from the thoracic aorta, and divide into several branches, some of which accompany the bronchial tubes to which they are distributed, and terminate in the deep bronchial veins; others are distributed to the areolar tissue, and terminate partly in the superficial, and partly in the deep bronchial veins; whilst a few ramify upon the walls of the terminal bronchial tubes and air cells, and terminate in the pulmonary veins, the blood having been purified in its passage through the capillaries.

The *bronchial veins*, superficial and deep, unite at the root of the lung, and empty on the right side into the vena azygos major, and on the left in the superior intercostal.

Nerves.—The lungs are supplied by the anterior and posterior pulmonary plexuses of nerves formed chiefly by branches from the pneumogastric and sympathetic nerves.

Lung tissue has an *acid reaction;* this is due to the presence of *pulmonic acid.* This substance is crystallizable, soluble, and is formed in the lung tissue, similar to the formation of sugar in the liver. This acid is supposed by some to decompose the alkaline carbonates of the blood in the lung, and in this way favor the development and elimination of carbonic acid in the lungs. In corroboration of this it has been shown by Bernard that a solution of bicarbonate of soda, injected into the jugular vein of a rabbit, is followed by so rapid a development of carbonic acid in the lungs, lung tissues, and cavities of the heart, as to cause instant death by the arrest of the circulation.

ACTION OF THE LUNGS.

The movements by which fresh air is taken into the lungs, and by which it is again expelled, are those of *inspiration* and *expiration*. This is called the *mechanical act*, in contradistinction to the *chemical*, which relates to the changes which take place between the blood and the atmospheric air.

INSPIRATION.—During inspiration the chest is enlarged in every direction, but chiefly in the vertical. This is effected principally by the contraction of the diaphragm, and its consequent descent towards the abdomen. The *ordinary* muscles of inspiration are the diaphragm, external intercostals, levatores costarum, serratus magnus, and serratus posticus superior. But in *extraordinary* or forced inspiration, as during a paroxysm of asthma, &c., the shoulders are fixed by the patient seizing something firmly, and the serratus magnus, pectoralis major and minor, trapezius, subclavian and scaleni muscles are called into action. The scaleni muscles fix the upper ribs, from which the external intercostals act, as from a fixed point, and elevate the lower ribs, by which the cavity of the chest is enlarged laterally. This action is also promoted by the action of the other muscles previously mentioned. The act of inspiration is slow, and occupies about two-thirds of the time consumed in the complete act of respiration.

EXPIRATION.—Expiration succeeds inspiration, after a brief interval, and is accomplished, in ordinary respiration, by the elastic recoil of the lungs and walls of the chest, after they have been dilated; and partly by muscular action. The *ordinary* muscles of expiration are the abdominal muscles, internal intercostals, except in front, serratus posticus inferior, and triangularis sterni.

The *extraordinary* are the quadratus lumborum, latissimus dorsi, sacrolumbalis, and those which assist in fixing the spine and pelvis. In difficult breathing, almost every muscle in the body is made subservient to the action of respiration. It is stated that the power of expiration exceeds that of inspiration by one-third.

FREQUENCY OF RESPIRATION AND RATIO TO THE PULSE.—The number of respirations in a healthy adult varies from sixteen to twenty in a minute. The proportion of respiratory movements to the pulsations of the heart is about one to four, and when this proportion is departed from, there is reason to suspect some obstruction to the aëration of the blood, or some derangement of the nervous system. Any disproportion between the number of respiratory movements and the number of pulsations, or the amount of blood sent to the lungs to be aërified, is attended with dyspnœa. When the action of respiration is confined to the diaphragm and abdominal muscles, the breathing is said to be *abdominal;* but when the muscles of the thorax are called into action, it is then said to be *thoracic.*

QUANTITY OF AIR RESPIRED.—The quantity of air taken in at each inspiration varies from twenty to thirty cubic inches; this is called *breathing* or *tidal air.* The quantity which an adult of average size (five feet eight inches) can inhale in a forced inspiration is about 280 cubic inches; the excess being called *complemental air* (250 to 260 cu. in). After ordinary expiration, such as that which expels the breathing or tidal air, a certain quantity remains in the lungs, which may be expelled by a forcible expiration. This is called *reserve* or *supplemental air.* But a quantity still remains, which cannot be forced out; this is called *residual air.*

The respiratory capacity of the chest is called the

vital capacity, and it varies according to *stature*, *weight*, and *age*. The vital capacity of an adult, five feet eight inches in height, is about 280 cubic inches; and for every inch in height above this standard, the capacity is increased about eight cubic inches. The influence of weight is not so marked as that of height; but it tends to diminish the respiratory power, when beyond a certain limit. The vital capacity increases from fifteen to thirty-five years of age, and from thirty-five to sixty-five it decreases nearly one and a half cubic inches per year.

The total quantity of air which passes through the lungs in twenty-four hours varies from 300 to 400 cubic feet, depending on the state of the health, bodily exertion, &c. Experience has shown that the minimum quantity of air which ought to be allowed for each person confined in prisons, hospitals, schools, &c., is about 800 cubic feet.

INFLUENCE OF NERVOUS POWER IN RESPIRATION.— The movements of respiration are presided over by the medulla oblongata, into which may be traced the principal excitor nerves, and from which proceed the principal motor nerves. The chief excitor of the movements of respiration is the pneumogastric nerve. When this is divided on both sides the number of respirations is diminished about one-half, and irritation of its trunk is followed by an act of inspiration. The respiratory movements are supposed to be caused by the presence of blood, loaded with carbonic acid, in the capillaries of the lungs, which makes an impression on the periphery of the pneumogastric nerve. The other excitors are the nerves distributed to the general surface of the body, but especially to the face. A current of cold air, or cold water dashed on the face, is sufficient to cause a deep inspiration; and a similar impression on the chest

or body, or a slap on the buttocks, will excite inspiratory movements when they would not otherwise commence, as in the new-born infant or in asphyxia. The first plunge into water, as in swimming, is usually accompanied by a deep inspiration. It is quite probable also that the sympathetic nerves, which receive filaments from the spinal nerves and communicate with the pneumogastric, may be excitors of this function.

The motor nerves concerned in the function of respiration are the phrenic, intercostals, facial and spinal accessory. The motor power of the respiratory nerves is exercised, however, not only in the muscles of respiration, but also on those which guard the entrance to the windpipe.

The respiratory movements, though partly voluntary, are in ordinary respiration essentially independent of the will; for example, during sleep or coma the respiratory function is carried on, although the person is entirely unconscious of the movements. At the same time, it is necessary that the respiratory actions should be partly under the direction of the will, since they are subservient to the production of those sounds by which individuals communicate their ideas to each other.

MODIFICATIONS OF THE RESPIRATORY MOVEMENTS.—These are *coughing, sneezing, sighing, yawning, laughing, crying, sobbing* and *hiccup. Coughing* is caused by any source of irritation in the throat, larynx, trachea or bronchial tubes. This act consists, first, in a full inspiration, the glottis is then closed and a violent expiration takes place, by which a sudden blast of air is forced up the air passages, forcing open the glottis and carrying before it any substance that may be present. The difference between *coughing* and *sneezing* is, that in the latter the blast of air is directed more or less completely

through the nose, in order to remove any irritating substance present there. *Sighing* is simply a deep inspiration, in which a larger quantity of air than usual is made to enter the lungs. *Yawning* is a still deeper inspiration, and is accompanied by a contraction of the muscles about the jaws. In *laughing*, the muscles of expiration are in convulsive movement, and send out the air from the lungs in a series of jerks, the glottis being open. *Crying* is very nearly the same as laughing, although occasioned by a different emotion. When the emotions are mixed, an expression is produced *"between a cry and a laugh."* *Sobbing* is caused by a series of short convulsive contractions of the diaphragm, the glottis being closed. *Hiccup* is caused by a sudden convulsive contraction of the diaphragm, the glottis suddenly closing in the midst of it; the sound is produced by the impulse of the column of air against the glottis.

CHANGES IN THE RESPIRED AIR.—The air consists of a mixture of 20.81 parts oxygen to 79.19 of nitrogen, in 100 parts by volume; carbonic acid from .3 to .6 parts in a thousand; a variable amount of aqueous vapour, and a trace of ammonia. The *changes* produced on the atmospheric air by respiration are—1st, an increase in the temperature equal to that of the blood; 2nd, an increase in the quantity of carbonic acid and aqueous vapour; 3rd, a diminution in the quantity of oxygen. The nitrogen remains nearly the same, and a small quantity of animal matter is eliminated by the lungs. The air is heated by contact with the interior of the lungs to a temperature of about 98° F.

EXHALATION OF CARBONIC ACID AND WATER BY THE LUNGS.—The presence of an increased amount of carbonic acid in expired air, may be demonstrated by breathing through lime water, which becomes milky by the

formation of insoluble carbonate of lime. It has been
ascertained that there are about 4.35 parts of carbonic
acid in 100 parts expired air, and subtracting the quan-
tity in the air when inspired, leaves about 4.30 parts
per cent. by volume, which is eliminated from the lungs
at each ordinary expiration. This would amount to
about sixteen cubic feet per day of carbonic acid, or
about $7\frac{1}{2}$ ounces of carbon. The elimination of carbonic
acid may be modified by a number of circumstances.

Digestion has been observed to be attended with an
increased exhalation of carbonic acid, most distinct
about an hour after eating; while *fasting*, on the other
hand, diminishes it. *Alcohol, ether* and *chloroform* intro-
duced into the system, are followed by a diminution in
the quantity of carbonic acid exhaled. *Exercise* increases
the exhalation of carbonic acid to about one-third more
than it is during rest. During *sleep*, on the other hand,
there is a considerable diminution in the quantity of
this gas evolved, owing probably to the tranquility of
the breathing; but directly after waking, the amount is
increased. *Age and sex* influence the quantity of carbo-
nic acid exhaled; in males it increases from eight to
thirty years of age; remains stationary from thirty to
forty, and then diminishes to extreme age. In females,
the quantity exhaled is always less than in males of the
same age; it is increased from the eighth year to the age
of puberty, and remains stationary as long as they con-
tinue to menstruate, but when menstruation ceases, from
whatever cause, the exhalation of carbonic acid again
augments, after which it diminishes to extreme age.

The temperature of the external air has an important
influence on the exhalation of carbonic acid. Observa-
tion made at various temperatures between 38° F. and
75° F. show that between these points every rise equal
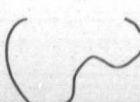
to 10° F. causes a diminution of about two cubic inches in the quantity of this gas exhaled per minute. *Cold*, on the other hand, within certain limits, increases it.

The respiratory movements also influence the exhalation of this gas. When the respirations are increased in frequency more carbonic acid is exhaled, although the per centage in proportion to the amount breathed is less. If the air has been previously breathed, the quantity of carbonic acid exhaled is very much diminished. It should also be borne in mind, that the continued respiration of an atmosphere charged with the exhalations from the lungs and skin is a most potent predisposing cause of disease, especially of the zymotic class.

The *amount of aqueous vapour exhaled* from the lungs in twenty-four hours may be estimated, in temperate climates, at from twelve to twenty ounces. A certain amount of carbonic acid and water is also eliminated by the integument.

AMOUNT OF OXYGEN INHALED.—The quantity of oxygen in respired air is always less than in the same air before respiration. Some of the oxygen unites with the carbon in the lungs to form carbonic acid; some is used in the chemico-vital changes which take place in the blood and tissues, and some is also used in oxidizing other substances besides the carbon, as for example, sulphur and phosphorus, which are eliminated in the urine in the form of sulphuric and phosphoric acid. The quantity of oxygen consumed varies in different persons, and in the same person at different times. It is increased by food, especially of the farinaceous kind, and is diminished during fasting. The interchange of gases in the lungs does not accord with the law of "diffusion of gases," otherwise the proportion between the oxygen consumed and the carbonic acid exhaled should never

vary. Besides, the law requires that both gases should be free, and under equal pressure; while, in reality, the gas in the blood is dissolved, is under pressure, and is also separated by a membrane from that into which it is to be diffused.

The *nitrogen* of the atmosphere serves only to dilute the oxygen, and moderate its action in the system. Under ordinary circumstances there is very little difference between the quantity of nitrogen inspired and exhaled. The absorption of nitrogen is increased by fasting; while, under opposite circumstances, it is diminished. There is also a small quantity of nitrogen given off in the form of ammonia.

CHANGES PRODUCED IN THE BLOOD BY RESPIRATION. —1st, its color is changed; 2nd, it absorbs oxygen; 3rd, it exhales carbonic acid and aqueous vapour, small traces of ammonia and animal matter. The most obvious change is that of *color*, the dark venous blood being exchanged for the bright scarlet of arterial blood. The supposed causes of this change have been already discussed in the chapter on blood. It is chiefly due to the exhalation of carbonic acid which exists in the blood, and the absorption of oxygen which is taken up principally by the corpuscles, and partly by the plasma, and carried to the tissues. The presence of oxygen in the corpuscles causes them to assume a biconcave disc, which reflects the light in such a way as to change their color.

With reference to the *oxygen*, it was formerly supposed that it combined with the carbon of the venous blood in the capillaries of the lungs, and was exhaled in the form of carbonic acid; but it has since been established beyond doubt that only a small amount is formed in the lungs—the principal part being already formed in the venous blood before it enters the lungs, and the

oxygen which is absorbed during respiration is mostly carried off in a free state with the arterial blood. Both the oxygen and carbonic acid exist in the corpuscles and plasma of the blood, partly in a state of solution, and partly in a state of chemical combination. The chief agents concerned in the absorption of the gases in the blood are the corpuscles.

The *exhalation of carbonic acid* is favored by the moist condition of the membranes of the lung, which liquefies the gas. This fact may be demonstrated by filling a bladder with carbonic acid, and then placing it in water; it will soon be found to collapse and become completely emptied. Carbonic acid is being constantly generated in the blood, and is removed by exhalation from the lungs as fast as it is produced; but if respiration is obstructed or seriously impeded, it accumulates in the blood, and may cause death by its poisonous effects on the nervous system. Carbonic acid is formed in three different ways in the system: 1st, in the blood, by the action of oxygen on certain elements introduced in the food, as starch, sugar, and fats, giving rise to a certain amount of animal heat; 2nd, in the capillaries, by the union of oxygen with the carbon produced in the disintegration of the tissues; 3rd, in the lungs, by the decomposition of the alkaline carbonates by the acid of the lung (pulmonic).

Respiration is partly a physical and partly a chemical process; *e.g.*, the introduction of oxygen and the exhalation of carbonic acid is a physical process; while the formation of the carbonic acid itself is essentially a chemical one.

The great object of respiration is to introduce oxygen into the blood, and remove the deleterious matters, as carbonic acid, animal matter, ammonia, &c., by the surface of the lungs.

EFFECTS OF THE ARREST OF RESPIRATION.—When
respiration is interfered with by any obstruction, or from
whatever cause, the circulation of blood through the
lungs is retarded, and at length arrested. This prevents
the exit of blood from the right ventricle, and is followed
by venous congestion of the nervous centres, and all the
other parts of the body. Besides, only a very small
quantity of blood finds its way into the left side of the
heart, and this is venous also. Hence, in death from
asphyxia, the left side of the heart is nearly empty,
while the lungs, right side of the heart, and veins are
gorged with venous blood. The cause of the reten-
tion of blood in the lungs is due to the non-elimina-
tion of the carbonic acid; for blood loaded with this
gas does not pass freely through the capillaries. The
fatal result is due, to some extent, to the weakened
action of the right side of the heart, in consequence of
its over-distension; and also to the venous congestion in
the medulla oblongata and nervous centres. The time
which is necessary for life to be destroyed by asphyxia
varies from one and one-half to four minutes. In drown-
ing, very few persons recover who have been submerged
more than four minutes. Cases have been recorded in
which recovery took place after the lapse of from fifteen
minutes to half an hour, and even longer; but in these
instances it is probable that a state of syncope had come
on at the moment of immersion.

CHAPTER X.

ANIMAL HEAT, LIGHT, AND ELECTRICITY.

HEAT.—This is closely connected with the process of respiration. The average temperature of the human body varies from 98° to 100°F.; birds, from 106° to 111°F.; fishes and reptiles, about 51°F. In mammals and birds the temperature of the blood and internal organs is always very much above the external air, and they are therefore called "*warm-blooded animals.*" In fishes and reptiles, on the other hand, the temperature of their bodies differs but little from that of the medium which they inhabit, hence they are called "*cold-blooded animals.*" In both classes, however, there is an internal source of heat, but it is more active in the one than the other. Even in vegetables a certain amount of heat-producing power is occasionally manifest, as for example, in the flowering of plants, malting of barley, &c. In disease, the temperature of the body may deviate somewhat from the natural standard, as *e.g.*, in scarlatina and typhus it rises as high as 106° or 107°F. In cholera, on the other hand, it often falls as low as 78° or 79°F. In some cases of yellow fever, a remarkable rise takes place very soon after death, in one instance as high as 113°F., fifteen minutes after death. The temperature of the body in health, is about 1½°F. lower during sleep than while awake. It is raised by exercise, and also after eating.

THEORY OF THE PRODUCTION OF ANIMAL HEAT.—There have been many theories regarding this subject.

Lavoisier supposed that the oxygen taken into the lungs combined with the carbon of the blood and formed carbonic acid, which was at once eliminated, the same amount of heat being produced as if the oxidation of a similar quantity of carbon in wood or coal had taken place, and that the heat thus developed radiated to the different parts of the body. This view was, however, soon ascertained to be incorrect, inasmuch as the heat of the lungs was found to be no greater than the rest of the body. It was also shown that the carbonic acid is formed principally in the blood and tissues, and that the oxygen is taken up by the blood corpuscles and carried away in the general circulation. According to Liebig, the heat of the animal body is produced by the oxidation or combustion of certain elements of the food, while circulating in the blood, as starch, sugar, and fats. He therefore divided the food into two classes,— 1st, *The plastic elements of nutrition*, which are used in the building up of the tissues, as albumen, fibrin, casein, muscular tissue, &c. 2nd, *The elements of respiration*, as starch, sugar, and fats, which are chiefly used in the production of animal heat, being oxidized in the circulation, and eliminated in the form of carbonic acid and water by the lungs. This theory, slightly modified, is the one which is most generally received.

The production of animal heat, then, is a phenomenon which results partly from the oxidation, or combustion, of the respiratory elements of the food, and partly from the chemico-vital changes which take place in the blood and the different organs of the body. Every change in the condition of the organic constituents of the body, in which their elements enter into new combinations with oxygen, must be a source of the development of heat; and the amount of oxygen consumed

bears a certain relation to the amount of heat produced—
the same amount of heat being produced, whether the
union be rapid or slow.   It is also found that the quan-
tity of heat generated in the body is, "*cæteris paribus,*"
in direct proportion to the activity of the respiratory
process.   For example, in birds, whose function of respi-
ration is very active, the animal temperature is very
high (111°F.), while in mammals, whose respiration is
less active, it is less (98° to 102°F).   In fishes and rep-
tiles, both the respiration and the animal heat are much
lower than in either of the preceding (51°F).   Besides,
the quantity and quality of the food used are different
in different climates and seasons; for example, larger
quantities of fats and oils are used in the food in cold
than in warm climates, in order to supply material for
the maintenance of animal heat.   Even in temperate
climates, more fats are used in winter than in summer.

INFLUENCE OF THE NERVOUS SYSTEM IN THE PRO-
DUCTION OF ANIMAL HEAT.—It has been observed that
after the division of the nerves of a limb the tempera-
ture falls, and this diminution of heat is still more
decidedly marked in cases of paralysis; *e. g.*, the hand of
a paralyzed arm was found to be 70°F., while that of the
sound side had a temperature of 92°F.   Again, when
death is caused by a severe injury, or removal of the
nervous centres, or in poisoning by woorara, &c., the
temperature of the body rapidly falls, even though arti-
ficial respiration be kept up.   On the other hand, severe
injuries of the nervous system are sometimes followed
by the direct opposite effect.   This is supposed to be
due to the dilatation of the arteries, in consequence of
which the blood reaches the part supplied by those
nerves in larger quantities; the nutrition is therefore
more active.   Certain emotions of the mind may cause a

momentary increase of temperature, while others cause a diminution. These circumstances, however, do not prove that heat is produced by mere nervous action independent of any chemical change. All the functions of the organism, as nutrition, secretion, excretion, &c., are under the influence of the nerves, and when they are divided, or otherwise injured, or paralyzed, chemico-vital action is in a great measure suspended.

LOSS OF HEAT BY EVAPORATION.—The temperature of the body is rendered uniform by the evaporation which is continually taking place on its surface. Evaporation produces cold, on the principle that "when a fluid passes into a state of vapour heat becomes latent," and hence the loss of heat will depend upon the amount of evaporation. When the atmosphere contains much moisture the evaporation is partly suspended, and all the effects of excessive heat are made more apparent than in a dry atmosphere, in which a greater amount of evaporation takes place, and consequently a greater amount of heat is removed from the system. Persons have been known to remain for several minutes in a dry atmosphere heated to 250°, without injury, the evaporation being sufficient to keep the temperature of the body within certain limits. Such a degree of heat in a moist atmosphere would be certain to cause serious injury.

In fevers and inflammation, the skin is hotter than in health, and is also dry; this is owing to the arrest of the natural secretion or perspiration, in consequence of which there is little or no evaporation to produce cold.

LIGHT.

The evolution of light from the living human body, is a phenomenon of rare occurrence. Luminous exhalations have been frequently observed in burial grounds,

and a luminous appearance has been sometimes noticed in newly dissected subjects in the dark. This is due to the development of phosphoretted hydrogen during decomposition of the tissues. A luminous appearance has been observed in old sores in the living subject, which were in a state of decomposition. It is also said that an evolution of light has been noticed, in two or three instances, in patients in the last stage of phthisis. The light, in these cases, was observed to play around the face, and, in all probability, proceeded from the breath, which had a peculiar smell, and was probably charged with phosphoretted hydrogen. The urine also, in some instances, has a luminous appearance, depending on the presence of unoxidized phosphorus which it contains. The breath of an animal may be rendered distinctly luminous by injecting phosphorus dissolved in olive oil, in the proportion of two grains to the ounce, into the veins.

ELECTRICITY.

This is generated by *chemical union* or *decomposition*, *heat*, and *motion* or *friction*. There are no two parts of the body (except probably those of opposite sides) whose electrical condition is precisely the same. This depends on the difference in the functional activity of the parts; *e. g.*, the skin, and most of the internal membranes, are in opposite electrical states. *Electrical currents* exist in muscles and nerves; this may be demonstrated by means of the *galvanometer*. The direction of the current is constant in each muscle; but different muscles have different currents, *e. g.*, in the gastrocnemius of the frog, the direction is from the foot towards the body; while in the sartorius it is the reverse. But, taking all the muscles of the limb together, the different currents are so unevenly

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balanced, that a constant current is established in one direction of the limb, and this, in the frog, is from the foot towards the body. The current of a man's arm is from the shoulder to the fingers.

