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PHYSIOLOGY

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NOTES

ON

PHYSIOLOGY

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PREFACE

TO

THE FIFTH EDITION.

IN the present edition the text has been thoroughly revised, and some new matter and seventeen new woodcuts have been added. The latter have been mostly taken from Stirling's translation of Landois' 'Human Physiology.'

H. A.

ST. JOHN STREET, MANCHESTER:
Feb. 1889.

PREFACE TO THE FIRST EDITION.

THESE Notes were originally compiled for the use of students of the Liverpool School of Medicine, when preparing for the primary examination of the College of Surgeons. They now appear in print, in the hope that they may prove useful to a wider class of students. The information they contain is founded, to a large extent, on Quain's 'Anatomy' (8th ed.), Gray's 'Anatomy,' and Foster's 'Text-Book of Physiology,' to which works the student is referred for his general reading. Fifty questions, taken for the most part from the Calendar of the College of Surgeons, are added.

H. A.

MANCHESTER :
Sept. 1878.

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CHAPTER I.

PHYSIOLOGICAL CHEMISTRY.

THE ultimate constituents of the human body comprise some fifteen or sixteen of the elements. They are—

Oxygen	Sulphur	Sodium	Silicon
Hydrogen	Phosphorus	Potassium	Fluorine
Carbon	Chlorine	Magnesium	Lithium
Nitrogen	Calcium	Iron	Manganese

Three only of the above elements occur in the body in their free state; viz., oxygen enters through the lungs and is found in all the fluids of the body, either in solution or loosely combined. Nitrogen is also found dissolved in the fluids of the body. Hydrogen occurs as a product of decomposition in the alimentary canal.

These sixteen elements are combined in various proportions, to form the compounds which exist in the tissues of the body. The simpler bodies are crystalline, as chloride of sodium and urea; the more complex, as albumen, are amorphous. The former, being crystalloids, readily pass out of the body through the excretory organs; the latter, being colloids, are better suited to form part of its tissues.

They may be divided into the following classes :—

I. Inorganic Compounds.
II. Organic Crystalline Salts, or the Urea Group.
III. Carbo-hydrates, or Sugars.
IV. Hydro-carbons, or Fats and their Allies.
V. Albuminous, or Proteid Compounds.
VI. Albuminoid, or Gelatinous Compounds.

I. The Inorganic Compounds include water, acids, bases, and salts.

Water, H_2O, forms about 70 per cent. of the whole body ; it is one of the chief constituents of the juices and tissues, and is a general solvent, by means of which various materials may be taken in as food, or excreted from the body. The various organs or liquids contain variable quantities ; thus, enamel contains 2 per cent ; saliva, 99·5 per cent.

Acids consist of—

Hydrochloric, which exists free in the gastric juice and in combination with bases in all the tissues and fluids.
Carbonic, with bases in blood, teeth, and bones.
Phosphoric, in combination with bases, in the bones, teeth, corpuscles, brain, &c.
Sulphuric, with bases, in blood, serum, and secretions.
Hydrofluoric, with bases, in bones and teeth.
Silicic, with bases in hair, epidermis.

Bases—

Sodium in all tissues and fluids.
Potassium, in the muscles, red blood corpuscles, nervous tissues, secretions.
Ammonium, sparely in the gastric juice, urine, saliva.

Calcium, in bones and teeth and fluids.

Magnesium accompanies lime.

II. The Organic Crystalline Bodies are very numerous; for the most part they are the result of the disintegration of albuminous material, and nearly all contain nitrogen. The principal members of this group, are urea, uric acid, xanthin, hypoxanthin, hippuric acid, kreatin, kreatinin, lactic acid, lecithin, neurin, cerebrin, leucin, tyrosin, and cholesterin.

Urea, CH_4N_2O or $CO(NH_2)_2$ forms the chief constituent of the solid portions of the urine of man and the carnivorous animals; it is also found, but less freely, in the urine of herbivorous animals, reptiles, and birds. It exists in minute quantities in the blood, lymph, and liver. It is found in larger quantities in all the fluids of the body in advanced Bright's disease.