When the two cut ends of a muscle are placed against the electrodes of a galvanometer, a very slight deflection of the needle is observed, and the same is the case with two points of a longitudinal section which are equally distant from the middle of the muscle. But the most powerful influence on the galvanometer is produced when the surface of a muscle is placed on one of the electrodes, and the cut end of it brought in contact with the other. These results may be obtained with small portions of the muscle, even with a single fasciculus. Hence, it would appear, that each integral particle or sarcos element is a centre of electromotive action, and contains within it positive and negative elements, the arrangement of which represents a galvanic pile thus:

$+$ It is supposed by some, that the light spots in the
$+$ muscular fibrillæ are electro-positive, and the
$+$ dark spots electro-negative. It has also been
$+$ observed, that during contraction of the muscle the
electric current is diminished. This may be exemplified by means of a common battery. It will be observed, that when the poles are held tightly in the hands, and the muscles firmly contracted, the shock is not so readily transmitted as when they are held gently. Since electricity is transmitted both by the muscles and nerves, it is probable that contraction of the former alters slightly the relative position of some of the positive or negative elements, and in this way the power of conducting by the muscles is, to a certain extent, destroyed.

There is also an electric current in nerves, similar to that in the muscles. When a small piece of nerve,

recently obtained from the living body, is placed so that its surface rests on one of the electrodes, and its cut extremity touches the other, a considerable deflection of the needle is produced in a direction which indicates that the current is from the interior to the exterior of the nerve. If the cut ends are applied to the two electrodes respectively, no marked effect is observed. The most powerful effect is produced by doubling the nerve in the middle, and applying both ends to one electrode, and the loop to the other. The nervous current, like the muscular, is due to the electromotor action of the molecules of the nerve.

The body would become surcharged with electricity were it not that the equilibrium is maintained by the free contact which is continually taking place between it and surrounding bodies. It is only when the body is insulated that it becomes apparent. The electricity of man is generally positive; of women, more frequently negative; and irritable men, of sanguine temperament, have more free electricity than phlegmatic persons. In some individuals, a crackling noise is produced when articles of dress, worn next the skin, are being removed, especially in dry weather. A case of a lady is mentioned in the *American Journal of Medical Sciences* (1838), in whom the generation of electricity was so great, that whenever she was insulated by a carpet, or any other feebly conducting medium, sparks passed between her body and any object she approached. As many as four sparks per minute would pass from her finger to the brass ball of the stove, at the distance of one and a half inches. This phenomenon was accompanied with a good deal of pain.

Some animals possess organs in which electricity may be generated and accumulated in large quantities,

and from which it may be discharged at will. The most remarkable examples are to be found in certain species of fishes, the best known of which are the *torpedo*, or electric ray, and the *gymnotus*, or electric eel. The shock of the gymnotus is sufficiently powerful to kill small animals; that of the torpedo is less severe, but is sufficient to benumb the hand that touches it.

Sparks of electricity may be produced in most animals having a soft fur, by rubbing the surface, especially in dry weather. This may be easily demonstrated by rubbing the back of a cat with the hand, in a darkened room, or by rubbing the horse, in a dark stable.

CHAPTER XI.

SECRETING GLANDS AND THEIR SECRETIONS.

THE LIVER.

THIS is the largest gland in the body, situated in the right hypochondriac region, and extending across the epigastric into the left hypochondrium. It measures from ten to twelve inches from side to side, and from six to seven from before backwards, and weighs about three to four pounds. It is intended mainly for the secretion of bile, and is also supposed to effect important changes in certain constituents of the blood in its passage through the gland. (See Descriptive Anatomy.)

MINUTE STRUCTURE.—The liver is surrounded by a reflection of the peritoneum, which constitutes its serous covering. This is attached to the substance of the gland, except at its point of attachment to the diaphragm, and in the bottom of the different fissures, by fine areolar tissue. The substance of the liver consists of lobules held together by delicate areolar tissue, the ramifications of the portal vein, hepatic artery and ducts, hepatic veins, nerves, and lymphatics.

The lobules (acini) are small, granular bodies, about as large as a millet seed, varying in size from $\frac{1}{10}$ to $\frac{1}{20}$ of an inch in diameter. They surround the small sublobular branches of the hepatic vein, to which each is connected at its base by a small intralobular branch. When divided longitudinally, they present a foliated margin, and on a transverse section, they have a polygonal outline. When one of the sublobular hepatic veins is laid

open, the bases of the lobules may be seen through the thin walls of the vein on which they rest. The base of each lobule presents a polygonal outline, in the centre of which may be seen the orifice of the intralobular vein. This gives them the appearance of a layer of tesselated or pavement epithelium.

STRUCTURE OF THE LOBULES.—Each lobule is a miniature representation of the whole gland of which it forms a part. It consists of a mass of cells, a plexus of biliary ducts, an intralobular vein (which is the commencement of the hepatic vein), arteries, nerves, and lymphatics.

The *hepatic cells* form the chief mass of the substance of a lobule; they lie in the interspaces of the capillary plexus, so as to form rows, which radiate from the centre to the circumference of the lobule. They are generally spheroidal in shape, but may be polygonal from mutual pressure, and vary in size from $\frac{1}{1000}$ to $\frac{1}{2000}$ of an inch in diameter. Each cell contains a distinct nucleus, sometimes two, and in the interior of the nucleus a highly-refracting nucleolus, and some granular matter. The contents of the cell are viscid, and contain yellow particles of coloring matter, and some oil globules.

BILIARY DUCTS.—These commence within the lobule by a minute plexus of ducts with which the cells are in immediate contact. The ducts then form a plexus between the lobules (interlobular), and the interlobular branches unite into vaginal branches, which lie in the portal canals. These branches finally join into two large trunks, which leave the liver at the transverse fissure, and joining form the hepatic duct.

PORTAL VEIN.—The portal vein, on entering the transverse fissure of the liver, divides into two branches, one for each lobe, which are situated in the portal canals,

together with the branches of the hepatic artery and duct, nerves and lymphatics. These vessels are surrounded by areolar tissue continued inwards from the transverse fissure of the liver (called Glisson's capsule). The portal veins, in their course in these canals, give off vaginal branches, which form a plexus. From this plexus, and from the portal vein itself, small branches are given off, which pass between the lobules and cover their external surface (called interlobular); these then pierce the lobules, and form a capillary plexus within each, from which arises the intralobular vein.

HEPATIC ARTERY.—This takes precisely the same course as the portal vein and hepatic duct. It is intended chiefly for the nutrition of the tissue of the liver. It gives off in the portal canals its vaginal branches, which supply the coats of the portal vein and hepatic duct, and also interlobular branches, which pass between the lobules; the latter pierce the lobules, and terminate in the radicles of the intralobular vein. They are supposed by some to terminate in the radicles of the portal vein, but this is improbable.

HEPATIC VEINS.—The hepatic veins commence in the interior of the lobules in the intralobular veins, which arise in the centre of the lobules, and leave them at their bases to join the sublobular veins. The sublobular veins unite to form larger branches, and these join again to form the large hepatic veins, which terminate in the inferior vena cava.

(For the secretion of the bile, and its function, see chapter on digestion.)

KIDNEY AND ITS SECRETION.

The kidneys are intended for the secretion of urine. They are situated in the back part of the abdominal

cavity, one in each lumbar and hypochondriac region, extending from the eleventh rib to within two inches of the crest of the ilium. They are invested by a thin, smooth, fibrous capsule, which is very easily removed from the surface of the gland.

STRUCTURE.—The kidney consists of two different substances, an *external or cortical,* and an *internal or medullary* substance. The *cortical substance* forms about three-fourths of the whole gland, is reddish in color, soft, granular, and friable in texture, and presents numerous reddish bodies (the malpighian bodies) in every part of it, excepting towards the free surface. It is composed of the convoluted tubuli uriniferi, blood-vessels, nerves and lymphatics, held together by a small quantity of areolar tissue, containing a transparent granular substance, and some small granular cells. The cortical substance is about two lines in thickness opposite the base of each pyramid, and it sends numerous prolongations inwards towards the sinus between the pyramids.

The *malpighian bodies* are found only in the cortical substance. They are small round bodies, of a deep red color, and of the average diameter of $\frac{1}{120}$ of an inch. They are nothing more or less than capsular dilatations of the tubuli uriniferi, and are divided into *lateral* and *terminal,* according as they are situated in the continuity of the tubes, or in their extremities. Within each body or capsule may be observed a vascular tuft, which consists of the ramifications of a small artery, the *afferent* vessel, which, after piercing the capsule, divides in a radiated manner into several branches, which ultimately terminate in a finer set of capillaries. The blood is returned from these by a vein, the *efferent* vessel, which pierces the capsule near the artery and forms a venous plexus

with other efferent vessels around the adjacent tubuli.
The capsules are lined by a layer of epithelium which, in
all probability, is prolonged over the tuft of vessels.

The *medullary substance*, which forms about one-
fourth of the gland, is pale-red in color, dense in texture,
and presents a striated appearance on account of the
number of diverging tubuli uriniferi.   It consists of
conical masses (the "malpighian pyramids"), which vary
in number from eight to eighteen, their bases being di-
rected towards the circumference of the organ, and their
apices towards the sinus, in which they terminate by
smooth rounded extremities, called the papillæ of the
kidney.   The conical masses consist of the tubuli urini-
feri, blood-vessels, nerves, and lymphatics, held together
by areolar tissue.   The tubuli uriniferi commence at the
apices of the cones by small openings, which vary from
$\frac{1}{200}$ to $\frac{1}{300}$ of an inch in diameter; as they pass towards
the base they divide and sub-divide, and diverge until
they reach the cortical substance, when they become
convoluted and anastomose freely with each other.   The
number of orifices on a single papilla is about 1,000;
from 400 to 500 large, and as many smaller ones.   The
tubuli uriniferi are lined by spheroidal epithelium, and
pour their secretion into the sinus.

SINUS OF THE KIDNEY.--This is a large cavity in
the interior of the kidney which communicates with the
tubuli uriniferi, on the one hand, and the ureter on the
other.   It consists of three prolongations, the infundi-
bula, one situated at each extremity of the organ, and
one in the middle.   Each infundibulum is divided into
from seven to thirteen smaller portions, the calyces,
each of which surrounds, like a cup, the base of one or
more of the papillæ.   It is lined by spheroidal epi-
thelium.

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SECRETION OF URINE.—The secretion of urine from the blood is effected by the agency of cells. It is probable, also, that the malpighian bodies furnish chiefly the fluid portion of the urine, for it has been observed that in those animals which pass the urinary excrement in a semi-solid state, the tufts of the malpighian bodies are very small. The secretion of urine is rapid in comparison with other secretions. It passes through the ureters and enters the bladder drop by drop; this may be seen in some cases of *ectopia vesicæ*. Some substances pass very rapidly from the stomach through the circulation, to be eliminated by the kidney; *e.g.*, a solution of ferrocyanide of potassium passed in one minute, while some vegetable substances, as rhubarb, occupied from sixteen to thirty-five minutes. The transit is slower when the substances are taken during digestion.

URINE.

Healthy urine is a clear, limpid fluid, of a pale straw or amber color, with a peculiar odor, and saline taste. When first voided, it has an acid reaction, but after a short time it becomes alkaline from the development of ammonia during decomposition. In some instances the urine may become turbid on cooling, although clear and transparent at first.

The *specific gravity* of urine varies from 1015 to 1025, depending on the time at which it is secreted, the kind of food, drink, &c. In consequence of this, the secretion has been divided into three varieties:—1st, *urina potûs*, or that which is secreted after the introduction of fluids into the body; 2nd, *urina cibi*, or that secreted after the introduction of solid food; 3rd, *urina sanguinis*, or that secreted from the blood when neither food nor drink has been taken. For purposes of investigation, the whole of

the urine passed during a period of twenty-four hours should be taken. In disease, as albuminuria, the specific gravity is diminished to 1004; while in diabetes it may be increased to 1050 or 1060. The whole quantity of urine secreted in twenty-four hours varies, according to the amount of fluid drank, and the quantity secreted by the skin, from thirty to forty ounces. The secretion of the skin is more active in warm weather than in cold, and consequently the quantity of urine secreted during winter is greater than in summer.

CHEMICAL COMPOSITION OF THE URINE.—The urine consists of water, holding in solution certain animal matters, salts, coloring matters, &c. Its composition is as follows, in 1000 parts. Becquerel:

Water	967.00
Urea	14.23
Uric acid	.47
Animal and extractive matter (creatine and creatinine), coloring matter and mucus	10.17
Chloride of sodium and potassium Sulphate of soda and potassa Biphosphate of lime, soda, magnesia & ammonia Hippurate of soda Fluate of potash	8.13
Silica	Traces.
	1000.00

WATER.—The quantity of water varies in different seasons, and according to the drink, exercise, action of the skin, &c. In some diseases it is very much increased, as in hysteria, diabetes, &c. In other diseases, as albuminuria, diarrhœa and dysentery, it is very much diminished. In fevers, and in inflammation also, the quantity of water is almost always diminished.

UREA.—$C_2 H_4 N_2 O_2$ ($NH_4O C_2NO$.) This constitutes nearly half of the solid matter of healthy urine. The quantity is increased by exercise, or by a purely animal or highly nitrogenous diet. An excess of urea is

often found in rheumatic and gouty patients. Urea exists already formed in the blood, and is simply removed by the kidneys. It is formed from the decomposition of the nitrogenous elements of the food, and from the disintegration of the azotized tissues. It may be readily obtained by evaporating urine to the consistence of honey, and acting on it with four parts alcohol; then evaporating and crystallizing. It crystallizes in acicular crystals, which appear, under the microscope, as four-sided prisms. It may also be obtained in the form of nitrate of urea ($C_2 H_4 N_2 O_2$, NO_5) by evaporating urine to one-half, and then adding an equal quantity of nitric acid, and crystallizing. Urea is identical in composition with cyanate of ammonia ($NH_4O C_2NO = C_2 H_4 N_2 O_2$), and may be prepared artificially by the chemist, by double decomposition from cyanate of potash, and sulphate of ammonia. Urea is colorless when pure, and destitute of smell, neutral in its reaction to test paper, and soluble in water and alcohol. When urine stands for some time, the urea is decomposed, and forms carbonate of ammonia. It is also decomposed, in some cases, before it leaves the bladder, as in paralysis, and some low forms of disease. Nearly half an ounce of urea is excreted from the body in twenty-four hours, when the kidney is in a healthy condition; but in some diseases, as, e. g., in desquamative nephritis, Bright's disease, or congestion of the kidney from any cause, a certain portion of the urea is kept back, and circulating through the system may, by its poisonous effects on the cells, give rise to dropsies in different parts of the body, or from its deleterious effects on the nervous system, occasion uremic convulsions and coma. It is supposed by Frerichs, that this substance is resolved, while in the circulation, into carbonate of ammonia, the presence of

which produces those effects usually attributed to the presence of urea.

URIC OR LITHIC ACID ($C_{10} H_4 N_4 O_6$). This substance is rarely absent from healthy urine. It is combined with soda and ammonia in the form of urates. It predominates in the urinary excrements of birds, serpents, and other reptiles; while urea predominates in the mammalia, especially the *herbivora*. The quantity of uric acid, like that of urea, is increased by the use of animal or highly nitrogenized food, and decreased by food which is free from nitrogen. It is increased in all febrile conditions, and in gout it is deposited in and around joints, in the form of urate of soda, and constitutes the (so-called "chalk stones"). Uric acid has been detected in the blood of healthy persons, and in considerable quantity in gouty patients. It is supposed to be formed in the system from the disintegration of the azotized tissues. Uric acid may be readily obtained by adding a few drops of hydrochloric acid to a portion of urine in a watch glass; after a few hours, it is found crystallized on the sides and bottom of the vessel. In larger quantities it may be obtained from the thick, white urinary excrement of serpents or birds, which consists almost entirely of urate of ammonia. This substance is dissolved in warm water, and then decomposed by nitric or hydrochloric acid. The crystals of uric acid assume very various and somewhat fantastic shapes, most frequently rhombic or diamond shaped. It is insoluble in alcohol and ether.

HIPPURIC ACID ($C_{18} H_8 NO_5 HO$.)—This acid exists in small quantity in human urine, probably in the form of hippurate of soda, but is very abundant in the urine of cows, horses, and other herbivorous animals. It is closely allied to benzoic acid ($C_{17} H_5 O_2 O HO$), and

this substance, when taken into the system, is excreted in the form of hippuric acid. Hippuric acid is chiefly formed from vegetable articles of food, and may be prepared from the urine of cows by precipitation with hydrochloric acid. It has a bitter taste, is slightly soluble in cold, but very soluble in hot water and alcohol.

ANIMAL EXTRACTIVE AND COLORING MATTERS.— Under this head are included certain substances, some of which, as creatine, creatinine, and urrosacine, have been separated, while others have not.

Creatine—(C_8 H_9 N_3 O_4) occurs in very small quantity in the urine. It is a colorless crystalline body, with a pungent taste, soluble in water, but almost insoluble in alcohol. It may be obtained from the flesh of animals. It is most abundant in the flesh of fowls, and in the heart of the ox.

Creatinine—(C_8 H_7 N_3 O_2) is also found in the urine. It crystallizes in colorless crystals, has a hot, pungent taste like caustic ammonia, and is soluble in water and alcohol. It may be formed from creatine by the action of hydrochloric acid. It is probably formed from creatine in the system.

Urrosacine, the coloring matter of the urine, has been already described, (see proximate principles).

Salts.—The salts of the urine constitute about one-fourth of the solid ingredients; some of them are similar to the salines found in other parts of the body; others are peculiar to the urine.

Chlorides of sodium and potassium form a large proportion of the salines of the urine, the former being more abundant than the latter. They are derived in part from the food, and also partly from chemical decomposition within the body. They may be readily precipitated by a solution of nitrate of silver, after the urine

has been acidulated by nitric acid. When nitrate of silver is added to healthy urine, a whitish precipitate of chloride of silver and phosphate of soda is thrown down; the latter may be dissolved by the addition of a little nitric acid. The chloride of silver is readily dissolved by a little ammonia.

The *sulphates* are more abundant in the urine than in the fluids and tissues of the body. They are increased by exercise, and in diseases accompanied by muscular exertion, as in chorea and delirium tremens, &c. The sulphuric acid is formed by the oxidation of sulphur which is derived from the decomposing *proteine compounds*.

The *phosphates* are more numerous, though less abundant than the sulphates. In the urine they are acid salts, as biphosphate of soda, lime, magnesia, &c., and these are supposed to give the urine its acidity. Phosphorus is derived from the decomposition of nerve substance, albumen and fibrin, and like sulphur, is oxidized at the lungs, and then unites with the bases to form salts. The phosphates are increased by great mental exertion, and in phrenitis, while they are diminished in delirium tremens.

Fluate of potash and silica are not constant ingredients in the urine. —

MAMMARY GLANDS AND THEIR SECRETION.

These are the organs which secrete the milk. They are large and hemispherical in the female, but are quite rudimentary in the male. They are situated in front of the pectoralis major, between the third and sixth ribs, and extending from the sides of the sternum nearly to the axilla. They are enlarged at puberty, increased during pregnancy and lactation, and diminished in old

age. The outer surface of the mamma presents, a little above the centre, a small conical eminence—the nipple—the surface of which is dark-colored, and surrounded by an areola, which has a rosy hue in the virgin, but becomes very dark-colored during pregnancy. Its summit is perforated by numerous openings, the orifices of the lactiferous ducts. It is also provided with a number of sebaceous glands situated near its base, and upon the surface of the areola, which secrete a peculiar fatty substance for the protection of the nipple during sucking. The nipple consists of numerous blood-vessels, nerves, lymphatics, ducts, erectile tissue, and nonstriated, muscular fibre-cells, and is capable of slight erection during sexual excitement or irritation.

STRUCTURE.—The mamma consists of numerous lobes, which are made up of small lobules, connected together by areolar tissue, blood-vessels, and ducts. Each lobule, which is a representation of the whole gland, consists of a cluster of rounded vesicles, which open into the smallest branches of the lactiferous ducts, and these, uniting, form larger ducts—the tubuli lactiferi. These vary in number from fifteen to twenty, and converge towards the areola, beneath which they form dilatations, or *ampullæ*, which serve as reservoirs for the milk; they then become contracted, and continue onwards to the summit of the nipple, where they open by separate orifices, which are narrower than the ducts themselves. The entire surface of the gland is invested by fibrous tissue, from which numerous septa are derived, which pass between the lobes. The fibrous tissue, also, contains some adipose.

MILK.—The secretion of milk is usually limited to the period succeeding parturition, yet this is not invariably the case. Numerous instances are on record where

young women who have never borne children, and even
old women, have been able to act as wet nurses. In
some rare cases, the male has been known to secrete
milk in the breasts. A fluid resembling milk may
frequently be expressed from the mammary glands of
infants. The *chemical composition* of human milk is as
follows, in 1000 parts:

Water	890
Butter	25
Casein	35
Sugar and Extractive	48
Fixed Salts	2
	1000

When milk is examined with the microscope, a large
number of minute particles may be seen, termed "oil
globules," which vary in size from $\frac{1}{3000}$ to $\frac{1}{12000}$ of an
inch. They are soluble in ether and alkalies, when
agitated. In the *colostrum*, or first milk secreted after
labor, large, yellow, granulated corpuscles may be seen;
they appear to be composed of small granules or glob-
ules of a fatty nature, being for the most part soluble in
ether. They are supposed to be exudation corpuscles,
by some; while others regard them as transformations
of the epithelial cells of the lactiferous ducts, the result
of fatty degeneration, depending on the activity of the
mammary gland during pregnancy. The colostrum has
a purgative effect on the child, which is useful in clear-
ing the bowels of the meconium which they contain at
birth. The *oleaginous matter* of milk chiefly consists of
the ordinary constituents of fat, together with a sub-
stance called "butyrin," to which the taste and smell of
butter are due. When this substance is treated with
alkalies, or suffers decomposition, the following volatile
acids are produced, viz.: butyric, caproic, caprylic, and
capric. These are called butter acids.

The *casein* of human milk is not so readily precipitated as cows' milk. It requires a large amount of acid, and rennet does not seem to take effect upon it, unless an acid be present.

Lactin, or *sugar of milk* (C_{24} H_{24} O_{24}), may be obtained from whey by evaporation and crystallization. It strongly resembles *glucose,* into which it may be converted by the addition of dilute sulphuric or hydrochloric acid. The action of a ferment causes lactin to undergo the lactic acid fermentation; and when lactic acid, or the lactate of lime is allowed to stand for some time, it is changed into butyric acid, or butyrate of lime, having undergone the "butyric acid fermentation."

The *saline matter* of the milk is nearly identical with that of the blood, with an increase in the phosphate of lime and magnesia. From what has been already stated, it will be observed that milk contains the four classes of principles which are required for human food, viz.: The *aqueous,* the *albuminous,* the *oleaginous,* and the *saccharine,* consequently it is well adapted to the nourishment of the young animal.

Certain medicinal agents, when administered to the mother, may pass into the milk, and in this way affect the child. As a rule, salines pass more readily than vegetable substances. Medicine may be administered to the mother, instead of the child, when it is desired to act upon the latter.

Certain emotions of the mind, as anger, grief, fear, &c., may produce peculiar changes in the quantity and quality of the milk; for example, anger produces very irritating milk, which causes griping in the child, and green stools. Grief diminishes the secretion, and frequently vitiates it. Fear also diminishes the secretion, and that which is secreted under these circumstances

is highly irritating. Violent exercise, or great anxiety of mind, has also a bad effect on the secretion of milk. Cases are recorded in which children have had convulsions and died shortly after sucking milk secreted under the foregoing circumstances.

CHAPTER XII.

DUCTLESS GLANDS.

THESE are so named from having no excretory ducts; they are the *spleen, supra-renal, capsules, thymus* and *thyroid* glands.

THE SPLEEN.

The *spleen* is situated in the left hypochondriac region, embracing the cardiac end of the stomach. It is of an oblong shape, highly vascular, very brittle, and of a bluish-red color. It measures five inches in length, three or four in breadth, and one and a half in thickness, and weighs from four to six ounces.

STRUCTURE.—It is invested by two coats, an *external serous*, and an *internal fibrous elastic* coat.

The *serous coat* is derived from the peritoneum, and is intimately adherent to the fibrous coat. It covers nearly the whole organ, being reflected from it at the upper end on to the diaphragm, and at the hilus on to the great end of the stomach, forming the gastro-splenic omentum.

The *fibrous coat* consists of white fibrous and yellow elastic tissue. It covers the exterior of the organ, and sends prolongations inwards in the form of vaginæ or sheaths, which surround the vessels. From these sheaths, and from the inner surface of the fibrous coat, numerous trabeculæ or bands pass in all directions, and these uniting form the areolar framework of the spleen. The presence of the elastic tissue permits of the great enlargement of this organ which is sometimes seen. The

spaces or areolæ between the bands are filled with a soft pulpy mass, of a dark brown color, consisting of *colorless* and *colored* elements, the proper substance of the spleen, and some rounded vesicles (the malpighian bodies).

The *colorless elements* form about one-half or two-thirds of the entire pulp, especially in well-fed animals, and consist of granular matter, free nuclei, about the size of red corpuscles, and a few nucleated cells, about $\frac{1}{1000}$ of an inch in diameter.

The *colored elements* consist of unchanged red blood corpuscles, and blood discs in various stages of decay. Besides these may be seen a number of granular bodies or crystals, which in chemical composition resemble the hematine of blood.

The *malpighian bodies* are rounded vesicles, from one-third to one-sixth of a line in diameter; of a semi-opaque whitish color, and are more distinct in early life than in adult age. Each consists of a membranous capsule, homogeneous in structure, and derived from a prolongation from the sheaths of the small arteries to which the bodies are attached. They are surrounded and embraced by the radicles of the arteries, and present a resemblance to the buds of the moss rose. Each capsule contains a soft white substance consisting of granular matter, nuclei, and nucleated cells, similar to the colorless elements of the pulp.

The *splenic artery* is large in proportion to the size of the gland, tortuous in its course, and divides into from four to six branches, which enter the hilus. Each branch runs transversely from within outwards, and divides into smaller branches; these ultimately terminate in tufts or pencils, which lie in direct contact with the pulp. The most striking peculiarity is, that each of the larger branches supplies chiefly that part of the organ to

which it is distributed, having no anastomosis with the adjoining branches.

The *capillaries* terminate either directly in the veins, or open into cæcal or lacunar spaces, from which the veins arise. The veins are much larger and more numerous than the arteries, and by their junction form from four to six branches which emerge at the hilus, and uniting form the splenic vein, the largest branch of the portal. From this it will be seen that the blood of the spleen passes through the liver before it enters the general circulation.

FUNCTION OF THE SPLEEN.—In consequence of the large amount of elastic tissue which this organ contains, permitting it to undergo great changes in volume, and from its peculiar position in reference to the portal circulation, it would appear to serve as a *diverticulum* to the liver, so as to relieve its vessels from undue turgescence, and prevent congestion of the liver, stomach, and bowels. Enlargement of the spleen is apt to occur from any obstruction to the hepatic circulation, or from internal venous congestion, such as occurs in the cold stage of intermittent fever. When intermittent fever is long-continued, the spleen is generally very much enlarged, constituting what is commonly called "ague cake." The spleen is larger four or five hours after food is taken than at any other time, and therefore it is supposed that this organ is the receptacle for the increased quantity of blood formed from the food, and which cannot be admitted into the system generally, without danger, until the volume of the circulating fluid has been reduced by secretion. In support of this theory, it has been stated that animals from which the spleen has been removed, are very liable to die of apoplexy, after taking large quantities of food. It would therefore appear to be a

storehouse of nutrient material, which may be drawn upon as the system requires. The increase of the fibrin in the splenic vein would show that the nutrient material is elaborated during its withdrawal.

The spleen is also supposed to promote the disintegration of the red corpuscles. The pain in the region of the spleen, so common in chlorotic patients, is probably connected with an excess of the disintegrating action of this organ.

SUPRA-RENAL CAPSULES.

The supra-renal capsules are situated upon the upper extremity of the kidney, somewhat triangular in shape, the base being applied to the kidney, and the apex directed upwards. Each gland is about one and one-half to two inches in length, rather less in width, about one-fourth of an inch in thickness, and weighs from one to two drachms.

STRUCTURE.—Like the kidneys, they are divided into a *cortical* and *medullary* portion.

The *cortical portion*, which forms the principal part of the organ, is of a deep yellow color, and consists of narrow, columnar masses, arranged perpendicularly to the surface, and held together by areolar tissue. These columnar masses measure about $\frac{1}{700}$ of an inch in diameter, and consist of closed parallel tubes, containing nucleated cells, dotted nuclei, granular matter, and oil globules. The granules are of various sizes, and are not changed by the action of most chemical reagents.

The *medullary substance* consists of a plexus of minute veins, having nuclei and granules in its meshes. It is soft and pulpy, very dark in color, hence the name *atrabiliary substance*, sometimes given to it.

FUNCTION.—Very little is known regarding their function. They are the diverticula of the kidney, and

are supposed to be concerned in elaborating some of the materials of the blood. It was observed by Addison that disease of the supra-renal capsules was associated with anemia, general weakness, and a peculiar change of color in the skin, the patient resembling a mulatto. The disease is called *morbus Addisonia*.

THYMUS GLAND.

This is only a temporary organ. It reaches its largest size at the end of the second year, and then declines until puberty, when only a small part remains. It is situated partly in the anterior mediastinum, and partly in the neck, extending from the lower border of the thyroid gland to the fourth costal cartilage. It is somewhat oval in shape, of a pinkish grey color, lobulated on its surface, and consists of two lobes. It is about two inches in length, one and one-half in breadth, three or four lines in thickness, and weighs about half an ounce.

STRUCTURE.—Each lobe consists of a central cavity or reservoir, around which are arranged numerous lobules, held together by delicate areolar tissue. The lobules vary in size from a pin's head to a pea, and each contains a small cavity from $\frac{1}{18}$ to $\frac{1}{50}$ of an inch in diameter, which communicates with the central cavity or reservoir of the organ. Each lobule is surrounded by smaller or secondary lobules, the cavities of which communicate with those of the primary lobules. The closed cavity of the organ contains a chyle-like fluid, consisting of granular corpuscles, and nuclei about $\frac{1}{4000}$ of an inch in diameter.

FUNCTION.—This organ would appear to be the diverticulum of the lungs, and is connected with the preparation of matter for the pulmonary arteries in early life. It probably forms fibrin from albumen and other substances, by the action of its nuclei.

THYROID GLAND.

The thyroid gland is situated at the upper part of the trachea, and consists of two lobes connected by a narrow band (the isthmus), which crosses the second and third rings. Each lobe is conical in shape, about two inches in length, and three-quarters of an inch in breadth, the right being the larger. The whole gland weighs from one to two ounces. It is of a brownish-red color, larger in females than in males, and is increased during menstruation. It is occasionally very much hypertrophied, and constitutes *bronchocele* or goitre.

STRUCTURE.—In structure it consists of lobules, held together by areolar tissue. Each lobule consists of a number of closed vesicles, oblong or spherical in shape, each containing an albuminoid substance, consisting of granules, oil globules, nuclei, and nucleated cells, the latter occupying the position of an epithelium within the vesicles. The vesicles vary in size from $\frac{1}{85}$ to $\frac{1}{2000}$ of an inch in diameter.

FUNCTION.—The thyroid gland acts as a diverticulum to the cerebral circulation. When the brain is inactive, the thyroid gland takes on an increased action, and accommodates the blood that would otherwise go to that organ. This view is based on the fact that the arteries which supply this gland arise in close proximity to those which supply the brain. The vesicles also probably remove, and store up from the blood, certain constituents which are not required in its passive state, to be returned to it when it resumes its activity.

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CHAPTER XIII.

THE NERVOUS SYSTEM.

THE nervous system consists of two portions, the *cerebro-spinal*, and the *sympathetic* or *ganglionic* system. The former was distinguished by Bichat as the *nervous system of animal life;* the latter as the *nervous system of organic life.*

The *cerebro-spinal system* includes the brain and spinal cord, the nerves associated with them, and their ganglia, viz:—The ganglia of the posterior root of the spinal nerves, the ganglion of the fifth nerve, and those of the glosso-pharyngeal and pneumogastric nerves. It includes the nervous organs in and through which are performed the several functions with which the mind is more immediately connected, as those relating to common sensation, volition, and the special senses, as well as those concerned in many nervous actions with which the mind has no connection.

The *sympathetic or ganglionic system* consists of a double chain of ganglia connected by nervous cords, which extend along each side of the vertebral column, from the cranium to the pelvis, and from which nerves, with ganglia upon them, proceed to the viscera in the thoracic, abdominal, and pelvic cavities. This system is more closely connected with the process of organic life than the cerebro-spinal, but is less immediately connected with the mind.

In the lower orders of the animal creation the nervous system is quite rudimentary. In its lowest and simplest form it may consist of but a single ganglionic

centre, with *afferent*, and *motor* or *efferent* nerves, whose function is essentially internuncial, impressions being made and responded to without any intervention of consciousness, the movements being purely excito-motor. A simple repetition of such ganglionic centres may exist to any extent without dissimilarity of function, or any essential departure from the mode of action just mentioned. A higher form of nervous system is that in which there is a multiplication of ganglionic centres to correspond with the diversity of functions, as in the higher articulata and mollusca, in which ganglionic centres are set apart for the actions of deglutition and respiration, as well as for those of motion, but their *modus operandi* is still the same—the actions being all excito-motor. In all but the very lowest invertebrata, the nervous system includes, in addition to the above, certain ganglionic centres which preside over the organs of sight, smell, hearing, &c. These sensorial ganglia constitute the "brain" in these animals. The highest degree of psychical perfection, as in the class of insects, consists in the exclusive development of the *instinctive faculty*, or of simple *automatic* powers, by virtue of which each individual performs those actions to which it is prompted by impressions made upon its afferent nerves, without any self-control or self-direction, so that it may be regarded as entirely a creature of necessity.

In the vertebrated series, on the other hand, the highest degree of psychical perfection, as shown in man, consists in the highest development of the *reason* and the supreme domination of the *will*, to which all the automatic actions—except those which are essential to the organic functions—are subject, so that each individual becomes not only a thinking and reflecting, but also a self-moving and self-controlling agent, whose

actions are performed with a definite purpose in view.
During the early period of life, however, the mental
faculties are but little in advance of that of the higher
invertebrata; for example, the infant is prompted to seize
the nipple, not from any knowledge gained by experi-
ence, that by so doing it will relieve the feeling of hun-
ger, but in consequence of the impulse arising out of
impressions made upon the afferent nerves. The super-
addition of more elevated endowments in the vertebrated
series is coincident with the addition of a peculiar gan-
glionic centre, the *cerebrum*, to the sensori-motor appa-
ratus.

The superiority of the mind of man over the lower
animals consists not only in the greater variety and
wider range of his faculties; but also in that dominant
power of the will which enables him to utilize them
with the highest effect. When the thoughts and feel-
ings of man are the mere result of the action of ex-
ternal impressions upon a respondent organism, he may
be considered irresponsible for his actions, his character
having been formed *for* him, and not *by* him. But,
whenever he can exert a volitional power of directing
his thoughts and controlling his feelings, he is morally
and intellectually responsible for his acts. Some per-
sons, however, in consequence of the weakness of their
will, are so much accustomed to act directly upon the
prompting of any transient impulse, that they can scarcely
be said to be voluntary agents; and others allow certain
dominant ideas or habitual feelings to gain such a mas-
tery over them as to usurp for the time the power of the
will.

The fundamental part of the cerebro-spinal system
is the *cranio-spinal axis*, which consists of the spinal
cord, medulla oblongata, and the sensory ganglia, the

latter consisting of those ganglia lying along the base of the skull in man, and in which the nerves of the *special senses* have their origin, viz., the corpora striata and quadrigemina, and thalami optici, &c. This cranio-spinal axis, which represents the whole nervous system of the invertebrata (except the rudimentary sympathetic they possess), exists without any super-addition in the lowest known vertebrated animal, as in the case of the little fish called the amphioxus. This condition may even be found in the human species, as in the case of acephalous infants, in which neither the cerebrum nor cerebellum is present; such have existed for several days, breathing, sucking, crying, and performing various other movements.

In man, however, and in all the higher vertebrata, large ganglia, which form the principal mass of the encephalon, are found superimposed upon and embracing the sensory ganglia. These are the *cerebrum* and *cerebellum;* the former is the seat of the will, and presides over, controls, and regulates all the actions and movements of the body, except the organic functions and automatic actions; the latter is concerned in the regulation and co-ordination of the actions of the spinal cord. The action of the cerebro-spinal system may be elucidated by the following diagram—Carpenter.

```
                              ┌───────── + The Will ─────────────┐
Intellectual operations—│                                        │
  +        +             ┤                                        │
│      Emotions.         ┤ ──────── + Cerebrum.                   │
│        +               │   Centre of emotional and ideo-motor reflexion. │
└──────── Ideas.         ┘                                        │
         +                                                        +
      Sensations ──────── + Sensory  ganglia ──────── + ┐
         +                Centre of sensori-motor reflexion.      ├ Motor Impulse.
      Impressions ─────── + Spinal Cord ──────── + ┘
                          Centre of excito-motor reflexion.
```
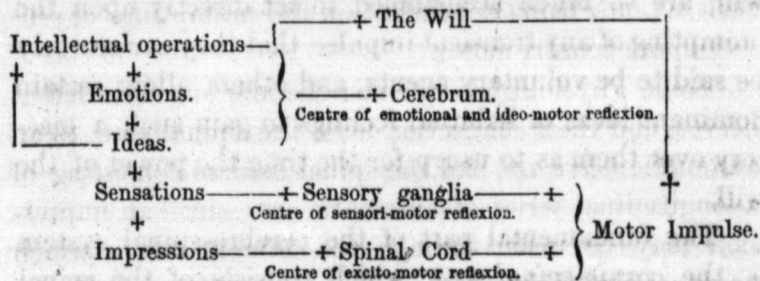
In consequence of the peculiar arrangement of the nervous apparatus, excitor impressions travel in the up-

ward direction; so in the left-hand corner of the diagram
the *impressions* are represented as passing upward. If
they meet with no interruption, they travel upwards
through the spinal cord until they reach the sensorium
or sensory ganglia, where they make an impression on
the consciousness of the individual, giving rise to *sensa-
tions*. These, passing from the sensory ganglia to the
cerebrum, form *ideas*. If these ideas are associated with
feelings of pain or pleasure, they give rise to *emotions;*
and either as simple or emotional ideas, they become
the subject of *intellectual operations* whose final issue
culminates in an act of the *will*, which may be exerted
in producing or checking a muscular movement, or in
controlling or directing the current of thought.

If this ordinary upward course be interrupted, or if
the action be automatic, the impressions will exert their
power in the transverse direction, and a *reflex action*
will be the result; for example, if the interruption be
produced by division or injury of the spinal cord, below
the sensory ganglia, reflex movements being produced
without sensation will be purely excito-motor. So, again,
if the connection between the sensory ganglia and the
cerebrum be severed, or if the function of the cerebrum
be in abeyance, they may react on the motor apparatus
by the reflex power of the sensory ganglia themselves;
such actions, being dependent on the promptings of sen-
sation, are sensori-motor.

Some Physiologists consider the afferent and efferent
nerves, and their connection with the spinal cord, as an
automatic *nerve arc*, and the spinal cord as consisting of
a longitudinal series of automatic arcs, since an impres-
sion may be made through the afferent nerve which
produces action of the muscles supplied by the efferent
nerve, the whole force being either consumed without

leaving behind any impression on the nervous centre, or a part of it being left in the vesicular matter of the nervous centre. The nerve arc may be connected to a ganglion by means of a band or commissure, through which a portion of the nervous influence passes to be stored up. This is called a *registering ganglion*, as, for example, the corpus striatum, thalamus opticus, &c., and these, in their turn, are connected to the cerebrum; this connection constituting what is called the *influential arc*. The registering ganglia are regarded as the sensorium, and correspond with the sensory ganglia. Their function appears to be to receive and retain impressions of ideas, events or occurrences, the time, place, and order in which they occurred, and other circumstances which are usually ascribed to the faculty of memory.

STRUCTURE OF THE NERVOUS SYSTEM.—The organs of the nervous system are composed essentially of two different substances, *fibrous nervous matter* and *vesicular nervous matter*. The former, on account of its color, is often called the *white* or medullary substance; the latter, the *gray* or cineritious substance.

FIBROUS NERVOUS MATTER.—This consists of two different kinds of nerve fibres, the *tubular* and the *gelatinous*. They are intermingled in most nerves; the tubular fibres being more numerous in the cerebro-spinal system; the gelatinous predominating in the sympathetic.

The *tubular fibres* appear to consist of tubules of simple homogeneous membrane, similar to the sarcolemma of striated muscular tissue, within which is contained the proper nerve substance, consisting of two different materials. The central part is a transparent material called the *axis cylinder;* the outer portion which surrounds the axis cylinder is usually opaque, and dimly

granular, and is called the *white substance of Schwann*. It is the predominance of this substance which gives the cerebro-spinal nerves their white appearance. The axis cylinder is probably the essential element of the nerve tube; the white substance of Schwann, and the tubular membrane or sheath, merely affording mechanical protection, and serving to isolate it from the neighboring fibres. In the recent state the nerve tubes are cylindrical, and contain a transparent and apparently homogeneous material; but after death they present a dark double contour, the outer line being formed by the tubular membrane or sheath, the inner by the white substance of Schwann. At the same time the white substance and axis cylinder, which now appear granular, collect into little masses which distend portions of the tubular membrane, while the intermediate spaces collapse, giving the fibres a varicose or beaded appearance. The contents of the nerve tubes are very soft, and readily pass from one part of the canal to another, or escape from the ends of the tube on pressure. The nerves vary in size from $\frac{1}{2000}$ to $\frac{1}{3000}$ of an inch in diameter in the trunk and branches of nerves, but are smaller in the gray matter of the brain and spinal cord, in which they are seldom more than $\frac{1}{10000}$ to $\frac{1}{14000}$ of an inch.

The *gelatinous fibres* constitute the principal part of the trunk and branches of the sympathetic nerves, and are mingled in various proportions in the cerebro-spinal nerves. They differ from the preceding chiefly in their fineness, being only half or one-third as large ($\frac{1}{4000}$ to $\frac{1}{8000}$ of an inch); in the absence of the double contour; in their apparently uniform structure, and yellowish gray color. These fibres appear to be formed exclusively of the substance which corresponds with the axis cylinder of the tubular nerves, and differ from them in not possessing the white substance of Schwann.

VESICULAR NERVOUS MATTER.—This, as its name implies, is composed of vesicles or corpuscles called *nerve cells* or *ganglion corpuscles*, containing nuclei and nucleoli. They are found only in the brain, spinal cord, and the various ganglia mingled with nerve fibres, being imbedded in a finely granular substance, and giving to these structures a peculiar reddish gray color. They present different shapes, some being oval or spheroidal, others caudate or stellate; some of the processes being continuous with a nerve fibre, and they vary in size from $\frac{1}{300}$ to $\frac{1}{4000}$ of an inch in diameter. Each cell contains a vesicular nucleus and nucleolus, the latter being generally clear and bright; and the contents are finely granular, and of a reddish gray color.

GANGLIA.—These may be regarded as separate and independent nervous centres, of smaller size than the brain, and less complex. They are found on the posterior roots of the spinal nerves; on the posterior root of the fifth nerve; on the facial, olfactory, glosso-pharyngeal and pneumogastric nerves; along the base of the brain, as the corpora striata, corpora quadrigemina and thalami optici; on each side of the vertebral column forming the trunk of the sympathetic, and on some of its branches of distribution. In *structure* they are similar to other nervous centres, being composed of a collection of vesicular nervous matter, and tubular and gelatinous nerve fibres. They are of a reddish gray color.

CHEMICAL COMPOSITION OF THE NERVE TISSUES.—
(LASSAIGNE.)

CONSTITUENTS	GRAY.	WHITE.
Water	85.2	73.0
Albuminous matter	7.5	9.9
Colorless fat	1.0	13.9
Red "	3.7	0.9
Osmazone and lactates	1.4	1.0
Phosphates	1.2	1.3
	100.0	100.0

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Nervous matter is a soft, unctuous substance, easily lacerated, and contains a large proportion of water. It would appear to consist of albumen dissolved in water, combined with fatty matters and salts. From the fatty matters may be obtained carbonic acid, cholesterin, oleo-phosphoric acid, traces of oleine, margarine, and fatty acids. The spinal cord is said to contain a larger pro-portion of fat than the brain.

DISTRIBUTION OF NERVE FIBRES.—Nerve fibres consist of round or flattened cords, communicating on the one hand with the nervous centres, and on the other, distributed to the various textures of the body, forming the medium of communication between the two. They are divided into *two* great classes, the *cere-bro-spinal*, or nerves of animal life, distributed to the organs of the senses, the skin, and the muscles; and the *sympathetic* or nerves of organic life, distributed chiefly to the viscera and blood-vessels.