Preparation—artificially.—By heating a mixture of potassic ferrocyanide and manganic dioxide on an iron sheet, potassic cyanate is formed, and is dissolved out with water. The potassic cyanate is treated with ammonium sulphate, ammonium cyanate and potassic sulphate being formed; the potassic salt is removed by crystallisation, and the mother liquor, on evaporation to dryness, and extraction of the dried residue with alcohol, yields urea.

It can also be made artificially by heating ammonium cyanate, a rearrangement of atoms taking place.

$$\underset{\text{Ammonium cyanate}}{NH_4CNO} = \underset{\text{Urea.}}{(NH_2)_2CO}$$

From urine.—The urine is evaporated to a thin syrup, and its own volume of colourless nitric acid added; nitrate of urea is formed and readily crystallises. The nitrate is decolourised by animal charcoal and recrystallised. To obtain the urea pure, the nitrate is decomposed by barium carbonate, the barium nitrate which is formed is allowed to crystallise out, and the liquor containing urea evaporated to dryness and extracted with alcohol.

Properties.—Urea crystallises from water in long thin colourless needles. If formed slowly the crystals are four-sided, and have pyramidal ends. It is a colourless substance of saline taste, soluble in water and alcohol, insoluble in ether. Urea is closely related (being isomeric) with ammonium cyanate, NH_4CNO, and carbamide, $(NH_2)_2CO$.

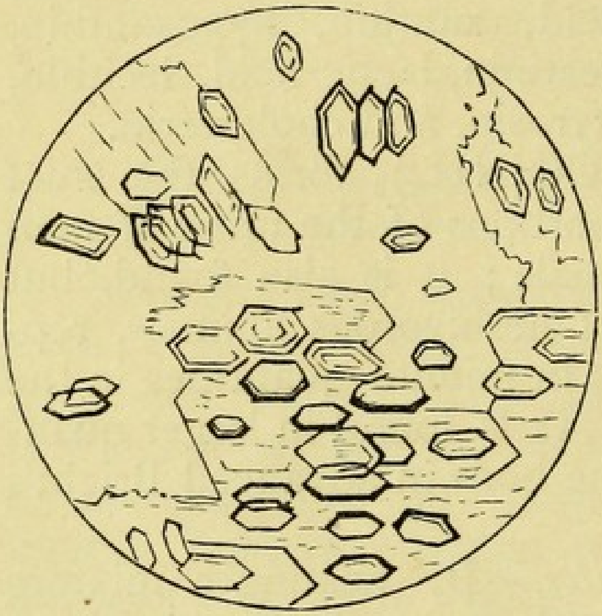

Fig. 1.—Crystals of nitrate of urea.

Amides are compounds in which hydroxyl HO is replaced by NH_2. Thus, if in the molecule of carbonic acid, $CO(HO)_2$, we replace one HO we get monamide or carbamic acid ; if we replace both we get carbamide or urea.

$$\mathrm{CO}\begin{matrix}\mathrm{HO}\\ \mathrm{HO}\end{matrix} \qquad \mathrm{CO}\begin{matrix}\mathrm{HO}\\ \mathrm{NH_2}\end{matrix} \qquad \mathrm{CO}\begin{matrix}\mathrm{NH_2}\\ \mathrm{NH_2}\end{matrix}$$

Carbonic acid. Monamide. Carbamide, or urea.

Characteristic reactions and tests—(1) Pure nitric acid gives in a strong solution of urea a crystalline precipitate of urea nitrate. These crystals are colourless six-sided prisms, and are sparingly soluble in alcohol (fig. 1).

(2) Mercuric nitrate gives a white precipitate in the absence of chlorides.