The *cerebro-spinal nerves* consist of a number of pri-mitive nerve fibres, enclosed in a simple membranous sheath, the neurilemma. These are called funiculi, and if the nerve is of small size it may consist of only one funiculus; but if large, there may be several connected together by a common sheath formed of areolar tissue. Every nerve fibre pursues an uninterrupted course from its origin at a nervous centre, to its destination, whether this be the periphery of the body, in another nervous centre, or the same from which it issued. They anasto-mose or communicate with each other in their course, sometimes joining at acute angles with others proceed-ing in the same direction; but they never coalesce, or unite with the substance of any other fibre; for although they cross and mingle with each other, yet each separate nerve fibre retains its identity throughout. The nerves,

in certain parts of their course, form *plexuses* in which they anastomose with each other, as in the cervical, brachial, lumbar, and sacral plexuses. In the formation of a plexus, the component nerves divide, then unite, and again sub-divide, and in this way the fasciculi become intricately interlaced. The object of such interchange of fibres is probably to give each nerve a wider connection with the spinal cord, so that the parts supplied may have wider relations with the nervous centres, and also that groups of muscles may be associated for combined action.

ORIGIN AND TERMINATION OF NERVES.—The point of connection of a nerve with the brain, spinal cord, or ganglia, is called, for convenience of description, its *origin, root,* or *central termination;* the point of distribution its *peripheral termination,* or *periphery.*

With reference to their *origin,* some of them may originate in *nerve corpuscles,* others probably form *simple loops.* As the nerve fibre approaches the nerve corpuscle, the white substance of Schwann gradually disappears, the tubular membrane or sheath dilates, so as to embrace the nerve corpuscle, which occupies the dilatation; it then contracts, and either ends in the corpuscle, or is continued onwards, the sheath becoming filled again with the proper nerve substance. In some instances more fibres have been counted leaving than entering a ganglion, from which it may be inferred that some of them arise from the corpuscles. It has not yet been determined whether this relation of nerve fibres to nerve corpuscles is common to all kinds of nerve fibres. It does not appear, however, to belong exclusively to either the cerebro-spinal or sympathetic nerves. Some are of opinion that sensitive fibres alone are brought into this intimate relation with nerve corpuscles.

The *peripheral termination* is also exceedingly difficult to determine, but examples of *five* different modes have been observed:

1st. In *loops*. In this so-called mode of termination, each fibre, after issuing from a branch in a terminal plexus, runs over or through the substance of the tissue; it then turns back and joins the same, or an adjacent branch, and pursues its way back to the nervous centre. This mode has been found in the internal ear, in the papillæ of the tongue, in the skin, in the tooth pulp, and in striated muscular tissue.

2nd. By *branching*. Each ultimate nerve fibre appears to divide into several branches, which spread out in the substance of the tissue, as is seen in the retina, and in the muscular tissue of the frog, and lower vertebrata.

3rd. In *plexuses*. This mode may be seen in certain serous membranes, as the peritoneum, arachnoid, &c.

4th. By *free ends*. The Pacinian corpuscles afford a good example of this variety. They are small, oval bodies, situated on some of the cerebro-spinal and sympathetic nerves, especially the cutaneous nerves of the hands and feet. They are named after their discoverer, Pacini. Each corpuscle is attached to the nerve on which it is situated by a narrow pedicle, and is formed of concentric layers of fine membrane, with intervening spaces filled with fluid. A single nerve fibre passes through the pedicle, and after traversing the several layers of membrane, it terminates in the central cavity in a bulbous enlargement, or a bifurcation.

5th. In *nerve corpuscles*. This mode of termination may be seen in the retina, and in the lamina spiralis of the internal ear.

Some nerve fibres appear to have no peripheral termi-

nation.   It has been shown by Gerber that nerve fibres occasionally form loops by their junction with a neighboring fibre in the same fasciculus, and return to the nervous centre without having any peripheral termination.   He considers these to be sentient nerves, for the supply of the nerve itself, the *nervi nervorum,* upon which the sensibility of the nerve depends.   This is somewhat similar to those nerve fibres met with at the posterior part of the optic commissure, where a set of fibres passes from one optic tract across the commissure to the tract on the opposite side, without having any connection with the optic nerves—the inter-cerebral fibres.   On the other hand, some nerve fibres appear to have no central connection with the cerebro-spinal centre, as in those forming the anterior fibres of the optic commissure—the inter-retinal fibres.   These commence in the retina on one side, pass along the optic nerve, and across the commissure to the retina of the opposite side.

The *sympathetic nerves* consist of tubular and gelatinous fibres, intermingled in various proportions in different nerves, and are enclosed in a sheath of areolar tissue. The mode of distribution of these nerves is essentially the same as that of the cerebro-spinal.   The most striking peculiarity is the frequent formation of ganglia in the course of the trunks, and their branches.   They are chiefly distributed to the head and trunk, being very limited in their connection with the extremities.

FUNCTION OF NERVE FIBRES.—The function of a nerve may be determined by comparing its *anatomy in man* with that of the lower animals; by *experiments* on recently-killed or living animals, and *by clinical observation.*

The office of the nerves is to convey or conduct nervous impressions. This function is of a two-fold

kind—*first*, they serve to convey to the nervous centres the impressions made upon their peripheral extremities, or on parts of their course; and, *secondly*, they serve to transmit impressions from the brain, and other nervous centres, to the parts to which they are distributed. These impressions are of two kinds, viz., those that excite muscular contraction, and those which influence the processes of secretion, growth, &c.

Those nerves that convey impressions from the periphery to the centre, are called *sensitive, centripetal* or *afferent* nerves, or *nerves of sensation,* and those which transmit impulses to the muscles, are called *motor, centrifugal* or *efferent* nerves, or *nerves of motion.* The nervous force (vis nervosa) by which secretion, nutrition, &c., are influenced, seems to be conveyed along both sensitive and motor sympathetic nerves. This peculiarity cannot be accounted for from any special variety of structure which the nerves possess, or the tissues to which they are distributed.

Nerve fibres require to be stimulated, in order to manifest their peculiar endowments, since they do not possess the power of generating force in themselves, or of originating impulses to action. The property of conducting impressions is called *excitability;* but this is never manifested until some stimulus is applied. The stimuli by which the action of nerves is ordinarily provoked, are of *two* kinds, *mental* and *physical;* the former relates to the will, the latter to the influence of external objects, and chemical, mechanical and electric actions or irritations. These stimuli, when applied to parts endowed with sensation, or to sensitive nerves, produce sensations, and when applied to the nerves of muscles produce contractions. Nerves, though divided, when irritated or stimulated have, by virtue of their excita-

bility, the power of exciting contractions in the muscles to which they are distributed; but when the continuity of the nervous matter, with the tubular fibres, is bruised, or seriously injured, the property of propagating nervous force is destroyed. Nervous action is also excited by temperature; for example, any very hot substance applied to the body produces muscular contraction, and a sensation of pain is transmitted to the nervous centre; the application of a very cold substance has a somewhat similar effect. Chemical stimuli excite the action of both sensitive and motor nerves, when their effect is not so strong as to destroy the structure of the nerve to which they are applied. A similar manifestation of nervous power is produced by electricity. Nerve force travels along the fibres with immense rapidity; its velocity will probably never be ascertained.

LAWS OF ACTION IN NERVE FIBRES.—All nerve fibres are mere conductors of impressions; that is, an impression made on any fibre is transmitted along it without interruption, and without being imparted to any of the fibres lying near it. This is probably due to the fact that the contents of each fibre are isolated from those of adjacent fibres by the membrane or sheath in which it is enclosed. It is also supposed that the white substance of Schwann acts as an insulator. No nerve fibre can convey more than one kind of impression; for example, the motor nerve conveys only motor impulse; the sensitive nerve transmits only sensation when propagated to the brain, and the nerves of special sense, as the optic and auditory, convey only sensations of light and sound. *Nerves of sensation* are able to convey impressions only from the parts to which they are distributed, towards the nervous centre with which they communicate; for example, when a sensitive nerve is divided, and irrita-

tion is applied to that portion still connected with the
nervous centre, sensation is perceived, or a reflex action
ensues; but when the distal portion is irritated no effect
is produced. When the trunk of a nerve is irritated,
the sensation is felt in all the parts which receive
branches from it; for example, if the ulnar nerve be
compressed behind the internal condyle of the humerus,
a peculiar tingling sensation is felt in the little finger,
and in the ulnar half of the ring finger. Even when
part of a limb has been amputated, any pressure or irri-
tation to the remaining portions of the nerves which
ramified in it, gives rise to sensations which the mind
refers to the lost part, as well as to the stump, and ting-
lings and pains are complained of in the lost finger, toe,
hand or foot, as the case may be. Again, when the
relative position of the peripheral extremities of sensi-
tive nerves is changed artificially, as in the restoration
of the nose from the integument of the forehead, the
new nose thus formed, while connected by its isthmus,
when touched, the sensation produced is referred to the
forehead. This peculiarity may be exemplified by the
following experiment:—Cross the middle finger of the
hand behind the index finger so that the extremity is
on the radial side of the latter, then roll the two fin-
gers over a pea or marble, and a sensation will be pro-
duced which leads the mind to suppose the existence of
two distinct bodies. This is owing to the impression
being made at the same time on the sides of the fingers
most removed from each other in the natural position.
Generally, however, the mind discerns the exact part of
a nerve fibre that is irritated, and even when, as is the
case in the retina, two or more impressions are made at
the same instant on different parts of the same fibre, the
mind can discriminate and perceive each, and compare
the one with the other.

Several of the *laws of action* in *motor nerves* are similar to the foregoing. For example, motor influence is transmitted only in the direction of the fibres going to the muscles, and irritation of a motor nerve excites contraction in all the muscles supplied by the branches given off below the point of irritation; but those supplied by branches given off above this point are never directly affected. Again, since motor nerves are isolated as completely as sensitive, the irritation of a part of the fibres of a motor nerve does not affect the motor power of the whole trunk, but only that of the portion to which the stimulus is applied.

DEVELOPMENT OF NERVE TISSUE.—*Nerve fibres* appear to be formed in the same manner as muscles. The primitive nerve cells arrange themselves in a linear manner, the contiguous walls break down, and a tube (or secondary nervous cell) is formed, in which are contained the nuclei and granular contents. At this period, as in muscle, a deposit of a whitish, fatty substance, formed from the granular matter, takes place on the inner surface of the tube. This is the *white substance of Schwann*. The nuclei become gradually absorbed, and the remaining cavity of the tube is filled, constituting the *axis cylinder*, or "band of Remak."

In the *vesicular nervous matter* the cells remain in their primitive state, the only change being that they increase in size, and develop in their interior some pigmentary granules.

In the *process of regeneration*, after incision or injury, the extremities of the nerves are united at first by fibrous tissue, which after a time is replaced by nerve tissue, if the cut extremities are not too far removed. Perfect restoration of the action of the nerve, however, does not generally take place, owing probably to the want of exact

coaptation between the cerebral and peripheral portions of the same fasciculi; for example, the cerebral portion of a motor filament might unite with the peripheral portion of a sensitive one, and in this way the action of each would be neutralized.

VASCULAR SUPPLY.—The blood-vessels supplying a nerve terminate in a minute capillary plexus, disposed similarly to those of muscles, running parallel to the nerve fibres. They are connected together by short transverse branches, forming narrow oblong meshes.

FUNCTION OF THE NERVOUS CENTRES.—The nervous centres embrace all those parts of the nervous system which contain nerve corpuscles, as the brain, spinal cord, and the ganglia of the cerebro-spinal and sympathetic system. Their function is that of variously disposing and transferring the impressions received through their several sensitive nerves. Nerve fibres, as already stated, are simple *conductors* of nervous influence. Nervous centres are not only *conductors*, but also *communicators* of nervous impressions. The brain *conducts, communicates*, and *perceives* or takes cognizance of impressions.

CONDUCTION.—When an impression is produced on the periphery of a nerve, as, *e. g.*, in the mucous membrane of the intestines by the presence of a portion of food, it is *conducted* to the adjacent ganglia of the sympathetic, from which a motor impulse returns to the intestines and produces a movement of the muscular coat. If, however, any irritant substance, as a drastic cathartic, be mixed with the food, a stronger impression is produced, and this is conducted through the nearest ganglia to others more remote, and from all these motor impulses proceed, which excite a more forcible and widely extended action of the small intestine; or the impression may be conducted through the ganglia of the

spinal cord, from which motor impulses may proceed to the abdominal and other muscles, producing cramp. Besides, the same morbid impression may be conducted through the spinal cord to the cerebrum, where the mind can perceive and take cognizance of it.

COMMUNICATION.—Impressions made on the nervous centres may be *communicated* from the fibres that brought them to others, and in this communication they may be either *transferred, diffused,* or *reflected.* The *transference* of impressions may be seen in disease of the hip joint. The impression made by the disease on the nerves of the hip is conveyed to the spinal cord; it is thence transferred to the central termination of the nerve fibres of the knee joint; through these the impression is conducted to the brain, and the mind, referring the sensation to the part from which it is accustomed, through these fibres, to receive impressions, feels as if the pain were in the knee. In the same way, when the sun's rays fall strongly on the retina, a tickling may be felt in the nose, causing sneezing; or irritation in any part of the respiratory organs gives rise to a sensation of tickling in the glottis, and produces coughing. The *diffusion* of impressions is exemplified when an impression received at a nervous centre is diffused to many other fibres in the same centre, the sensation extending far beyond the part from which the primary impression proceeded, as is seen in toothache, in which the adjoining teeth and surrounding parts are similarly affected. The pain caused by the presence of a calculus in the ureter or bladder, is diffused far and wide.

REFLECTION OR REFLEX ACTION.—The reflection of impressions exhibits an important function common to all nervous centres, and is the source of all reflex movements. The preceding examples are all instances of

reflection, or *reflex action*, for the manifestation of which three conditions are necessary. *First*, sensitive nerve fibres, to convey an impression. *Secondly*, a nervous centre, to which the impression may be conveyed, and in which it may be reflected. *Thirdly*, motor nerve fibres, upon which this impression may be conducted to the contracting tissue. If any of these conditions be absent, a proper reflex action cannot take place. They are all involuntary, and in health they have a distinct purpose to subserve in the animal economy, as in the movements of the intestines, the respiratory organs, contraction of the pupils, closure of the glottis, &c.; but in disease many of them are irregular and purposeless, as in chorea, convulsions, &c.

NERVE FORCE *(vis nervosa)*.—The special endowment by which nerves act and manifest their vitality is a peculiar one inherent in the structure and constitution of the nervous substance. It manifests itself in its effects on the muscles, in sensation, secretion, excretion, nutrition, &c. Nervous force, though not identical, presents many points of resemblance to voltaic electricity. For the production of the latter, the ordinary requisites are two dissimilar metals, as zinc and platinum, or copper and an interposed compound fluid, as dilute sulphuric acid. When these metals are placed in contact with each other, chemical action commences, and a current sets in a definite direction, a state of *polarity* or *electrical tension* being produced. The production of nervous force, or nervous polarity, may have as analogues two kinds of nervous matter, vesicular and fibrous, and the presence of a fluid.

From the structure and peculiarity of the nervous centres, there is much to justify the opinion that each nerve vesicle, and fibre connected with it, together with

the blood-vessels and fluid surrounding them, is a distinct apparatus for the development of *nervous polarity*. The whole nervous system is therefore in a constant state of nervous polarity, and is prepared at any moment to receive, conduct, or communicate impressions, or convey motor impulses. A slight mechanical or chemical stimulus to a nerve, is capable of producing in it a state of polarity, and rendering it capable of conducting impressions or motor impulse; *e.g.*, pain is excited by touching a sensitive nerve, and contractions may be produced by irritating the motor nerve of an amputated limb.

THE SPINAL CORD.—The spinal cord is a cylindrical column of nerve substance, connected above with the brain, through the medulla oblongata, and terminating below—about opposite the first or second lumbar vertebra—in a slender filament of grey substance, the *filum terminale*, which lies among the leash of nerves forming the *cauda equina*. It presents two enlargements, one in the cervical region, extending from the third cervical to the first dorsal vertebra, and the other in the lumbar, opposite the last dorsal or first lumbar. The spinal cord consists of two symmetrical halves, united in the middle line by a commissure. They are separated in front and behind by a vertical *fissure*, the *posterior fissure* being deeper, but narrower than the *anterior*. On each side of the anterior fissure, a linear series of foramina may be seen, from which emerge the anterior roots of the spinal nerves; this is the so-called *anterior lateral fissure* of the cord. On each side, near the posterior part of the cord, and corresponding with the posterior roots of the spinal nerves, may be seen a delicate fissure, the *posterior lateral fissure*. On each side, and near the posterior fissure, is a slight longitudinal furrow—the *posterior medio-lateral fissure*. These fissures divide each

half of the cord into four *columns, anterior, lateral, poste-rior* and *posterior median* columns. The *anterior column* is situated between the anterior median and the ante-rior lateral fissures. It is continuous with the anterior pyramid of the medulla oblongata, in which decussation of the anterior columns takes place. The *lateral column* is situated between the anterior lateral and posterior lateral fissures, and is continuous above with the lateral tract of the medulla. The *posterior column* is situated between the posterior lateral and the posterior medio-lateral fissures, and is continuous with the restiform body of the medulla. The *posterior median column* is a narrow segment situated between the posterior medio-lateral and the posterior median fissures, and is continu-ous above with the posterior pyramid of the medulla oblongata.

STRUCTURE OF THE CORD.—The cord consists of fibrous and vesicular, or white and gray nervous sub-stance; the former is more extensive, and situated exter-nally; the latter occupies the centre, and consists of two crescentic masses, connected together by a transverse band, the gray commissure. Both in front of and behind the gray commissure is a transverse band of white sub-stance, the anterior and posterior white commissures; these connect the white substance of each lateral half of the cord, and form the floor of the anterior and posterior median fissures respectively. Each crescentic mass of gray matter presents an anterior and a posterior horn; the former is short and thick, and does not quite reach the anterior lateral fissure; the latter is long and slen-der, and extends to the posterior lateral fissure. The anterior roots of the spinal nerves are connected with the anterior horn, and the posterior roots with the posterior horn. The white substance of the cord consists of trans-

verse, oblique, and longitudinal nerve fibres, blood-vessels and areolar tissue; and the gray substance consists of smaller nerve fibres, nerve cells, blood-vessels, and areolar tissue.

SPINAL NERVES.—The spinal nerves consist of thirty-one pairs, issuing from the sides of the whole length of the cord. Each nerve arises by two roots, an *anterior* or motor, and a *posterior* or sensitive. The posterior root is larger than the anterior root, (except the first), and has a ganglion developed on it. Immediately beyond this ganglion the two roots coalesce, and the trunk thus formed passes through the intervertebral foramen, after which it again divides into two branches, an anterior, which supplies the anterior surface of the body and the extremities, and a posterior, which supplies the posterior part of the body, each branch containing fibres from both roots. The anterior roots arise from the antero-lateral columns, and are also connected with the anterior horn of the gray substance; and the posterior roots arise from the postero-lateral columns and the posterior horns of the gray substance; the former consist exclusively of motor fibres, and the latter exclusively of sensitive fibres.

FUNCTION OF THE SPINAL CORD.—The spinal cord transmits impressions from the periphery to the brain, and also enables the latter to bring into action the motor nerves. Division of, or injury to the spinal cord, causes an interruption of voluntary motion and sensation in those parts supplied by nerves below the part affected, while the functions of the parts above remain unimpaired. But though the influence of the brain in receiving sensation, and exciting voluntary motion is cut off or interrupted, the portions of the cord below the affected part still possess an automatic power, and hence

the cord may be regarded as a nervous centre; for example, in cases of paralysis, muscular action may be excited by tickling the palms of the hands, or soles of the feet with a feather. It has been shown, by experiment, that irritation to the anterior columns of the cord is followed by convulsive movements of all the parts supplied with motor nerves below the irritated part, but no signs of pain are manifested; while irritation of the posterior columns appears to cause excruciating pain, without producing any muscular movement besides such as may be produced by the will or reflection. Again, when the spinal cord is completely severed, irritation of the posterior columns of the severed part produces no effect; but irritation of the anterior columns is followed by violent movements. On the other hand, irritation of the posterior columns of the portion of the cord connected with the brain causes acute pain and reflex movements; while irritation of the anterior columns of the same produces no effect. Again, when both anterior columns alone are divided, the power of voluntary motion is lost in parts below, the sensibility remaining perfect; and when both posterior columns are divided, sensation is lost in the parts below, the power of motion remaining unimpaired. From this it would appear that the anterior columns are motor, and the posterior sensitive; nevertheless, the results of injuries, and diseases of different parts of the cord, are not always in accordance with it, but in some instances directly contrary to it; for example, cases have been seen in which complete loss of motion occurred without any impairment of sensation, as the result of lesion of the posterior columns of the cord, the anterior being wholly intact.

The spinal cord has a *crossed action* for both motion and sensation; for example, in cerebral apoplexy the

paralysis and loss of sensation is always on the side opposite to that on which the effusion has taken place. The decussation of the fibres of motion occurs between the anterior pyramids of the medulla oblongata, and may be seen with the naked eye. The discovery of the crossed action for sensation is due to Brown-Séquard. His experiments show that a decussation of sensitive impressions takes place between the posterior columns throughout the whole extent of the cord. The sensitive impressions reaching the cord, either ascend or descend for a short distance, the majority probably descend, and ultimately pass across to the opposite side of the spinal cord to reach the brain, so that if the posterior column of one side be impaired, sensation is lost on the opposite side of the body.

The spinal cord, as an aggregate of many nervous centres, has the power of communicating impressions from fibre to fibre by *transference, diffusion* and *reflection*. This has been already referred to. (See Function of Nervous Centres.)

The *reflex function* of the spinal cord is essentially similar to that of all the other nervous centres, and may or may not be under the control of the will. In health the will can, in a great degree, control and prevent the development of reflex actions in the extremities. If one of the legs be paralyzed, as in hemiplegia from disease of the brain, and a stimulus be applied to the sole of the foot in the paralyzed limb, reflex actions are readily produced; but on applying the same stimulus to the sound limb, no such movements occur, the patient being able to resist the tendency to action which it produces. In cases of paraplegia from disease of the spinal cord, even where the loss of motion and sensation is complete, patients are sometimes tormented with involuntary

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movements of the lower extremities at night, which not only prevent sleep, but also occasion pain and distress. It is no doubt caused by irritation at the seat of the lesion.

Some reflex movements are partly voluntary, and partly involuntary; for example, the respiratory movements may be performed while the mind is fully occupied, or during sleep; yet, in an emergency, the mind can direct and strengthen them, and adapt them to the several acts of speech, effort, &c. Again, other reflex actions are entirely involuntary, as for example, the contraction of the pupil, the movements of the intestines (except defecation), the action of the uterus in parturition, &c. When the limb is pinched or pricked, it is involuntarily withdrawn from the instrument of injury, and the eye is involuntarily closed when a blow on the face is threatened.

The phenomena of spinal reflex action in man are more marked in disease than in health; e. g., in tetanus a slight touch on the skin, or a breath of air, is sufficient to throw the whole body into convulsions; a similar state is induced by the introduction of strychnine or opium. In these instances, the spinal cord is in a state of polar excitement, and is kept so by the constant irritation propagated to it by the wounded part, on the one hand, or the poisonous substance circulating in the blood, on the other, there being no inflammatory or congested condition either of the cord or its membranes.

The spinal cord, with its encephalic prolongation, may be said to supply, by its reflex power, the conditions requisite for the maintenance of the various muscular movements which are essential to the continuance of the organic processes; and, as Marshall Hall has pointed out, it especially governs the various orifices of

ingress and egress. Thus, the act of deglutition is entirely dependent on the spinal axis (medulla), and the nerves proceeding from it. The action of the cardiac and pyloric orifices of the stomach is wholly regulated without the consent of the will. The movements of the intestines are influenced by the spinal cord through the sympathetic system. The external sphincter which surrounds the orifice of egress, is also under its influence, although partly subject to the control of the will. The reflex action of the spinal cord is also exhibited in the expulsion of the generative products, as the semen, in defecation, micturition, and in parturition in its second stage.

The spinal cord is constantly in activity; in all periods and phases of life, the movements which are essential to its continued maintenance are kept up without sensible effort. "The spinal system never sleeps;" it is the brain alone which is torpid during sleep, and whose functions are affected by this torpidity.

ENCEPHALON.

The encephalon is situated in the cranial cavity, and consists of the *medulla oblongata, pons varolii, cerebellum* and *cerebrum.*

MEDULLA OBLONGATA.—The medulla oblongata is the cephalic prolongation of the spinal cord, and connects it with the brain. It is larger than the spinal cord, and is divided into segments, which are continuous with the columns of the spinal cord below. It is separated into two lateral halves by fissures, which correspond with the anterior and posterior fissures of the cord, and each lateral half is again subdivided by minor grooves into four columns, the *anterior pyramid, lateral tract and olivary body, restiform body* and *posterior pyra-*

mid. These are continuous with the anterior, lateral, posterior and posterior median columns of the spinal cord respectively.

STRUCTURE.—The *anterior pyramid* is composed entirely of white fibres derived from the anterior column of the cord of its own side, and from the lateral column of the opposite half of the cord, and is continued upwards into the cerebrum and cerebellum; the decussation between the anterior pyramids may be distinctly seen with the naked eye. Some of the fibres enter the pons varolii in their passage upwards to the cerebrum.

The *lateral tract* is continuous with the lateral column of the cord. Its fibres pass in three different directions; the external join the restiform body, and pass to the cerebellum; the internal pass forwards, pushing aside the fibres of the anterior column, and form part of the opposite anterior pyramid, and the middle fibres ascend to the cerebrum, forming the *fasciculi teretes* in the floor of the fourth ventricle. The *olivary body* presents, on a transverse section, a whitish substance externally, and a grayish-colored body in the interior—the *corpus denta-tum*—which presents a zig-zag outline, and contains some white substance in the interior, which communicates with that on the external surface by means of an aperture in its posterior part.

The *restiform body* is continuous below with the posterior column of the cord, and receives some fibres from the lateral and anterior columns; superiorly, it *divides* into two fasciculi; the external one enters the cerebellum, the internal one joins the posterior pyramid, and blends with the fasciculi teretes as it passes up to the cerebrum.

The *posterior pyramid* joins the restiform body, and passes with it up to the cerebrum.

In the lower part of the medulla the gray matter is arranged as in the cord; but in the upper part it becomes more abundant, and is disposed apparently with less regularity.

FUNCTION OF THE MEDULLA OBLONGATA.—The general function of the medulla oblongata is similar to that of the spinal cord. It may be regarded as a conductor of impressions, in which respect it has a wider extent of function than any other part of the nervous system. In consequence of the decussation of the anterior pyramids, motor impressions proceeding from the brain pass across to the opposite side of the spinal cord; for example, in injury to one side of the head, producing paralysis, the loss of motion is always on the side opposite to that on which the injury was received.

Besides the function of conduction, the medulla oblongata, acting as a nervous centre, presides over the functions of respiration and deglutition. The brain may be wholly removed above, and yet life may continue, and the respiratory function be carried on. The same is the case when the spinal cord below the phrenic nerve is removed; and even when both the brain and spinal cord are removed the function of respiration maybe continued; but whenever the medulla is wounded the function is instantly arrested, and the animal dies as if asphyxiated. The medulla ablongata may continue to discharge its functions as a nervous centre after the part which is only a conductor has ceased to act; thus, in coma from apoplexy or compression, and in anesthesia from ether or chloroform, patients continue to breathe, although they are wholly insensible.

The medulla oblongata also exhibits the property of reflex action, and is peculiar from having a very wide range of connection. The principal centripetal nerves

engaged in respiration are the pneumogastric; but that these are not the only ones may be shown by their division when respiration becomes slower, but is not arrested. The wide range of connection which belongs to the medulla is further shown by the fact that impressions on the surface of the body may induce respiratory movements, as, *e. g.*, dashing cold water on the face or body is instantly followed by a deep inspiration. From the medulla also arise the movements required in the act of deglutition. This may be shown by the persistence of the power of deglutition after removal of the cerebrum and cerebellum, and by its complete arrest when the medulla is injured. The reflex power of the medulla in deglutition is much simpler and more restricted than in respiration.

PONS VAROLII.—The pons varolii is the bond of union between the cerebrum, cerebellum, and medulla oblongata. In structure it consists of *longitudinal* and *transverse* fibres, intermixed with gray matter. The *longitudinal* fibres are continued up through the pons from the anterior pyramids, olivary bodies, lateral and posterior columns of the cord. The *transverse* fibres connect the two hemispheres of the cerebellum, forming the transverse commissure, and are divided into a *superficial* and *deep* layer; the former passes across the surface of the pons, and the latter, situated deeply, decussates with the longitudinal fibres.

FUNCTION OF THE PONS.—Its function is two-fold; it acts as a conductor, and also as a nerve centre. As a conductor it is the channel through which impressions are conveyed from the spinal cord to the cerebrum and cerebellum, and also between the two hemispheres of the cerebellum. As a nervous centre, it may be regarded as the connecting link between the different portions of

the encephalon, for when the cerebrum and cerebellum are removed the mind may still have sensation of impressions, or exercise the will. At all events, it is a nervous centre for higher and more definite reflex acts than the medulla or any part of the spinal cord.

CEREBELLUM.—The cerebellum consists of two lateral hemispheres connected together by a transverse commissure or band. It is situated in the posterior fossa of the cranium, beneath the posterior lobes of the cerebrum, from which it is separated by the tentorium cerebelli. It is oblong in shape, measuring from three and a half to four inches transversely; from two to two and a half from before backwards, and two inches in thickness, and weighs from five to six ounces. Each hemisphere is divided into several lobes, of different sizes, and its surface is marked by numerous curved furrows or sulci, which vary in depth in different parts.

STRUCTURE.—It consists of gray and white matter; the former, darker than that of the cerebrum, occupies the surface; the latter the interior. When divided vertically it is seen to consist of a central stem of white matter, which contains in its interior a grayish mass—the corpus dentatum. The central stem of white matter sends forth laminæ towards the surface, which are surrounded by the gray matter so that the cut surface of the organ presents a foliated appearance, to which the name of *arbor vitæ* has been given. The cerebellum is connected with the rest of the encephalon by processes or prolongations, called peduncles. They are three in number, the *superior*, *middle*, and *inferior*.

The *superior peduncles* connect the cerebellum with the cerebrum. They pass upwards beneath the testes to the crura cerebri and optic thalami, each peduncle forming part of the lateral boundary of the fourth ven-

tricle. Beneath the corpora quadrigemina the inner-most fibres of each peduncle decussate with each other, some fibres from one side of the cerebellum communi-cating with the opposite side of the cerebrum.

The *middle peduncles*, the largest of the three, con-nect together the two hemispheres of the cerebellum, and form the transverse fibres of the pons varolii.

The *inferior peduncles* (crura cerebelli) connect the cerebellum with the medulla oblongata. They pass downwards to the back part of the medulla, and form part of the restiform bodies.

Function of the cerebellum.—The cerebellum is itself insensible to irritation, and may be cut away without causing pain; but if any of the crura be touched, pain is instantly felt. Its removal is not attended with any loss or disorder of sensibility; the animal can see, hear, smell, &c., as before its removal; but he has lost the power of springing, flying, walking, standing, &c., and his actions are like those of a drunken man. If one-half of the cerebellum be removed, the animal exhibits a tendency to roll over upon its longitudinal axis, and from the side injured. From the above circumstances it would appear that the function of the cerebellum is to regulate and coördinate the voluntary movements of the body. The influence of each half of the cerebellum is directed to muscles on the opposite side of the body.

The cerebellum is supposed by some to be the organ of sexual instinct, or of amativeness; this view is gen-erally received by Phrenologists. The facts in favor of it are—1st, cases in which atrophy of the testes and loss of sexual passion have resulted from injuries to the cere-bellum; 2nd, disease of the cerebellum has been attended with almost constant erection of the penis, and frequent seminal emissions; 3rd, that it has seemed possible to

estimate the degree of sexual passion in different persons by an external examination of the region of the cerebellum. In reference to the first class of facts, the loss of sexual passion may have been the consequence of the loss of the testes, and hence these facts have little bearing on the question, unless it can be shown that the loss of sexual passion followed the injury of the cerebellum, before the testes began to diminish. Disease of the cerebellum proves nothing, because the same thing more generally occurs in disease of the medulla and spinal cord. On the other hand, cases are recorded in which the whole of the cerebellum has been disorganized, or completely absent, without loss of the sexual passion. Besides, among animals there is no proportion between the size of the cerebellum and the development of the sexual passion, and castration in early life is not followed by any diminution of the cerebellum. From all that has been observed, it would appear that no other office is manifest in it than that of regulating and coordinating muscular movements.

THE CEREBRUM.—The cerebrum occupies the upper part of the cranial cavity, resting upon the anterior and middle fossæ of the base of the skull, and is separated posteriorly from the cerebellum by the tentorium cerebelli. It is ovoidal in shape, and is divided into two lateral hemispheres, which are connected together by a broad transverse commissure of white matter—the *corpus callosum*. The average weight of the brain is about fifty ounces in the male, and forty-five in the female. The weight of the brain increases rapidly up to the seventh year, more slowly up to twenty, and still more slowly up to the fortieth year. When it reaches the maximum, it remains stationary for a few years, and then declines as age advances, about one ounce for each

subsequent decennial period. As a rule, the size of
the brain bears a general relation to the intellectual
capacity of the individual. Cuvier's brain weighed
rather more than sixty-four ounces; Dr. Abercrombie's,
sixty-three; Dupuytren's, sixty-two and a half. The
brain of the late D'Arcy McGee, the celebrated Cana-
dian statesman, weighed fifty-nine ounces. On the
other hand, the brain of an idiot seldom weighs more
than twenty-three ounces. In only two animals is the
brain larger than in man, viz., the elephant and the
whale.

The *mere* comparative size of the brain, however, does
not always give an accurate measure of the amount of
mental power, for not unfrequently men possessing large
and well-formed heads are seen, whose mental capability
is not greater than that of others whose crania have the
same general proportion, but are much smaller. Large
brains, with deficient activity, are commonly found in
persons of a lymphatic temperament; whilst small brains,
and great activity, characterize the sanguine and nervous
temperaments. The *quality* of the nerve tissue, and the
number and extent of the convolutions, also bear a
certain relation to the intellectual capacity of the indi-
vidual.

STRUCTURE.—The cerebrum consists of two kinds of
nerve tissue, the *gray* and the *white;* the former is situ-
ated externally, the latter internally. The surface of
the cerebrum presents a number of *convolutions* or fold-
ings, separated from one another by depressions or sulci
of various depths. The outer surface of each convolu-
tion is composed of gray matter, which is sometimes
called the cortical substance, and the interior consists of
white matter. The convolutions are admirably adapted
to increase the extent of surface or amount of gray mat-

ter, without occupying much additional space. The gray matter of the convolutions, when closely examined, however, appears to consist of from four to six layers of gray and white tissue placed alternately, from two to three layers of gray substance, and an equal number of white; the latter occupying the surface. The *sulci* are generally about an inch in depth; but they vary in different brains, and in different parts of the same brain, being usually deepest on the outer surface of the hemispheres. The number and extent of the convolutions, and the depth of the sulci, bear a close relation to the intellectual power of the individual. They are entirely absent in some of the lower orders of mammalia, and increase in number and extent as we ascend the scale. The largest and most constant convolutions of the human brain are the convolutions of the corpus callosum, supra-orbital convolutions, and the convolutions of the longitudinal fissure. The convolutions of the brain are the centre of intellectual action. The *white* matter consists of three kinds of fibres: *diverging* or *peduncular*, *transverse* and *longitudinal* commissural fibres.

The *diverging* or *peduncular* fibres connect the cerebrum with the medulla oblongata and spinal cord, and constitute the crura cerebri. Each crus consists of two bundles, *superficial* and *deep*, separated by a dark gray mass in the interior—the locus niger. The *superficial* fibres are continued upwards from the anterior pyramids to the cerebrum. The *deep* fibres are contined upwards from the lateral and posterior columns of the medulla and the olivary bodies. As the peduncles of the cerebellum enter the hemispheres, they diverge from one another to enclose the interpeduncular space, and the fibres of each pass through two large masses of gray matter, the ganglia of the brain, called the thalami

optici and corpora striata, which project from the upper and inner side of each peduncle. Above these masses is situated the great transverse commissure—the corpus callosum—which connects the hemispheres together. The space bounded by the peduncles and ganglia on the sides, and the corpus callosum above, forms the general ventricular cavity. The upper part of the cavity is divided into *two lateral ventricles* by the septum lucidum, and the lower part constitutes the *third ventricle*, which communicates above with the lateral ventricles, and behind with the *fourth ventricle.* The *fifth ventricle* is situated in the space between the two layers of the septum lucidum. The *transverse* fibres connect together the two hemispheres. They form the corpus callosum, and the anterior and posterior commissures.

The *longitudinal* fibres connect together distant parts of the same hemisphere. They form the fornix, tænia semicircularis, peduncles of the pineal gland, striæ longitudinales, gyrus fornicatus, and the fasciculus uncinatus, which connects together the anterior and middle lobes.

VASCULAR SUPPLY.—The blood-vessels of the brain are numerous and capacious, it being supplied by four large arteries; the two internal carotids and the two vertebral arteries. These vessels, in their passage, pursue a winding course to reach the brain, the object of which is to increase the extent of surface over which the blood passes, and thus add to the amount of impediment produced by friction, in order that the supply may be more equable and uniform. These curvatures in the vessels also tend to moderate the force with which the blood may be sent to the brain under certain circumstances, as during great excitement, violent exercise, and the like. These vessels also anastomose freely with each other after entering the

cranial cavity. This takes place not only between the smaller branches, but also between the primary trunks; the former is seen all over the surface of the encephalon; the latter constitutes the well-known *Circle of Willis.* This is formed in front of the anterior cerebral and anterior communicating arteries, on each side, by the trunk of the internal carotid and the posterior communicating, and behind by the posterior cerebral and point of the basilar. These vessels divide and subdivide upon the surface of the brain, until they terminate in very small arteries, which are connected together by some areolar tissue, constituting the pia mater, from which smaller vessels are given off which pierce the brain substance. No medium-sized vessels pierce the cerebral substance except at the perforated spaces; but prolongations of the pia mater, carrying with them the blood-vessels, pass into the interior of the brain at the transverse fissure, to form the velum interpositum and choroid plexuses which are situated in the ventricles.

FUNCTION OF THE CEREBRUM.—From its anatomical relation the brain does not appear to be one of the essential or fundamental portions of the nervous system, but is a superadded organ, receiving all its impulses to action from the parts below, and acting upon the body at large through them. But its great size, its position at the summit of the cerebro-spinal system, and the vesicular substance of its convolutions affording a termination to the fibres in connection with it, mark it out as the highest in its functional relations, and as the organ through which all the processes of thought, reason, and intelligence are carried on.

There is a very close correspondence between the relative development of the cerebrum, in the several tribes of vertebrata, and the degree of intelligence they

respectively possess.   In the lower animals it is difficult
to say what part of their actions may be regarded as
instinctive, and what as intelligent.   Intelligent actions
are exhibited : 1st, in the variety of means used to accom-
plish the same ends by different individuals, and by the
same individual at different times ; 2nd, in the improve-
ment in the mode of accomplishing the object, which re-
sults from experience ; 3rd, in the adaptation of means
to altered circumstances.   The difference between the
intelligence of lower animals and pure instinct, is well
seen in comparing birds with insects. ˙Their instinctive
propensities are nearly similar ; but in the adaptation
of their operations to peculiar circumstances birds display
a certain degree of intelligence.   Certain tribes of birds,
especially the parrot and its allies, are capable of being
taught to perform tricks and to pronounce words, in
which they exhibit simple acts of reasoning, similar to
those of a child when first learning to talk.   Some of
the domestic animals, as the dog and the horse, manifest
a considerable degree of intelligence.   There is no evi-
dence, however, that any of the lower animals have the
power of directing their mental operations in obedience
to the will.

With reference to the sensibility of cerebral matter, it
has been ascertained by experiment that neither sensa-
tion nor motion is produced by irritation of the vesicular
or fibrous substance.   In fracture of the skull, accom-
panied by protrusion of the cerebral matter, it may be
separated without exciting either sensation or convulsive
motion.   When one of the hemispheres is removed from
an animal, it is followed by temporary weakness of the
limbs on the opposite side of the body, and a loss of
sight in the opposite eye, but the pupil remains active.
When both hemispheres are removed, the animal appears

to be in a sleepy state, from which it cannot be fully aroused, but consciousness still remains, the persistence of which proves that the cerebrum is not its exclusive seat. In this state a reptile or a bird may survive many weeks if its physical wants be supplied. The influence of disease on the cerebrum is somewhat anomalous. In some instances extensive disease has occurred in one hemisphere, without any obvious injury to the mental powers, or interruption of the influence of the mind on the body; but morbid phenomena are invariably present when both hemispheres are affected. On the other hand a sudden lesion, although of a trifling character, may occasion very severe symptoms; for example, a slight effusion of blood in or around the substance of the corpus straitum is followed by paralysis in the opposite side of the body. Some of the muscles of the face are also paralyzed on the side opposite the injury as a general rule; but in a few exceptional cases, the side corresponding to the injury is affected. This appears very singular, when it is borne in mind that the nerves which supply the muscles of the face are given off above the place where the anterior pyramids decussate. The exceptional cases may be explained by the fact of a double injury having been sustained; the paralysis of the limbs resulting from injury to one side of the brain, and the paralysis of the face from injury to the other. When the corpora quadrigemina, or the part below, are involved in the injury, the paralysis is accompanied by convulsions on the same side. The conclusion to be drawn from what has been already stated is, that the cerebrum is the organ of *intellectual action, emotion, ideo-motor action* and *volition*, the seat of which is the gray matter of the convolutions.

The *crura cerebri* are the principal conductors of im-

pressions to and from the cerebrum. When one of them is divided, the animal moves round and round on a vertical axis from the injured to the sound side; this is caused by a partial paralysis on the side opposite the injury.

The *corpora quadrigemina* are the representatives of the optic lobes in birds, reptiles and fishes, and may be considered as the centres of the sense of sight, since their removal or diseased condition is accompanied with blindness. Injury or disease on one side is followed by blindness of the opposite eye, and a slight rotatory motion, as after division of the crus cerebri; the pupil is also dilated. They are not only the centres from which the optic nerves arise in part, but also the organs in which the mind perceives the sensation of light.

The *thalami optici* are also concerned to a certain extent in the function of vision, for part of the fibres of the optic tracts may be traced to their surfaces. In persons born blind, the optic thalami, and also the corpora quadrigemina, are found extremely small. Destruction of one of them produces effects similar to those of division of the crus cerebri; the animal remains standing, and turns continually round.

The *corpora striata* were supposed by Magendie to be the centres of motor power for *backward* movement, and that *forward* movement was excited by the cerebellum, these two powers being exactly counterbalanced, and hence division of the corpora striata caused an irresistible tendency to run forwards. This, however, has not been confirmed by other experimenters. Longet and others assert that animals remain stupid and immovable after division of the corpora striata, and it is only when irritated by pinching or pricking that they exhibit any disposition to move.

The *corpus callosum* connects together the two hemispheres of the cerebrum. It is entirely absent in birds, reptiles and fishes. Its division is followed by severe general injury. It probably enables the two sides of the brain to act in concord in the performance of its highest functions.

THE MIND AND ITS RELATION TO THE BODY.—With reference to the relation of mind and matter, and the nature and source of mental phenomena, there are two theories, that of the *materialist* and the *spiritualist*. The materialist supposes that all the operations of the mind are but "expressions of material changes in the brain;" that thus man is but a thinking machine, his whole conduct being determined by his original constitution, his character being formed *for* him and not *by* him, his actions being simply the result of the reaction of his cerebrum upon the impressions which called it into play. According to this doctrine, the highest elevation of man's *psychical* nature is to be attained by proper attention to those circumstances which promote his *physical* development. The arguments in support of this theory are:—1st, the dependence of the normal activity of the mind upon the healthy nutrition of the brain, and its proper supply of pure blood; 2nd, the peculiar effects of lesions of the brain upon the intellectual operations, as is seen in loss of speech, memory, &c., after severe injury to the head; 3rd, the production of mental imbecility as a result of disease in the parents, or defective nutrition in the offspring during childhood; and—4th, the complete perversion of the mind and moral feelings which is produced by intoxicating agents. Now, though this doctrine recognizes some great facts regarding the dependence of mental operations upon the organization and functional activity

of the nervous system, yet there is beyond and above all this a *self-determining power* which can rise above the promptings of external suggestions, and which can suit external circumstances to its own requirements, instead of being completely subjugated by them.

The *spiritualist* regards the mind in the light of a separate immaterial existence connected with the body, but not in any way dependent upon it, except as deriving its knowledge of external things through its agency, and as making use of it to execute its determinations so far as these relate to material objects. According to this theory, the operations of the mind, having no relation to those of the body, are never affected by its irregularities or defects of functional activity; and the mind, thus independent of the body, is endowed with a complete power of self-government, and is responsible for all its actions. But nothing can be more plain than that the introduction of intoxicating agents into the system really perverts the action of the mind, and occasions many strange results at variance with its normal action. So that, however true it may be that there is something in our mental constitution beyond and above any agency which can be attributed to matter, the operations of the mind are in a great degree determined by the material conditions with which they are so intimately associated. The whole system of education recognizes the importance of external influences in the formation of the character; and it is the duty of every teacher to foster the development and promote the right exercise of that power by which each individual becomes the director of his own conduct.