(3) Nitrous and hypobromous acids decompose urea, nitrogen and carbonic acid being liberated.

$$CO(NH_2)_2 + 3HBrO = CO_2 + N_2 + 2H_2O + 3HBr$$
$$\text{Urea} + \text{Hypobromous acid} = \text{Carbonic acid} + \text{Nitrogen} + \text{Water} + \text{Hydrobromic acid}$$

(4) Fused with caustic potass, or treated with concentrated sulphuric acid, urea is resolved into ammonia and carbonic acid. The same change takes place in the presence of decomposing animal matters as in stale urine, the urine becoming ammoniacal :—

$$CO(H_2N)_2 + 2H_2O = (NH_4)_2CO_3.$$
$$\text{Urea} + \text{Aq.} = \text{Ammonium carbonate.}$$

Uric Acid, $C_5H_4N_4O_3$, is present in small quantities in the urine of man and the carnivora, in smaller quantities in that of the herbivora. It never occurs in the free state in normal urine, but in combination with soda, potash, or ammonia. It is present in the spleen, liver, and also in the blood in gout ; and urinary calculi are often composed of it. It forms about 90 per cent. of the solid residue of the urine of snakes, and is present in large proportion in the urine of birds.

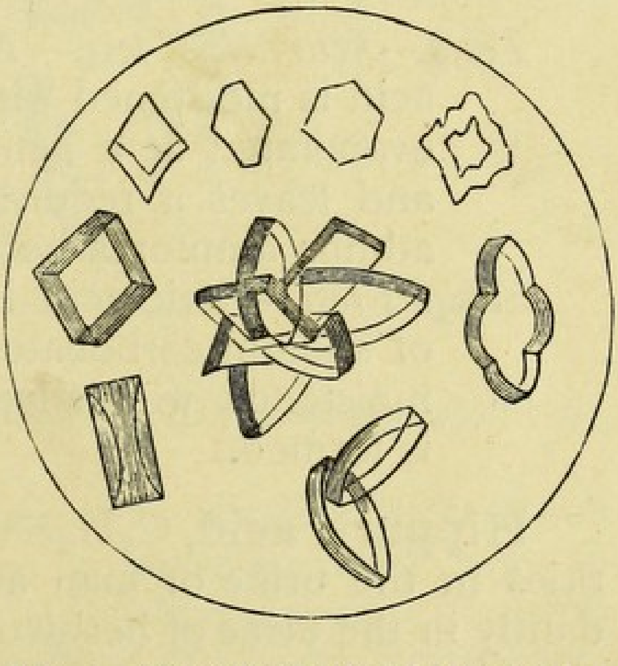

FIG. 2.—Crystals of uric acid from urine.

Preparation.—It is best obtained from the excrement of snakes, by boiling with caustic potass until the urate of ammonium of which it consists is decomposed, ammonia being evolved. The uric acid is precipitated in an impure state by adding hydrochloric acid. The precipitate is re-dissolved in potass and re-precipitated by acid.

From urine.—By acidulating with hydrochloric acid, and allowing to stand for twenty-four hours, reddish crystals of impure uric acid being precipitated (fig. 2).

Properties.—Pure uric acid is a white crystalline powder, almost insoluble in cold water, insoluble in alcohol and ether. The crystals vary in shape, but are for the most part of a rhombic form. It is dibasic, and combines with bases to form soluble salts, as the urates of ammonium, potassium, and sodium.

By oxidation, uric acid yields: In presence of acids, alloxan and urea; in presence of alkalies, allantoine and carbonic acid. Uric acid has never been formed artificially.

Tests—Murexide test.—A small portion of uric acid is moistened with strong nitric acid, and evaporated at a gentle heat. It effervesces, and leaves a reddish colouration, which on adding ammonia becomes purple.

Schiff's test.—Uric acid is dissolved in a solution of sodium carbonate; and dropped on paper moistened with silver nitrate a brown stain is formed.

Hippuric acid, $C_9H_9NO_3$, occurs in small quantities in the urine of man and carnivora, but abundantly in the urine of herbivora; in the latter it is the chief means of passing N out of the body. It is precipitated by iron salts. Heated in a test-tube, it is decomposed into benzoic acid and ammonic benzoate, which condenses on the sides of the tube, and an oily substance remains behind. Most of its other salts are soluble. It crystallises in fine needles (*see* fig. 3).