Hence it will be seen that any attempt to bring mind and matter into the same category is attended with difficulty, since no relation of identity can exist between

them. But although no relation of identity or analogy subsists between mind and matter, a very close relation may be shown to exist between *mind* and *force*, or between *mind-force* and *nerve-force*. In the phenomena of voluntary movement the will operates upon the nervous matter, and developes nerve-force, the transmission of which along the nerve trunks is the determining cause of muscular contraction. Here is evidence of the excitement of nerve-force by mental agency. The converse of this is equally true, viz., that mental activity may be excited by nerve-force. This is the case in every act in which the mind is excited through the instrumentality of the sensorium; the impression is first conveyed to the sensorium (or sensory ganglia), in which it produces a certain active condition of the nervous matter, which is the immediate antecedent of all consciousness—whether of emotions or ideas. And since the will can develope nerve-force, and as nerve-force can develope mental activity, there must be a *correlation* between the two forces, not less intimate than that which exists between nerve-force and electricity. The nervous matter of the cerebrum is the material *substratum* through which the metamorphosis of nerve-force into mind-force, and mind-force into nerve-force is effected, and like all other changes, every act of the mind involves the disintegration of the nervous substance which ministers to it.

When impressions are made upon some part of the body that is supplied with afferent nerves, they are transmitted through them to the sensorium, and occasion affections of the consciousness, which are called *sensations*. Every impression which affects the consciousness produces some change in the nervous centre, by which that impression is perpetuated in such a manner as to permit of its being again called up before the mind

at any future time. The nature of the change by which
sensory impressions are thus *registered* is not understood,
and probably never will be. The acuteness with which
particular sensations are felt depends on the degree of
attention they receive from the mind; for example, ordi-
nary impressions are not felt during sleep, or when the
mind is engaged in some deep subject of study. On the
other hand, impressions which are in themselves very
slight may produce painful sensations, when the mind
is directed strongly towards them. They are also much
modified by the influence of habit. Sensations *not
attended to* become blunted by frequent repetition; whilst
sensations *attended to* become much more readily cogni-
zable by the mind. Every student knows that the
effluvia of the dissecting room becomes tolerable after
the nose has become habituated to it.

In some instances, sensations may be produced by
internal causes; these are called *subjective sensations*, in
contradistinction to *objective*, which are caused by a real
material object. The most common cause of these sub-
jective sensations is congestion or inflamation; *e. g.*, con-
gestion in the nerves of common sensation gives rise to
pain or uneasiness; in the retina or optic nerve, it pro-
duces "flashes of light;" and in the auditory nerve it
occasions "a noise in the ears." Again, subjective sen-
sations may be produced by sensations originating in
objective impressions on other parts, as *e. g.*, a calculus
in the bladder gives rise to pain in the glans penis;
disease of the hip occasions pain in the knee.

The mental recognition of the cause of sensation is
called *perception*. For the production of a sensation a
conscious state of the mind is all that is required; but
for the exercise of the perceptive power, the mind must
be *directed towards* the sensation, and hence, when the

mind is inactive, or engaged in study, the sensation may not be perceived or remembered. The perception of sensation gives rise to *ideas;* some of these partake of the nature of *feeling;* others relate to *knowledge.* An *idea* is a mental representation of an object which has been perceived by the mind—something grasped by the mind, and held up before it as an intelligible object of contemplation. Ideas may be communicated and rendered intelligible to other minds by means of visible signs, or by spoken language, in which certain combinations of sounds are used to express ideas; and the nearer the signs or sounds employed are to the natural expressions of the ideas which they represent, the more readily are they comprehended.

When ideas are associated with feelings of pain or pleasure, they give rise to *emotions.* These, unlike ideas, cannot be communicated or expressed in language to others; they are unutterable. Those emotional states of the mind which determine a great part of the conduct of individuals, are the result of the attachment of the feelings of pleasure and pain, and of other forms of emotional sensibility to certain classes of ideas. Thus, *grief* is the painful contemplation of loss, misfortune, or evils of any kind. *Joy* is the pleasurable feeling which accompanies success, good fortune, or good prospects, &c. *Fear* is a painful emotion excited by an expectation of future evil. *Hope* is the pleasurable expectation of future enjoyment. *Benevolence* is the pleasurable contemplation of doing good to others. *Malevolence* is a positive pleasure in the contemplation of the misfortunes of others, and so on. The emotions are partly under the control of the will, and partly independent of it.

The capacity for performing mental acts is known as

the *intellect*, or the reasoning power; and the capacities
for those various forms of intellectual activity which
pertain to the mind are called the *intellectual faculties*.
They are *perception, imagination, memory* and *judgment*.
It is, however, quite erroneous to suppose that the entire
intellect can be split up into a certain number of facul-
ties, since each faculty expresses only a mode of activity
in which the whole mind is engaged at once, just as the
whole power of the steam engine may be employed in
propelling the vessel forwards or backwards, according to
the direction given to the power. It is also quite absurd
to attempt, with the phrenologist, to parcel out the
cerebrum into distinct organs for these respective
faculties, the whole of it being called into operation and
acting as a unit in every kind of intellectual process
which occupies the attention at the time. The empi-
rical method by which Gall first fixed upon certain parts
of the brain as the seat of certain faculties, is exposed to
the serious fallacy that a part on the surface of the brain
may appear largely developed in consequence of the
large size of some subjacent or neighboring part,—for
example, a thick neck and large occipital region may
indicate a large pons and medulla more frequently than
a large cerebellum. Again, with respect to the cranium
itself, large prominences just above the eyebrows may
indicate large frontal sinuses rather than a large develop-
ment of "certain organs" on the anterior lobes of the
cerebrum. Gall divided the whole cerebrum into
twenty-seven different organs to represent different facul-
ties, and Spurzheim divided it into thirty-five.

The *determining power of the will* acts both upon the
body and the mind; but the only sensible effect which
the strongest effort of volition can produce on the bodily
frame is that of contraction of the voluntary muscles.

The immediate operation of the will is not upon the muscles, but upon the brain, in which it excites nerve force, which is transmitted along the nerves, and stimulates the muscular tissue to contraction. With reference to the action of the will upon the mind, it may be said that it possesses the power of recalling ideas which are present in the mind, excluding some and bringing others more prominently before it. This is effected by the power of *voluntary attention*, which is the chief means through which the sequence of our thoughts is directed by the will. When the will is most strongly exerted, it causes the consciousness to be so completely engaged by one train of ideas that the mind is, for the time, incapable of receiving any other idea or impression, the individual being as insensible as if he were in a profound sleep. This power of concentration of the mind on the subject of study, is of very great importance and advantage in the acquirement of knowledge and the pursuit of truth, and one which is capable of cultivation to a considerable extent by habitual exercise.

The *influence of the mind over the body* is a most remarkable phenomenon, and one well worthy of attention. Many of its effects are quite familiar; for example, fear or great anxiety of mind produces a desire for frequent micturition, and not unfrequently the bowels are moved also. The announcement to the patient of the arrival of the accoucheur, suspends for a time the labor pains. The sight, or even the thought of very unpalatable medicine, produces nausea, and sometimes vomiting. Under the influence of the mind, opium pills have been known to produce catharsis, when the patient supposed that he had taken a cathartic. In this way also, persons have been much benefited, and in some instances entirely cured, by the simplest remedies. Much of the

success of the Homœopathist is no doubt due to this
fact. In all modes of treatment, therefore, it is abso-
lutely necessary to have the entire confidence of the
patient. It has also been observed, that when the mind
is directed to any tumor or growth of the body, its in-
crease is greatly accelerated.

In consequence of the waste of nerve tissue during
its activity, it is necessary that a periodical suspension
should take place in order to permit of nutritive regene-
ration; this is called *sleep.* In deep sleep there is a
state of complete unconsciousness, and the body may
remain for a considerable time motionless; but the indi-
vidual is capable of being aroused by external impres-
sions. In this it differs from *coma,* which is generally
the result of some pressure upon the brain, in which the
patient is incapable of being aroused. The tendency to
fall asleep is favored by a succession of dull, monotonous
sounds, as a dull, prosy speech or sermon; or by sounds
accompanied by gentle movements, as is seen in putting
infants asleep. Another method is to close the eyes and
fix the attention upon some object, or repeat a certain
word until the mind becomes completely lost or uncon-
scious.

The average amount of sleep required by a healthy
adult is about eight hours in twenty-four; children re-
quire more. On some occasions the sleep is more or
less disturbed by *dreams.* These generally refer to some-
thing that has engaged the attention previously; but in
some instances they would appear to indicate things that
are to happen; at all events, there is in many instances
a singular coincidence between dreams and occurrences
which follow them. An uneasy or anxious state of
mind is unfavorable to sleep. It is said that criminals
under sentence of death sleep badly while they have

hopes of a reprieve, but as soon as they are assured that their death is inevitable, they usually sleep more soundly.

Derangement of the digestive organs, or a disturbed state of mind, in some instances, gives rise to a dreaming state called *somnambulism*. In this state the individual acts as if he were awake, and as if all the phenomena presented to him were real. He answers questions rationally and with readiness; he walks with precision and avoids obstacles; yet, not unfrequently, accidents happen which show that he has not full command of his senses.

A state remarkably analogous to somnambulism may be induced in some persons, which has been called *mesmerism*. The production of this state requires the apparent influence of another individual, who looks directly in the face of the person experimented upon, and makes certain movements before him called *passes;* or the person is required to gaze steadfastly upon a piece of metal or other substance held in the hand, until a state of unconsciousness is induced. Remarkable statements have been made, implying that in these cases the faculties are very much exalted, and the person acquires powers of a superhuman kind. Such statements, however, are made by those interested in such *séances,* or by those who are ignorant of the deception resorted to in order to obtain notoriety.

CRANIAL NERVES.

The cranial nerves include those nerves which arise from some part of the cerebro-spinal centre and are transmitted through foramina at the base of the brain. There are nine in number on each side, and they are

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arranged in pairs in the following order from before backwards:

1st Olfactory	7th {	Facial or portio dura
2nd Optic		Auditory or portio mollis
3rd Motor Oculi		Glosso-pharyngeal.
4th Pathetic	8th {	Pneumogastric.
5th Trifacial or trigemini		Spinal accessory.
6th Abducens	9th	Hypoglossal.

They may be subdivided into four groups, according to the peculiar function of each, viz., 1st, *nerves of special sense*, as the olfactory, optic, auditory, the lingual branch of the trifacial, and part of the glosso-pharyngeal; 2nd, *nerves of common sensation*, as the greater portion of the fifth, and part of the glosso-pharyngeal; 3rd, *nerves of motion*, as the motor oculi, pathetic, part of the tri-facial, abducens, facial, and hypoglossal; and 4th, *mixed nerves*, as pneumogastric and spinal accessory.

The *olfactory nerves* arise from the cerebrum by three roots, and present a bulbous enlargement which rests upon the cribriform plate of the ethmoid bone, from which delicate filaments are given off which supply the nose. They are the nerves of the special sense of smell. In structure they differ from the other nerves, in being soft and grayish in color, and destitute of the white substance of Schwann.

The *optic nerves* are distributed to the eye, in which they expand to form the internal layer of the retina, and are the nerves of the special sense of sight. Division of the optic nerve produces total blindness and dilatation of the pupil, but does not destroy ordinary sensibility or paralyze muscular action.

The *auditory nerves* are the special nerves of the sense of hearing. They convey to the brain the sensation of sound, and are incapable of transmitting any other, being entirely destitute of ordinary sensibility.

The *filaments* are distributed to the cochlea, semicircular canals and vestibule.

The *motor-oculi* is a nerve of motion, and is distributed to all the muscles of the eyeball, except the superior oblique and external rectus. It also supplies motor filaments to the *circular* fibres of the iris. In paralysis of this nerve, the upper eyelid falls down over the eye, so that it appears half closed, the pupil is dilated, the movements of the eyeball are nearly suspended, and the eye is directed outwards, owing to the action of the external rectus. This condition of the eyelid is called *ptosis.* The stimulus of light on the retina produces contraction of the circular fibres of the iris and partial closure of the pupil. This is a reflex action, the stimulus being conveyed by the optic nerve to the brain, and thence reflected through the third nerve to the iris; consequently the iris ceases to act when either the optic or third nerve is divided or destroyed, or the nervous centre injured or compressed.

The *radiating* fibres of the iris are probably supplied by filaments from the ophthalmic or ciliary ganglion.

The *pathetic nerve*, the smallest of the cranial nerves, is also a nerve of motion distributed to the superior oblique muscle. When the nerve is irritated the muscle acts spasmodically, and its division causes paralysis and a loss of rotary motion of the eyeball on its axis, and sometimes double vision.

The *abducens* supplies the external rectus with motor power. Irritation of this nerve produces an effect similar to the preceding. Division or injury is followed by convergent *strabismus.*

The *trifacial nerve* closely resembles the spinal nerves. It arises by two roots, an anterior, smaller or motor, and a posterior or sensory, which has a ganglion developed

on it.   The functions of this nerve are various; it is the great sensitive nerve of the head and face; the motor nerve of the muscles of mastication (except the bucci-nator), and its largest branch is one of the nerves of the special sense of taste.   This nerve, within the cranium, is divided into three branches—the *ophthalmic*, which passes through the sphenoidal fissure, the *superior maxillary*, which passes through the foramen rotundum, and the *inferior maxillary*, which passes through the foramen ovale.   The first and second divisions are purely sensitive; the third division contains filaments of special sense, sensation and motion.   It is the most intensely sensitive nerve in the body; its irritation is followed by intense pain.   Any irritation to this nerve, or any of its branches, as *e. g.*, a carious tooth, may give rise to neuralgia of the corresponding side of the face, and in many instances one-half of the tongue is found covered with a white fur, while the other half is perfectly clean.   Division of the fifth nerve produces loss of sensibility, and motion in the parts supplied by it, and is followed by inflammation of the corresponding eye, which usually goes on to complete and permanent destruction, and sloughing of the organ.   Injury to the fifth nerve, or some of its branches, is sometimes followed by total blindness in the corresponding eye.   The blindness is probably the result of defective nutrition to the retina. Paralysis of the third nerve may also follow neuralgia of the fifth nerve.

The *facial nerve* supplies all the muscles of the face, the platysma, buccinator, the muscles of the external ear, digastric and stylo-hyoid, the palate, lingualis, stapedius, and laxator tympani muscles.   It is a nerve of motion, and not of sensation, and therefore its division, which was formerly resorted to in cases of *tic douloureux*,

is incapable of relieving neuralgic pains, but is followed by paralysis of the muscles which it supplies. Division or paralysis of the facial nerve also prevents the eye from being closed, and its continued exposure to the air, and particles of dust, is apt to produce inflammation. The sense of hearing and taste may also be impaired. In *facial paralysis* there is an absence of expression on the affected side, the angle of the mouth is lower, and the eye has an unmeaning stare. In drinking, the fluids flow out at the corner of the mouth, and the food lodges between the cheek and gums. When the tongue is protruded it is drawn to the sound side, in consequence of the paralysis of the muscles on the affected side.

The *glosso-pharyngeal nerve* is distributed to the tongue and pharynx, being the nerve of sensation to the mucous membrane of the pharynx, the fauces and tonsil; of motion to the pharyngeal muscles, and a special nerve of taste to the posterior part of the tongue. The tongue is therefore supplied by two special nerves—the lingual branch of the fifth, and the glosso-pharyngeal; the former supplies the anterior and lateral parts of the superior surface, and the latter the posterior and lateral parts. This may be proved by division of either of these nerves, when the sense of taste is lost in the part supplied by the injured nerve.

The *hypoglossal nerve* is a nerve of motion, and is distributed to the muscles which belong to the hyoid bone and tongue. Irritation of this nerve produces muscular contraction, and is sometimes attended with pain, the sensibility having been borrowed from the nerves with which it communicates.

The *pneumogastric nerve* is one of the most remarkable and important in the body. It supplies the larynx, pharynx, œsophagus, heart, lungs, stomach and liver. It

possesses motor, sensitive and sympathetic or ganglionic nerve fibres, and is therefore regarded as a *triple-mixed nerve*. The pharyngeal branch supplies the muscles of the pharynx; the superior laryngeal is chiefly sensitive, and supplies the mucous membrane; the inferior is for the most part motor, and supplies the muscles; the branches to the œsophagus supply its muscular tissue; the cardiac branches constitute a channel through which the influence of the central organs and the emotions of the mind are transmitted to the heart; the pulmonary branches form a channel through which the impressions on the lungs are conveyed to the medulla oblongata; the motor filaments of the pneumogastric nerve supply the motor influence by which the function of deglutition is performed. In the functions of the larynx, the sensitive filaments supply that acute sensibility by which the glottis is guarded against the ingress of foreign bodies or irrespirable gases. These are instances of " reflex action."

Division of the pneumogastric nerves is at once followed by a *diminution of the frequency of the respiratory movements*. In young animals it is often quickly fatal, owing to the closure of the glottis, which is due to the yielding nature of the cartilages; but in older animals death ensues more slowly, owing to the rigidity of the cartilages which surround the glottis. Death takes place in from one to six days after the operation, and is caused by the engorgement of the lungs. They are commonly very much congested, nearly solid, and the bronchial tubes are filled with a frothy, bloody fluid and mucus. This is due in part to the slowness of the respiratory movements, the imperfect aëration of the blood, and the accumulation of carbonic acid in the air cells, and also in part to the paralysis of the blood-vessels

themselves. Since respiration is still carried on after division of the pneumogastric nerves, it is evident that though they are the chief agents by which the respiratory stimulus is conveyed to the medulla oblongata, they are not the only ones.

The sensations of hunger and thirst still remain, and the secretion of gastric juice continues after division of the pneumogastric nerve; but the digestive function is more or less disturbed in various ways. In many instances the food taken by the animal never reaches the stomach owing to the paralysis of the œsophagus, but is regurgitated in a few moments afterwards—this action being excited by the influence of the sympathetic nerves. The muscular coat of the stomach is also paralyzed by section of this nerve.

Division of the pneumogastric nerve also interferes with the proper function of the liver, and any irritation in the course of the nerve is followed by the rapid development of sugar in this organ.

The *spinal accessory nerve* arises partly from the medulla oblongata, and partly from the spinal cord. It is. essentially a motor nerve; but it also contains sensitive fibres, and is connected with the ganglion of the pneumogastric. From these circumstances it may be regarded as a *mixed nerve*. It supplies the sterno-mastoid and trapezius muscles, and it is also connected with the vocal movements of the glottis. If the spinal accessory nerve be divided on both sides, or its branch of communication with the pneumogastric nerve, the voice is instantly lost, the animal being incapable of uttering a single sound. It may be stated as a general law, that when any part of the body receives nervous filaments from two different sources, it is for the purpose of enabling it to perform two different functions.

This is exemplified in the muscles of the larynx. These muscles are concerned in the respiratary movements, the nervous stimulus for which is conveyed by the facial, hypoglossal, and pneumogastric nerves; but they are also concerned in the formation of the voice, the nervous influence for which is conveyed by the spinal accessory.

SYMPATHETIC SYSTEM.

The sympathetic system consists of a series of ganglia connected together by intervening cords extending on each side of the spinal column from the base of the skull to the coccyx; some of the ganglia may also be traced into the cranium. These two gangliated cords lie parallel with one another as far as the coccyx, where they communicate through a single ganglion—*ganglion impar*. It is also stated that they communicate at their cephalic extremity through a small ganglion, situated on the anterior communicating artery—*the ganglion of Ribes*.

They are arranged as follows:—In the cephalic region there are four ganglia on each side (and the ganglion of Ribes); in the cervical region, three; in the dorsal region, twelve; in the lumbar region, four; in the sacral region, five; and in the coccygeal region, one—the ganglion impar. Each ganglion may be regarded as a distinct centre from or to which branches pass in various directions, as follows:—1st, communicating branches between the ganglia; 2nd, communicating branches to the cerebral or spinal nerves; 3rd, primary branches of distribution to the arteries in the vicinity of the ganglia, to the viscera, or to other ganglia in the thorax, abdomen, or pelvis. The latter consist of two kinds of nerves, the *sympathetic* and *spinal*, and have a remarkable tendency to form intricate plexuses which surround the blood-vessels, being conducted by them to the vis-

cera. Many of these primary branches, however, pass to a series of ganglia in the thorax and abdomen, the chief of which are the cardiac and semilunar ganglia. It was named the sympathetic system, because it was thought that through it was carried the several sympathies in morbid action which distant organs manifest.

The sympathetic system is endowed with sensibility and the power of exciting motion; but in the exercise of these functions it is less active than the cerebro-spinal system. When irritation is applied to a sensitive nerve in one of the extremities, the evidence of pain or motion is acute and instantaneous; while, on the other hand, irritation to the sympathetic nerve is felt distinctly enough, but is only responded to after somewhat prolonged application. This comports very much with what is known of these organs, supplied chiefly by the sympathetic system, e.g., the movements of the stomach and intestines are not felt under ordinary circumstances; but any excessive or prolonged irritation may cause them to become exceedingly painful.

The ganglia of the sympathetic system are regarded by some writers as reservoirs of nervous force, which they equalize and correctly balance, by storing up all transient excesses of it, and furnishing all transient deficiencies. Complex as the whole sympathetic system appears, however, each of its parts exhibits a wonderful simplicity; for each ganglion with its afferent and efferent nerves forms a simple nervous system, and might serve for the illustration of all the nervous actions with which the mind is unconnected.

The general processes which the sympathetic system appears to influence are those of involuntary motion, secretion, and nutrition. Parts supplied with sympathetic nerves are usually capable of only involuntary

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movements, as, *e.g.*, the heart, stomach, and intestines, and these parts may still continue to move for a short time after the death of the animal. Thus, in the mammalia the heart continues to beat for one or two minutes after it is taken from the body; in reptiles and amphibia, for hours; and the peristaltic action of the bowels continues under the same circumstances.

Division of the sympathetic nerve produces immediately a *vascular congestion* in the parts supplied by it. This was first pointed out by Bernard; he divided the sympathetic nerve of a rabbit in the middle of the neck, and he found that congestion of the corresponding side of the head immediately followed, which was most distinctly marked in the ears, and the venous blood returning from the part had a ruddy hue. The pupil is also contracted and the eye partially closed, owing to the increased sensibility of the retina from vascular congestion of the parts. The congestion appears to be caused by the dilatation of the vessels and consequent increased rapidity of the circulation, for when any irritation is applied to the divided end of the nerve, the vessels contract and the congestion disappears. The vessels therefore appear to be under the influence of the sympathetic nerves, which accompany them in all their varied distributions and minute ramifications. They supply the muscular coat of the vessels, the function of which is to regulate the supply of blood to the various organs. The congestion of the vessels caused by division of the sympathetic nerve is also accompanied by an *elevation of temperature* in the affected part; this increase of heat has been found as high as 8° to 9°F., and like the vascular congestion, to which it is due, may last a considerable length of time.