Kreatin, $C_4H_9N_3O_2$, exists in the muscles, and can be obtained from extract of meat. It occurs in colourless oblique rhombic prisms. Soluble in hot, sparingly soluble in cold water. It has a neutral re-

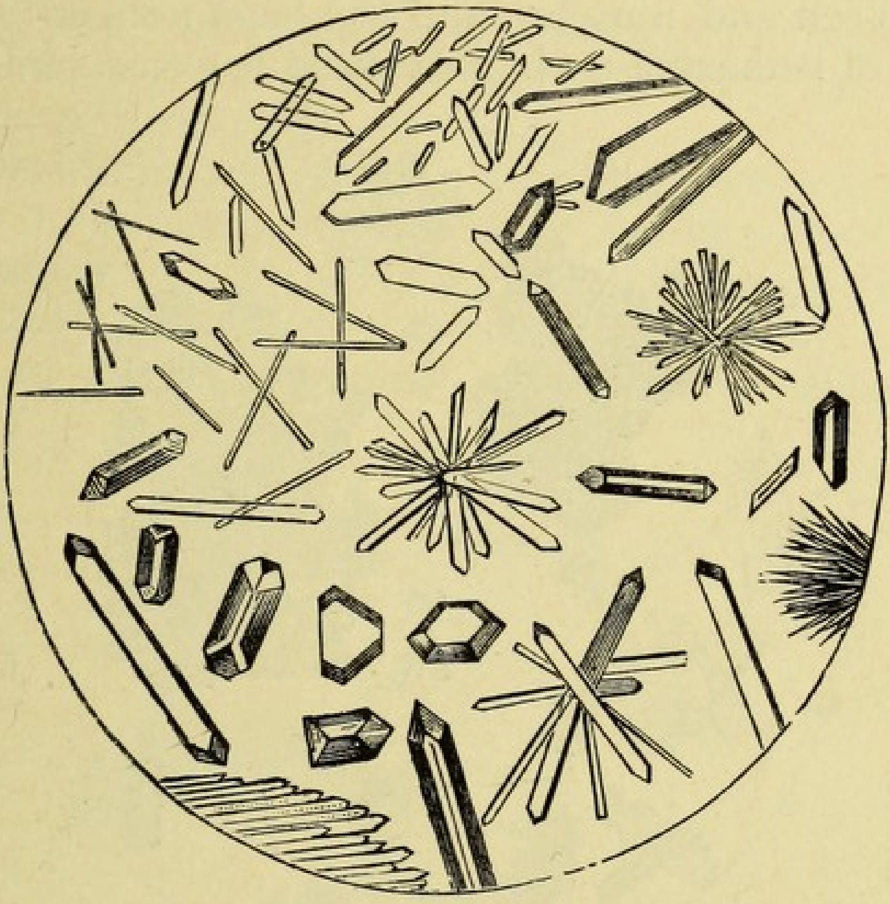

FIG. 3.—Crystals of hippuric acid (Landois and Stirling).

action, and when boiled with baryta water, splits up into urea and sarcosin.

Kreatinin, $C_4H_7N_3O$, is an alkaline body which exists in small quantities in muscle-extract and in urine. It crystallises in colourless prisms. Kreatin, on boiling with HCl, ~~takes up~~ H_2O and forms krea- * gives off tinin. It can be separated from the urine by precipitating with mercuric chloride. It unites with zinc chloride, forming crystals, which help to identify it (*see* fig. 4).

Xanthin, $C_5H_4N_4O_2$, exists in small quantities in urine, in the spleen, and muscles. It is insoluble in water, soluble in nitric and hydrochloric acid. When heated with nitric acid and evaporated, a yellow residue is left. It occurs in some calculi.

Hypoxanthin, $C_5H_4N_4O$, occurs in the tissues of the spleen and muscles, and has been noticed in the urine of leukæmia ; when oxidised it forms xanthin.