With reference to the influence of the sympathetic nerve in the processes of secretion and nutrition, little is known except that it is in great measure connected with the supply of blood to the parts. It serves as a medium of reflex action between the sensitive and motor portions of the digestive, excretory and generative organs, and it also takes part in reflex actions which may be referred to the cerebro-spinal system; for example, the contact of food in the intestine excites, through the medium of the sympathetic nerves, a peristaltic movement in the muscular coat. The irritation produced by undigested food in the alimentary canal may give rise to diarrhœa, or it may produce, through the medium of the sympathetic and cerebro-spinal systems, epileptic convulsions, especially in children.

CHAPTER XIV.

THE SPECIAL SENSES.

THE special senses are *five* in number, *smell, sight, hearing, taste,* and *touch.* The last two have been already casually referred to.

SMELL.—The sense of smell is limited to the nasal cavity, and is confined to that portion on which the olfactory nerves are distributed, viz., the roof, the septum, and the upper part of the lateral walls. The nasal cavity is lined by mucous membrane, called also the pituitary or Schneiderian membrane; it is lined by columnar ciliated epithelium, except in the upper part and the roof, in which they are non-ciliated. The filaments of the olfactory nerves pass through the foramina in the cribriform plate of the ethmoid bone, and are distributed beneath the mucous membrane; they convey the sensitive impressions made by the odoriferous particles upon the mucous membrane to the sensorium, which give rise to the sense of smell. The sense of smell is confined to the olfactory nerves, as has been shown by their division, after which the sense of smell was completely lost, while sensibility still remained, and their irritation is not followed by any muscular action, either of a direct or reflex character.

The sense of smell may be impaired by division of the fifth nerve, or some of its branches, which supply the nose. It cannot be inferred from this, however, that it is a nerve of the special sense of smell; the result is to be attributed to the dry and otherwise deranged

state of the mucous membrane, occasioned by the al-
tered nutrition of the parts.

The *meatuses* and *sinuosities* of the nasal cavities are
well adapted not only to increase the extent of mucous
surface, but also to impede the air and odoriferous par-
ticles which it may contain, in their passage through
them, so as to bring them into more immediate contact
with the mucous surface, by means of which their pecu-
liar characters are more fully impressed on the olfactory
nerves.

The *frontal sinuses* are supposed to assist in the exten-
sion of the sense of smell; but since they do not receive
filaments from the olfactory nerves, and are largely devel-
oped in some animals, as the grey-hound, in which the
sense of smell is by no means acute, it is highly improba-
ble. The sense of smell varies much in different individuals,
and, like all the senses, may be improved by frequent
practice. But the sense of smell may become blunted
by long-continued exposure to one kind of smell, as, for
example, the effluvia of the dissecting room. Various
odors also affect it differently, as musk, asafœtida ; and
some produce nausea and even fainting.

The irritation produced by the contact of substances
which act mechanically or chemically on the mucous
membrane, as ammonia, nitrous acid, &c., must not be
confounded with the sense of smelling. These impressions
are conveyed to the sensorium by the fifth nerve, which
is the nerve of sensation. The sense of smell may be
impaired or destroyed by the obstruction of the air
passages, as in the case of polypi; by chronic inflam-
mation, as catarrh, ozæna, &c.; by the frequent use of
snuff, &c., which tends to blunt its acuteness and cover
the surface with its particles.

Besides the olfactory and fifth nerve, there are some

filaments from the spheno-palatine ganglion distributed to the nose. The function of these is not very well known; but from the connection with the fifth nerve and the sympathy between the senses of smell and taste, they are probably nerves of *associate function.*

SIGHT.

The eye is the organ of the special sense of sight, and is situated in the cavity of the orbit. It is spherical in form, having the segment of a smaller and more prominent sphere engrafted on its anterior surface. It measures about an inch in the antero-posterior diameter, and a little less transversely. It consists of *three coats;* an outer, consisting of the *sclerotic and cornea;* a middle, consisting of the *choroid coat, ciliary processes,* and *iris;* and an internal, the *retina;* and *three* refracting media,— the *aqueous humor,* the *vitreous humor,* and the *crystalline lens and capsule.*

The *sclerotic* is a dense, fibrous membrane, which covers the posterior five-sixths of the eye, and is continuous in front with the cornea, and behind with the sheath of the optic nerve, which is derived from the dura mater. Behind, it is pierced, a little to its nasal side, by the optic nerve, around which are openings for the passage of the ciliary vessels and nerves.

The *cornea* projects forwards, somewhat resembling a watch-glass, and covers the anterior sixth of the globe. It is concavo-convex, the degree of curvature varying in different individuals, and in the same individual at different periods of life, being generally more prominent in youth than in advanced life. This difference in the curvature influences considerably the refractive power of the eye, and is the principal cause of *long* and *short-sightedness.* The cornea, in health, is perfectly transpa-

rent, and consists of five layers,—the cornea proper, a central fibrous structure; in front of this, the anterior elastic lamina, covered by the conjunctiva; behind, the posterior elastic lamina, covered by the lining membrane of the anterior chamber of the eyeball.

The *choroid* is a thin, highly vascular membrane, of a dark color, which covers the posterior five-sixths of the globe, and is situated between the sclerotic and retina. It is pierced behind by the optic nerve and terminates in front of the ciliary ligament, where it bends inwards and forms the ciliary processes. It is composed of *three layers*,—the *external*, which consists of the larger branches of the ciliary arteries, but chiefly the veins and some star-shaped pigment cells; the *middle*, which consists of a fine capillary plexus (tunica Ruyschiani); and the *internal* or *pigmentary* layer, which is made up of a single layer of hexagonal cells, loaded with pigment granules, so arranged as to resemble tesselated epithelium. In perfect albinoes the cells contain no pigment.

The *ciliary processes* are formed by the folding inwards of the middle and internal layers of the choroid around the margin of the lens, behind the iris. They vary in number from sixty to eighty, and are about one-tenth of an inch in length. They are similar in structure to the corresponding layers of the choroid.

The *iris* (ιρις, a rainbow) is a thin, circular-shaped contractile curtain, suspended in the aqueous humor behind the cornea and in front of the lens, and presenting, at the nasal side of its centre, a circular opening, the pupil, for the transmission of light. It separates the cavity for the aqueous humor into two parts, the anterior and posterior chambers. It consists of *muscular tissue, fibrous tissue*, and *pigment cells*. The *muscular tissue* consists of *circular* fibres which surround the

pupil, and *radiating* fibres which converge from the circumference of the iris to the margin of the pupil; the former contract the pupil, the latter dilate it. (See motor oculi.) The *fibrous* tissue forms a delicate mesh in which the pigment cells, vessels and nerves are contained. The *pigment cells* are found in the stroma, and also as a distinct layer on the anterior surface. On the posterior surface of the iris there are several layers of round cells filled with pigment granules. These are called the *uvea*, from their resemblance in color to a ripe grape. The iris is connected to the choroid and to the external coat of the eyeball at the junction of the sclerotic and cornea, by means of a circular band of white fibrous tissue, the *ciliary ligament.*

The middle coat of the eye is also connected to the external by means of a circular band of nonstriated muscular tissue, the *ciliary muscle.* It is about one-eighth of an inch broad, thicker in front than behind, and is attached anteriorly, or *arises* at the point of junction of the sclerotic and cornea, and passing backwards is *inserted* into the choroid in front of the retina. By its action it draws the ciliary processes towards the line of junction of the sclerotic and cornea, and compresses the vitreous humor which pushes forward the lens, and in this way adjusts the eye to the vision of near objects.

The *retina* is the delicate nervous membrane upon the surface of which the images of external objects are received. Behind, it is continuous with the optic nerve; in front it terminates by a serrated margin, the *ora serrata;* its inner surface is in contact with the hyaloid membrane which surrounds the vitreous humor; externally it is in relation with the choroid. In the centre of the posterior part, corresponding to the axis of

the eye, is seen a round, yellowish spot called the
limbeus luteus, or the yellow spot of Sömmering. The
retina in this part is very thin, and the sense of vision is
most perfect. About one-tenth of an inch to the inner
side of this spot is seen the entrance of the optic nerve;
here the power of vision is entirely absent.

The retina is composed of *three layers,* together with
blood-vessels and areolar tissue; the *external* or *columnar,*
consisting of solid columnar rod-like bodies, with hollow
cones interspersed at regular intervals; the *middle* or
granular layer, consisting of *two laminæ* of rounded
particles, the outer *globular,* the inner flattened, and look-
ing like pieces of money seen edgeways, called the
nummular layer; the *internal* or *nervous* layer, consisting
of an expansion of the terminal fibres of the optic nerve
and the nerve cells.

The *aqueous humor* occupies the anterior part of the
globe, and completely fills the anterior and posterior
chambers of the eye. It is a clear, thin fluid, having an
alkaline reaction, which is due to the presence of chloride
of sodium. In the adult, the anterior and posterior
chambers communicate through the pupil; but in the
fœtus, before the seventh month, the pupil is closed by
the membrana pupillaris. The persistence of this mem-
brane sometimes occasions congenital blindness.

The *vitreous humor* occupies the posterior four-fifths
of the globe. It is perfectly transparent; of the consis-
tence of jelly, and is surrounded by the hyaloid mem-
brane. It is hollowed out in front for the reception of
the crystalline lens. The vitreous humor contains some
salts and a little albumen. In the fœtus, a minute
artery passes through the centre to the posterior part of
the capsule of the lens, but it disappears in the adult.

The *crystalline lens,* enclosed in its capsule, is situated

in front of the vitreous humor and behind the pupil. The *capsule* is a transparent brittle membrane, highly elastic, and is disposed to curl inwards upon itself when ruptured. It surrounds the lens, to which it is connected by a layer of nucleated cells, and is held in position by the *suspensory ligament*, which connects it to the anterior margin of the retina. The suspensory ligament consists of two layers blended together; the *outer*, a milky, granular layer, comes in contact with the inner surface of the ciliary processes; the *inner*, is an elastic transparent membrane. This ligament forms part of the boundary of the posterior chamber of the eye; its posterior surface is separated from the hyaloid membrane by a triangular interval—the *canal of Petit*. This canal is about one-tenth of an inch wide, bounded in front by the suspensory ligament, behind by the hyaloid membrane, and the base is formed by the capsule of the lens.

The *lens* itself is a transparent double convex body, being more convex behind than in front. It measures about four lines transversely and three lines from before backwards. It appears to consist of concentric laminæ, like the coats of an onion, the central ones forming a hardened nucleus. It also appears to consist of three triangular segments; this is readily demonstrated by boiling or immersing it in alcohol.

There are therefore two forms of the lens in the human eye, viz., the *concavo-convex* or *meniscus*, as the cornea; and the *double-convex*, as the crystalline lens.

The essential parts of the eye, then, appear to be: 1st, a dark coat to absorb the rays of light—the choroid; 2nd, a nervous expansion to receive and transmit to the brain the impression of light—the retina; 3rd, a concavo-convex lens to collect the rays of light from the object and direct them inwards, and a double convex lens to

collect the rays of light and bring them to a focus, so as to form a correct image on the retina—the cornea and lens; 4th, a contractile curtain with a central opening, to regulate the quantity of light entering the eye—the iris. The eye is thus a simple optical instrument, endowed with vitality, and acting as required without assistance.

PHENOMENA OF VISION.—In order fully to understand the physiology of vision, it will be necessary to refer briefly to some of the laws which regulate the transmission of light.

1st,—Light travels in parallel rays through a medium of uniform density.

2nd,—When the rays meet with a medium of increased density, they become refracted, or changed in direction, towards a line which falls perpendicularly to the surface of the body which they enter.

3rd,—When the rays of light meet with a medium of diminished density, they are refracted from the perpendicular line.

4th,—When the rays of light fall upon a convex lens, they are collected; and if this be a double convex body, they come to a point or focus at a certain distance, depending on the greater or lesser convexity of the lens; the greater the convexity the shorter the distance, and vice versa. The image formed by the refraction of the rays of light in coming to a point or focus will be an inverted one. Those rays which pass through the lens towards its circumference come to a focus earlier than those that pass through the central axis, and thus a certain amount of spherical aberration is produced.

5th,—If the convexity of the lens be too great, the focus will be formed in front of the mirror or reflecting body. If too slight, the focus will be formed beyond it.

Vision is accomplished by the formation of an image of the object looked upon, on the internal surface of the retina. The impression made upon this produces a sensation, which is conveyed to the sensorium by the optic nerve, and the mind takes cognizance of it.

The image is formed in the following manner:—The rays of light are reflected from the object, and impinge on the outer convex surface of the cornea, through which they pass, becoming refracted towards the perpendicular. Those which fall on the circumference of the cornea impinge upon the iris, and are reflected, showing the color of this structure; those which pass nearer its centre, converge and enter the pupil. They now penetrate the crystalline lens, by means of which they are still further converged, their convergence being completed by their passage through the vitreous humor, and are brought to a focus on the inner surface of the retina. Since rays of light come from all points of the object, and are refracted in their passage, they must cross each other, and thus the image of the object on the retina will be inverted. The angle of crossing is called the *visual angle*. The inversion of the image may be shown by means of an eye of a recently killed animal, on which the image is distinctly formed in an inverted position. The inversion of the image is corrected by the sensorium.

When there is too great a degree of curvature of the cornea and lens, or of either of them, the rays of light are brought to a focus before they reach the retina, and the image is unseen. This condition is called *myopia*, or *near-sightedness*, and is most common in early life. On the other hand, if either or both of these bodies are preternaturally flattened, the rays of light are brought to a focus beyond the retina, as it were, and the image is imperfect; this is called *presbyopia*, or *far-sightedness*,

and is more common as age advances. Both these conditions may be corrected by the use of artificial lenses, which supply the natural defect.

ACCOMMODATION OF THE EYE TO VISION.—It is quite evident that some arrangement of the refractive parts of the eye is necessary to adapt it to the vision of near and distant objects. The precise manner in which this accommodation is effected is a disputed point; some maintain that it is due to an alteration in the position of the lens; while others regard it as being due both to an alteration in the shape and position of the lens. The eye, in its normal state, is accommodated for distant vision under the guidance of the recti muscles; this may be called its *passive* condition. The *active* accommodation of the eye for the vision of near objects is caused by the advance of the crystalline lens towards the cornea, and probably, also, by its increased convexity. It is advanced towards the cornea chiefly by the action of the *ciliary muscle* and partly by the compression exercised upon the posterior three-fourths of the eyeball by the recti muscles. It may therefore be inferred that the recti muscles adapt and adjust the eye for ordinary vision; while the ciliary muscle may be regarded as the *fine adjuster*, which regulates the eye for the vision of near or very small objects.

The formation of *distinct* and *correct* images on the retina is favoured by the action of the pupil, which prevents the rays of light from passing through any part of the lens but its centre, and thus preventing any tendency to *spherical aberration*. It is also further secured by the black coating of pigment on the inner surface of the choroid, which absorbs any rays of light which may be reflected within the eye, and prevents them being

thrown back again upon the retina, so as to produce dazzling of the image there formed.

The eye, in the uneducated state, cannot comprehend the properties of the objects seen, as color, form, &c., or the distance of the object; this is acquired by experience.

Impressions once produced on the retina *remain for a short time* afterwards; their duration depends on the intensity of the impression they have left; a momentary impression of moderate intensity continues about one-eighth of a second. This is the reason why the act of winking does not interfere with the continuous vision of surrounding objects. There is in front of the eye a certain space within which objects are perceived, and beyond which nothing can be distinctly seen ; this is called the *circle of vision.* For example, if the eye is intently fixed upon one word in the middle of the page, this word and those that immediately surround it, which are in the circle of vision, are distinctly visible, while those at the circumference are imperceptible while the eye remains fixed.

SIMULTANEOUS ACTION OF THE TWO EYES.—Although an image of the object is formed on each retina, yet the impression of the object conveyed to the mind is single. This is, no doubt, owing to the fact that the image is formed on identical points of both retinæ, giving rise to but one sensation, and the perception of a single image— the result of a mental act. This unity of action may be favoured by the continuation of the optic filaments across the anterior part of the *chiasma* of the optic nerve, but is not dependent on it; for, if the visual axis of one eye be altered, objects are seen double. This may be demonstrated by pressing the eyeball on one side with the finger in order to rotate it upon its axis, while the eyes are fixed upon some object, as a book or lamp.

HEARING.

The ear is the organ of hearing, and is composed of three portions, the *external, middle* and *internal* ear.

The *external ear* consists of an expanded portion, the pinna, and the meatus auditorius externus, or canal. Its use is to collect the vibrations of the air, and conduct them to the membrana tympani, or drum of the ear. This structure separates the external from the middle ear.

The *middle ear* or *tympanum* is situated in the petrous portion of the temporal bone, between the membrana tympani externally, and the internal ear or labyrinth internally. It is filled with air, and communicates with the pharynx through the eustachian tube. It is crossed by a chain of movable bones, which receives the impressions from the membrana tympani, and serves to transmit them to the internal ear, upon which the auditory nerve is distributed. The bones of the ear are the *malleus, incus,* and *stapes;* the handle of the malleus is received between the inner and middle layers of the membrana tympani, and the stapes is implanted in the fenestra ovalis.

The *internal ear* or *labyrinth* consists of the cochlea, semicircular canals, and vestibule. It consists of a series of cavities hollowed out of the petrous portion of the temporal bone, communicating externally with the middle ear through the fenestra ovalis and fenestra rotunda, and internally with the cranial cavity through the meatus auditorius internus, which transmits the auditory nerve. Within the osseous labyrinth is contained the membranous labyrinth upon which is distributed the filaments of the auditory nerve. The membranous labyrinth is filled with a transparent fluid, and is the essential part of the organ of hearing.

Sounds are produced from vibrations of the external atmosphere, which are collected by the external ear and transmitted to the membrana tympani. They are here modified by the tense or lax state of this membrane, produced by the action of the laxator and tensor tympani muscles. The modified vibrations from the membrana tympani are thence conducted along the chain of bones, and through them transmitted to the auditory nerve which is distributed to the labyrinth. The auditory nerve receives the impressions, and conveys them to the sensorium. From various experiments which have been performed, it appears that tension of the membrana tympani is unfavorable generally to the propagation of sounds, especially those of a low pitch. This may be shown by making a continuous effort of expiration or of inspiration, while the mouth and nostrils are closed by the hand. The effort of expiration causes the air to be forced into the tympanum through the eustachian tube, the membrana tympani is made to bulge out and become *tense*, and the hearing is indistinct. The effort of inspiration exhausts the air from the cavity of the tympanum, and the pressure from without causes the membrana tympani to bulge inwards and become tense, and is followed by temporary deafness.

The action of the chain of bones, as conductors, is enhanced by the presence of air in the cavity of the tympanum. It serves to isolate the bones so as to propagate the vibrations with concentrated intensity, and prevent the dispersion of sound. The air is supplied through the eustachian tube, which communicates with the pharynx just behind the posterior nares. When persons are listening very intently, the mouth is usually partly open, in order to allow a free current of air to pass through the eustachian tube.

The *vestibular portion* of the membranous labyrinth would appear, from its persistence in the lower animals, to be the essential part of the organ of hearing. It contains a fluid through which the impressions are finally communicated to the auditory nerve. A fluid substance seems best adapted to convey the impressions, in consequence of the soft condition of the structure of the nerve itself.

Any irritation or excitement of the auditory nerve, as congestion, cerebral disease, &c., may give rise to ringing or buzzing sounds in the ears. They are called *subjective sounds*, because they are produced by internal causes.

The sense of hearing varies much in different individuals, and in the same individual at different times; some will discern the most delicate sounds without the least difficulty, whilst others are wholly incapable of receiving similar impressions. Hearing may be impaired by a preternaturally dry state of the membrana tympani, or the partial closure of the external meatus by collections of wax, particles of dust, &c. In some of the lower animals the sense of hearing is very acute.

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CHAPTER XV.

VOICE.

THE organ of voice is the *larynx*, which is situated at the upper part of the air passages. It is in this organ that the sounds are originally produced; but they may be modified during and after their production, constituting, in man, the faculty of speech. The larynx, in man, is situated between the trachea and base of the tongue, at the upper and anterior part of the neck; it is narrow and cylindrical below, but is wide and triangular at the upper part. It is composed of cartilages, held together by ligaments, moved by numerous muscles, and is lined by mucous membrane. The upper part of the larynx presents a triangular-shaped orifice, wider in front than behind—the *glottis*. This opening is guarded by the *epiglottis*, which is situated in front, between the opening and the root of the tongue. The epiglottis closes the orifice during the passage of food or fluids, and prevents their passage into the larynx. Within the cavity of the larynx, on each lateral wall, may be seen two elevated bands, the *superior* and *inferior vocal cords*, separated by an elliptical depression—the *ventricle of the larynx*. Of the two vocal cords, the inferior consists of a band of yellow elastic tissue, covered by mucous membrane, and is called the true vocal cord; while the superior, which is formed entirely by a folding of the mucous membrane, is called the false vocal cord, because it is not concerned in the production of the voice.

The interval between the true vocal cords in the median line is called the *rima glottidis*, or chink of the

glottis, the narrowing or widening of which, and the tension or laxity of the cords, produce those variations of sound which are characteristic of the human voice. The narrower the opening and the tenser the cords, *cæteris paribus*, the higher the pitch of the note. The tension of the vocal cords and the size of the aperture are regulated by muscles which are situated in the larynx. It has been proved by observations on the living subject, as well as by experiments on the larynx of the dead body, that the sound of the voice is caused by the vibration produced by the currents of expired air passing over the margins of the true vocal cords. For example, if a free opening be made in the trachea, the sound of the voice ceases, but returns as soon as the opening is closed. Again, distinct vocal sounds may be produced in the dead subject by forcing a current of air through the larynx, and this will occur even when all the structures above the vocal cords are removed.

The *compass of the voice* varies from one to three octaves, and some singers may even exceed three octaves. Before puberty, the pitch of the male and female voice is nearly the same; but at this period the larynx undergoes certain changes, during which the voice is said to "*crack*," and the pitch falls about one octave. This change does not take place in eunuchs, and they retain the puerile character of voice. The different pitch of the male and female voice depends on the different length of the vocal cords in the two sexes. There are two kinds of male voice, the bass and tenor, and also two kinds of female voice, the contralto and soprano, all differing from each other in tone. The bass voice reaches lower than the tenor, and its strength lies in the low notes; while the soprano reaches the highest in the scale. The essential distinction between the different voices, however, con-

sists in the tone which distinguishes them when they are singing the same note. Most persons have the power of modulating their voices through a double series of notes of different characters, viz.: the notes of the natural voice, or *chest notes*, and the *falsetto notes*. The former are produced by the ordinary vibrations of the vocal cords ; the latter, in all probability, by the vibration of only the inner border of the vocal cords.

The voice is principally used in man in the formation of speech. The tone of the speech depends much upon the state of the chordæ vocales, and the development of the larynx; but *articulation*, or modification of the sounds, is effected by the lips, teeth, mouth, tongue, fauces and nose. The sounds produced in speech, or articulate sounds, are commonly divided into *vowels* and *consonants;* the former are sounded by the larynx, while the latter are produced by the interruption of the current of air above the larynx. All vowel sounds can be expressed in a whisper, without vocal tone—*mutely.* The consonants cannot be sounded except *consonantly* with a vowel, hence the name.

Ventriloquism appears to consist in the varied modification of the sounds produced in the larynx, so as to imitate the voice as heard from a distance. It is accomplished by taking a full inspiration, then keeping the muscles of the neck and chest fixed, and speaking with the mouth almost closed and the lips motionless, while air is slowly expired through a narrow glottis, care being taken that none of the expired air passes through the nose. The attention of the audience is at the same time generally directed to that part of the room from which the sound is expected, a circumstance which adds materially to the success of the performance.

Stammering, in most instances, is an affection of the

nervous system, and not of the articulating organs. It consists in an imperfect power of co-ordinating the muscles of speech, associated with a spasmodic action of certain muscles concerned in the formation of the voice. Some stammer only on attempting to articulate certain letters; others do so at every attempt to speak. It is much increased by any mental excitement, surprise, &c. Females seldom stammer, although more subject to nervous disorders generally than males. The cure of stammering is best effected by training the muscles in the production of the sounds most easily formed, and thence proceeding to the most difficult; to avoid all causes of excitement to the patient, and prevent him from thinking about his condition as much as possible. Some have recommended the use of pebbles in the mouth, or small pieces of ivory; but it is very doubtful whether or not these can be of any great service.

CHAPTER XVI.

REPRODUCTION.

THE process of reproduction comprises the several provisions made for the multiplication of individuals and the propagation of the species. There are three modes by which the multiplication of individuals takes place in the lower orders of organized beings, while in the higher forms it is restricted to one of these types.

The *first* and simplest *mode* consists in the division of the being into two, each of these again subdividing into two others, and so on. This is *multiplication by subdivision; or, fissiparous multiplication*. It is seen in the lowest plants, as in the cells of fungi and lichens, and also in cartilage cells. The joints of the common tape-worm multiply in this manner. Some organizations, as the polyp, when divided artificially into segments, have the power of developing into a perfect form from each segment.

The *second mode* takes place by a process of *gemmation*, or budding from the parent stalk. These buds, which consist of a mass of cells, are at first entirely nourished by the parent stalk, but gradually become less dependent, and at last detach themselves and maintain a separate existence. This is termed *multiplication by gemmation* or *gemmiparous multiplication* The hydra affords a good example of this variety. The first change which is observed is a slight elevation on the surface, which assumes a globular form; a cavity is then formed in the interior, which communicates

with the parent. After a time this channel of communication closes, the newly-formed polyp drops off, and a new creature is formed.

The *third mode* is called *true generation*, and consists in the union of the contents of two different cells, the *sperm cell* and the *germ cell*, from which is produced a new being differing from both. The simplest form of this process is seen in the Algæ in *conjugation*. At first the opposite cells of two filaments form a process on the sides next each other; these at length meet and fuse, the contents of the two cells becoming mixed and forming a new body termed a *spore* or sporangium, from which the new plant is formed.

In the higher plants and animals distinct organs are set apart for the formation of the sperm cells and germ cells; the former are produced by the male organs of generation; the latter by the female. Through the action of the contents of the sperm cell the ovum becomes impregnated, and an embryo is formed from which the adult animal is gradually developed. In some instances, however, as in the class of insects, several distinct changes or *metamorphoses* are passed through before the animal is fully developed, as the larva, chrysalis, and perfect animal. In other instances the embryo, instead of being developed into the perfect animal, only attains a sort of larval condition, and there may be several series of these imperfect or larval forms, each larva producing other larvæ, until at last they give rise to perfect forms, which propagate only by the production of ova. This is called by Prof. Owen *metagenesis* and *parthenogensis*.

ACTION OF THE MALE.—The male furnishes the spermatic fluid or sperm, which is secreted by the *testes*. This fluid contains the sperm cells in which are developed

the *spermatozoa*. These are the essential elements of the spermatic fluid, and are set free by the breaking down of the parent cell. They are transparent filamentous bodies, about $\frac{1}{600}$ of an inch in length, and from $\frac{1}{5000}$ to $\frac{1}{10000}$ of an inch in thickness, being thicker at the anterior extremity or head than the posterior or tail. Their movement is accomplished by the constant vibration of the tail; they are said to move at the rate of one inch in seven and one-half minutes. Their movements may be suspended, and their power of impregnation destroyed by the action of solutions which act chemically upon them, as solution of nitrate of silver, sulphate of zinc, chloride of zinc, &c. In the female organs of generation the movements continue longer than in any other situation.

In the act of coition the seminal fluid is deposited in the vagina, and the spermatozoa make their way into the uterus and meet the ovum at or soon after its discharge from the ovary. The fecundation of the egg may take place either in the uterus, fallopian tube or ovary, in each of which situations spermatozoa have been found after coition. The high degree of nervous excitement which attends the act of coition is followed by a corresponding amount of depression, and the too frequent repetition of it is very injurious to the general health. This is still more the case with that *solitary vice* which it is to be feared is practised by too many youths. Nothing is more certain to reduce the powers both of *body* and *mind* than excesses in this respect.

ACTION OF THE FEMALE.—The essential parts of the female organs of generation, and counterpart of the testes, are the *ovaries*, in which the ova are developed. The ovary is partially invested by peritoneum, beneath which is the proper covering of the organ—the *tunica albuginea*

—which is a dense, firm membrane, enclosing a highly vascular fibrous structure—the *stroma*. In the meshes of this tissue are imbedded the Graafian vesicles, which contain the ova. They vary in size from a pin's head to a pea, and are from fifteen to twenty in number. Each *Graafian vesicle* consists of an *external vascular* and an *internal serous coat*, named the *ovicapsule*. The internal coat is lined internally by a layer of nucleated cells, called the *membrana granulosa*, and within this is situated the *ovum*. The cells of the membrana granulosa are accumulated in large numbers round the ovum, forming a granular zone, the *cumulus, discus proligerus*, *retinacula* or *chalaza*.

The *ovum* is a small spherical body, about $\frac{1}{120}$ to $\frac{1}{240}$ of an inch in diameter. It consists externally of a transparent envelope, the *zona pellucida* or *vitelline membrane*, and within this is the *yelk* or *vitellus*. Imbedded in the substance of the yelk is a small vesicular body, the *germinal vesicle*, and within the germinal vesicle is the *germinal spot*. The latter varies in size from $\frac{1}{3600}$ to $\frac{1}{2400}$ of an inch.

At the approach of the menstrual period one or more of the Graafian vesicles enlarges, approaches the surface of the ovary, and when mature, forms a small projection on the surface. It finally bursts and the ovum escapes, being caught by the fimbriated extremity of the fallopian tube, and by it conducted to the uterus.

CORPUS LUTEUM.—As the ovum escapes it leaves behind it the external vascular and the internal serous coat of the Graafian vesicle, the cavity of which is immediately filled with a bloody fluid which soon coagulates, and the cicatrix presents a yellowish appearance; hence it has been called the *corpus luteum*. After a short time the coagulum contracts, and the membranes

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become convoluted and hypertrophied, so that when the
corpus luteum is divided transversely, about three weeks
after its formation, it is seen to consist of a central firm
coagulum surrounded by a convoluted wall of a reddish
yellow color.

Corpora lutea are divided into *true* and *false;* the
former are found only when conception has taken place;
the latter are met with in the unimpregnated state. They
are both produced in the same way, and for the first
three weeks there is no distinction between them; but
the true corpus luteum becomes larger and remains
longer than the false, in consequence of the increased
vascularity of the parts after impregnation. At the end
of the third week they each measure about one-half or
three-fourths of an inch in diameter. After this the
false corpus luteum begins to diminish, and entirely dis-
appears in the course of about two months, while the
true increases in size until about the third or fourth
month, and then gradually declines until after parturi-
tion, when it rapidly disappears.

ACTION OF THE OVIDUCTS.—In the human subject the
oviducts commence by a wide-fringed expansion—the
fimbriated extremity of the fallopian tubes. The ovum,
in passing through the fallopian tube to the uterus,
absorbs a certain quantity of fluid, increases in size, and
if impregnated soon presents a number of minute villi
on its surface which give it a *shaggy* appearance. This
is called the chorion.

In fowls, as the ovum leaves the ovary it enters the
oviduct, and in passing the first portion, which is about
two inches in length, it absorbs fluid and becomes more
flexible and yielding. In the second portion, which is
about nine inches in length, the mucous membrane is
thick and glandular. In the upper part it secretes a

viscid fluid which surrounds the yelk and forms a gelatinous deposit around the vitelline membrane, and from the rotation given to the egg by the oviduct the two ends become twisted in opposite directions from the poles of the egg and form the *chalazæ*. The membrane which connects the chalazæ is called *chalaziferous membrane*. In the rest of this portion an albuminous secretion is poured out to form the *albumen* or white of the egg. In the third division, which is about three inches in length, a material is poured out which condenses and forms three fibrous membranes, an *internal, middle* and *external*. The egg then passes into the fourth division, which is about two inches long. This pours out a secretion containing calcareous matter, which is deposited in the meshes of the external membrane of the egg, forming the shell. After the expulsion of the egg, evaporation of some of the watery ingredients takes place through the pores of the shell, its place being filled with air. The air cavity is situated between the internal and middle membranes at the large end of the egg. The vitellus is the essential part of the egg, the white simply contributing to the nourishment of the chick until it leaves the shell, and the membranes and shell affording the protective coverings.

DEVELOPMENT OF THE OVUM.—After the ovum is impregnated a remarkable change takes place, which is known as the spontaneous division or *segmentation* of the vitellus. A furrow first shows itself surrounding the vitellus in a vertical direction, which gradually becomes deeper until it has divided into two portions. Each of these portions is again subdivided into two, and the four segments thus produced are divided into sixteen, and sixteen into sixty-four, and so on, until the whole mass has assumed a *mulberry appearance*, and is finally

converted into "true animal cells," which, adhering
together, form the *blastodermic membrane.* These cells
are sometimes called the *primordial* or *primitive* cells, or
germinal vesicles. The albuminous matter liquefies
and gradually passes by osmosis through the vitelline
membrane into the interior of the egg. The blastoder-
mic membrane then divides into two layers, the *external
blastodermic, serous* or *animal layer,* and the *internal blas-
todermic, mucous* or *vegetative layer,* both of which are
composed of cells. The former produces the spinal col-
umn and organs of animal life; the latter the alimentary
canal and organs of vegetative life. Up to this stage
the process is the same in all animals, birds, fishes,
reptiles and mammalia.

The simplest form of development is seen in the
egg of the *frog.* The egg, when discharged from the
body and fecundated, is deposited in the water, sur-
rounded by a layer of albuminous matter, and is freely
exposed to the light and heat of the sun. The first
sign of organization is the thickening and condensation
of the external blastodermic membrane in one part, form-
ing an elongated oval spot with opaque edges. This is
called the *embryonic spot.* Enclosed within this is a
narrow transparent space, the *area pellucida,* in the cen-
tre of which is a longitudinal line, the *primitive trace.*
On each side of the primitive trace in the area pellucida
the blastodermic membrane rises up in two plates, called
the *dorsal plates,* which at last meet and enclose a foramen,
the *spinal canal,* in which nervous matter is deposited
to form the spinal cord, being enlarged anteriorly to
accommodate the brain. At the same time the external
blastodermic membrane grows outwards and downwards,
to form the abdominal walls which embrace the internal
blastodermic membrane and the fluid in its cavity. Be-

neath the spinal canal is formed a cartilaginous cord, which is called the *chorda dorsalis*, from which the vertebræ are subsequently developed. As the whole mass grows rapidly, the head becomes thick and voluminous, while the tail begins to project backwards, and the embryo assumes an elongated form. The internal blastodermic layer forms the alimentary canal, the mouth and anus being developed by atrophy and perforation of the external layer of the blastodermic membrane at these points respectively. The young tadpole then ruptures the vitelline membrane and escapes, after which the extremities are developed by a process of budding or sprouting, and when fully formed, the tail atrophies and disappears. The animal at first breathes by gills; but these are subsequently replaced by the lungs.

In the *fish*, the internal blastodermic membrane is divided into two parts by a constriction, one of which forms the intestinal canal, while the other, remaining outside, forms the *umbilical vesicle*, which is surrounded by a portion of the external blastodermic membrane, and is gradually atrophied as development proceeds.

In the *human embryo* the umbilical vesicle becomes more completely separated, and forms a cord by its constriction, at the distal extremity of which is situated the vesicle, which contains a clear transparent fluid. The umbilical vesicle may continue until the end of the third month, after which it gradually disappears in the advancing development of the adjacent parts.

FORMATION OF THE AMNION AND ALLANTOIS.—These are two accessory organs which belong to the higher order of animals. The amnion is formed from the external layer of the blastodermic membrane, and the allantois from the internal; the former forms a cavity or sac containing fluid in which the fœtus floats; the latter is a

vascular structure destined to bring the blood of the embryo to the external sources of nutrition and atmospheric influence. These are not necessary to the development of the egg of the frog and fish, since absorption can readily take place through the vitelline membrane from the media by which they are surroundud.

The *amnion* is first formed; this takes place by double foldings of the external blastodermic membrane, which pass upwards from the abdominal surface on all sides of the embryo, until they meet at a point over the back which is called the *amniotic umbilicus.* Fusion then takes place at this point, the inner layer of the fold forming the amnion, the outer, blending with the vitelline membrane, forms the external investing membrane of the ovum. A shut sac is thus formed between the amnion and the fœtus called the amniotic cavity, which is filled with a clear fluid—the *liquor amnii.*

About this time the *allantois* commences as a prolongation or diverticulum from the posterior part of the intestinal canal, and follows the course of the amniotic fold which preceded it, lying between its two layers. It gradually increases in size until it covers the body of the embryo, together with the amnion; it then meets and fuses over the back as did the amniotic folds. It therefore lines the whole internal surface of the investing membrane of the ovum with a flattened vascular sac, the vessels of which come from the interior of the body of the embryo. The cavity of the allantois is continuous with the cavity of the intestines. The umbilical vesicle is situated between the amnion and allantois.

In the chick the allantois comes immediately in contact with the shell membrane, taking the place of the albumen which has been liquefied and absorbed, and through the pores of the shell an interchange of gases

takes place, oxygen being absorbed from the air, and carbonic acid exhaled from the blood-vessels of the allantois. It will be seen, therefore, that a true respiration takes place by means of the allantois through the external covering. When the chick arrives at maturity, it breaks open the shell and escapes from its confinement, the allantoic vessels are torn off at the umbilicus, and the allantois remains behind in the abandoned egg shell.

FORMATION OF THE CHORION.—In the human embryo the obliteration of the cavity of the allantois takes place very early, so that it does not enclose a cavity, but fuses together, and uniting with the outer fold of the amnion and the vitelline membrane, constitutes the *chorion.* Hence there are two membranes in the fœtus, the *amnion* and the *chorion*, and the umbilical vesicle is situated between the two. The chorion in the human subject is identical with the allantois of the lower animals, its chief peculiarity being that its opposite surfaces are adherent instead of enclosing a cavity. The next peculiarity of the chorion is that it becomes shaggy, owing to the number of minute *villi* or "villosities" which are found on its surface. The villi may be distinctly seen as soon as the ovum has reached the uterine cavity, even when it is still very small. They continue to grow and elongate, and divide into a number of branches by the process of sprouting, each filament terminating in a rounded extremity. The whole tuft bears a certain resemblance to some varieties of seaweed. The vessels of the chorion pass into the villosities, forming loops like the vessels in the villi of the small intestines. The villi of the chorion therefore bear a slight resemblance to those of the small intestines; but are unlike any other structure of the body, and their presence in the uterus or its discharges may be considered as a *proof of pregnancy.*

The villi are the organs through which nourishment is supplied from without, at this stage of existence. At about the end of the second month the villi become atrophied, except at the part which corresponds with the insertion of the fœtal vessels, and the chorion becomes partly *bald.* Those villi which remain continue to grow, and ultimately form the placenta, which attaches itself to the uterus.

PREPARATION OF THE UTERUS TO RECEIVE THE OVUM.—As the impregnated ovum is about to descend into the cavity of the uterus, the mucous membrane becomes greatly hypertrophied, tumified, and vascular, and projects in rounded eminences into the uterine cavity. The tubules or follicles are elongated and enlarged so that their open mouths may be seen with the naked eye. The hypertrophied mucous membrane is called the *decidua vera.* When the ovum reaches the uterus it insinuates itself between the opposite surfaces of the mucous membrane, and becomes lodged in one of the depressions between the projecting eminences of the decidua, where it subsequently becomes fixed. At this point a rapid development of the mucous membrane takes place, and a folding or prolongation of the decidua surrounds and envelopes the ovum, called the *decidua reflexa.*

It was formerly supposed that the decidua was an entirely new product thrown out by exudation from the surface of the uterus, similar to the inflammatory exudation of croup, &c. This surrounded the whole internal surface of the uterus, and was called the *decidua vera,* and as the ovum passed from the fallopian tube into the uterus it pushed before it a folding of the decidua vera, which formed the *decidua reflexa.* The closure of this folding behind the ovum was called the *decidua serotina.* This was the theory of William Hunter. It is now

known to be no other than the mucous membrane itself, very much thickened and hypertrophied.

FORMATION OF THE PLACENTA.—The placenta is formed partly by the vascular tufts of the chorion, and partly by the hypertrophied mucous membrane to which they are connected. About the commencement of the third month the villi which are destined to enter into the formation of the placenta continue to elongate, and penetrate or are pushed into the follicles of the mucous membrane (like the fingers into a glove), which are enlarged for their reception. The growth of the villi and that of the follicles go on simultaneously, and keep pace with each other. The capillaries of the villi are enlarged and become tortuous, and those on the exterior of the follicles enlarge excessively and become dilated into wide *sinuses*, which are filled with blood derived from the arteries of the uterus, so that two membranes intervene between the capillaries of the villi and the sinuses of the uterus, viz., the covering of the villi and the lining membrane of the follicles. These afterwards fuse together and blend with the walls of the capillaries on the one hand, and the walls of the sinuses on the other. The tufts of the villi are prolonged into the sinuses, pushing before them the walls, and are everywhere bathed with the blood of the mother. The process of osmosis takes place through the thin fused membrane, there being no direct communication between the foetal and maternal vessels. The placenta is fully formed about the commencement of the fourth month, and constitutes the channel through which nourishment is conveyed from the mother to the fœtus. The nutritive material passes from the blood of the mother through the intervening membrane by *osmosis*, and enters the blood of the fœtus. Besides, the placenta is an organ of exhalation as well as

of absorption. The impurities circulating in the blood of the fœtus are here discharged into the maternal vessels, to be removed by the excretory organs of the mother; so that the placenta may be said to fulfil the double office of the lungs and stomach in the fœtus. In consequence of the intimate relation existing between the mother and the fœtus, there is no doubt that nervous impressions experienced by the former, such as fear, anger, disgust, &c., which disturb the circulation, may occasion deformities and deficiencies of various kinds, nævi, warts, &c., in the latter. The circulation in the fœtus has been already described. (See page 205.)

UMBILICAL CORD AND AMNIOTIC FLUID.—The umbilical cord, or funis, is the connecting link between the fœtus and placenta. In early life it is very short, and consists of that portion of the allantois or chorion next the abdomen. The umbilical vesicle is situated between the amnion and chorion, the rest of the space being filled with a gelatinous fluid. The amnion continues to expand, the quantity of liquor amnii increases, and about the beginning of the fifth month the amnion comes in contact with the chorion, the umbilical vesicle and gelatinous fluid gradually disappearing. The umbilical cord at the same time elongates in proportion to the increasing size of the amnion, and towards the close of gestation the amnion and chorion blend together and constitute what is commonly called the "membranes." As the cord lengthens it twists from right to left. It consists of the two umbilical arteries, the umbilical vein, the urachus, and the remains of the umbilical vesicle, imbedded in a gelatinous material and surrounded by a folding of the amnion. The cord at full term varies in length from one to three feet.

GENERAL DEVELOPMENT OF THE EMBRYO.—The development of the different parts formed by the external blastodermic membrane have been already casually referred to. The internal blastodermic membrane forms the intestinal canal and organs of vegetative life. The intestinal canal is formed at a very early stage, and is at first straight, but after a time it becomes convoluted. The bladder is next developed from the *urachus;* this is a hollow tube which connects the posterior part of the intestines with the allantois. As the abdomen closes at the umbilicus, the part of the urachus outside the body forms part of the cord, while the portion included in the abdomen becomes dilated and fusiform at the lower part, and forms the bladder. The liver is also developed at a very early period, and is of large size in proportion to the body; it secretes a substance which is thrown into the intestines, termed the *meconium.* The Wolffian bodies are developed about the end of the first month. They take the place of the kidneys, by which they are replaced about the end of the second month. The ducts which connect the Wolffian bodies to the bladder become the vasa deferentia or fallopian tubes as the case may be. The development of the heart has been referred to, (page 156). The lungs are developed by small tubercles in front of the œsophagus, and gradually extend laterally to fill the thorax, and a growth extending upwards forms the trachea.

PARTURITION.—The discharge of the ovum is termed parturition. This is effected by the contraction of the muscular fibres of the uterus, assisted in the second stage by the contraction of the diaphragm, abdominal, and other muscles of the body. The placenta is separated from its attachment to the inner surface of the uterus, during which the sinuses are lacerated and a certain

amount of hemorrhage occurs, which, however, is soon
arrested by the contraction of the uterus and consequent
closure of the mouths of the vessels leading to the
sinuses.

After parturition the uterus undergoes the process
of *involution*. This consists in a diminution in the size
of the uterus, and a change in the appearance of the
muscular fibre cells. The muscular fibres of the uterus,
during gestation, are very much increased in size, and
granular in appearance. After parturition they appear
to undergo a fatty degeneration; fat globules make their
appearance in the interior of the muscular fibre cells;
the tissue becomes soft and is gradually absorbed, its
place being supplied by new cell fibres.

FINIS.

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