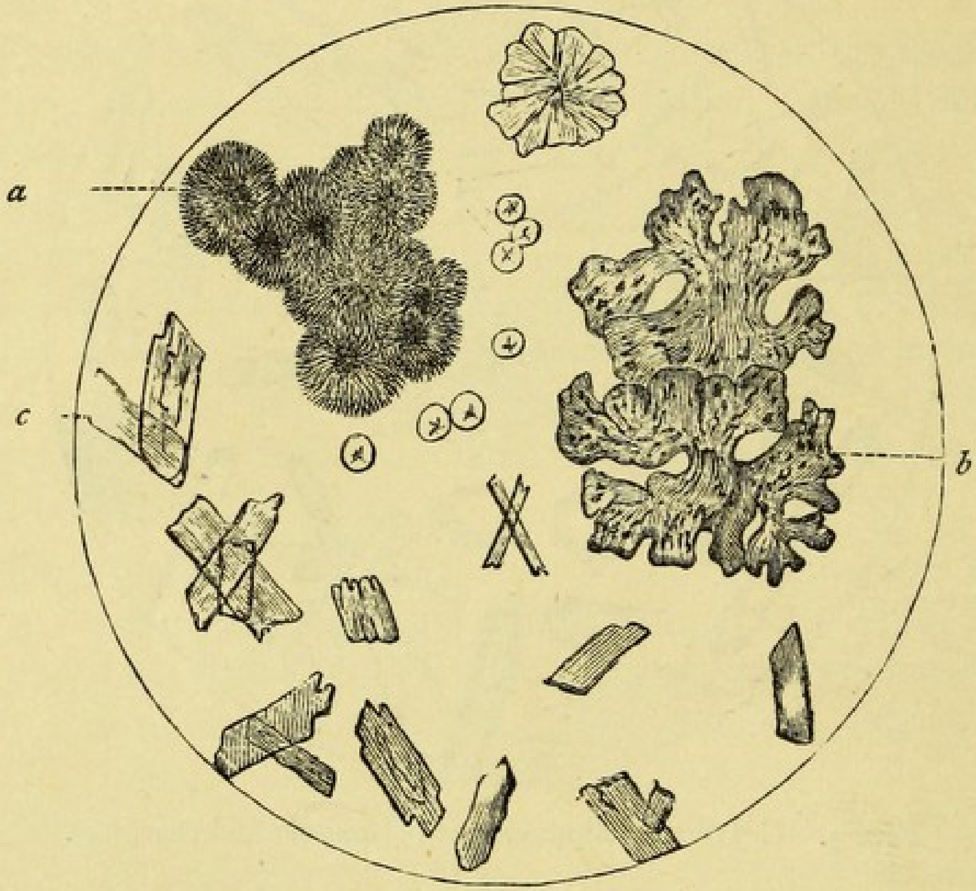

FIG. 4.—Kreatinin, zinc chloride. *a*, in balls with radiating lines ; *b*, crystallised from water ; *c*, from alcohol (Landois and Stirling).

Lactic acid, $C_3H_6O_3$, is the acid formed during lactic fermentation, and is found in sour milk and in the alimentary canal. *Sarco-lactic acid* has the same composition as lactic, but differs from it in the solubility and crystalline form of its zinc and calcium salts. It is found in the muscles, and can be obtained from muscle-extract.

Indican, $C_8H_7NSO_4$ is a substance derived from indol, the basis of indigo, formed in the intestine as a product of digestion ; it is present in variable quantities in the urine; when treated with an equal quantity of HCl and a drop of solution of chloride of lime, indigo blue is formed.

Lecithin, $C_{44}H_{90}NPO_9$, occurs in the brain, yolk of egg, pus, and in smaller quantities in the blood and bile. It is a white crystalline substance, soluble in hot alcohol and ether.

Cerebrin and **Neurin** are two substances which occur in the brain, and the latter also in yolk of egg.

Leucin, $C_6H_{13}NO_2$, in conjunction with tyrosin, is found in many of the organs and fluids of the body, in the pancreas, liver, spleen, in the peptones of

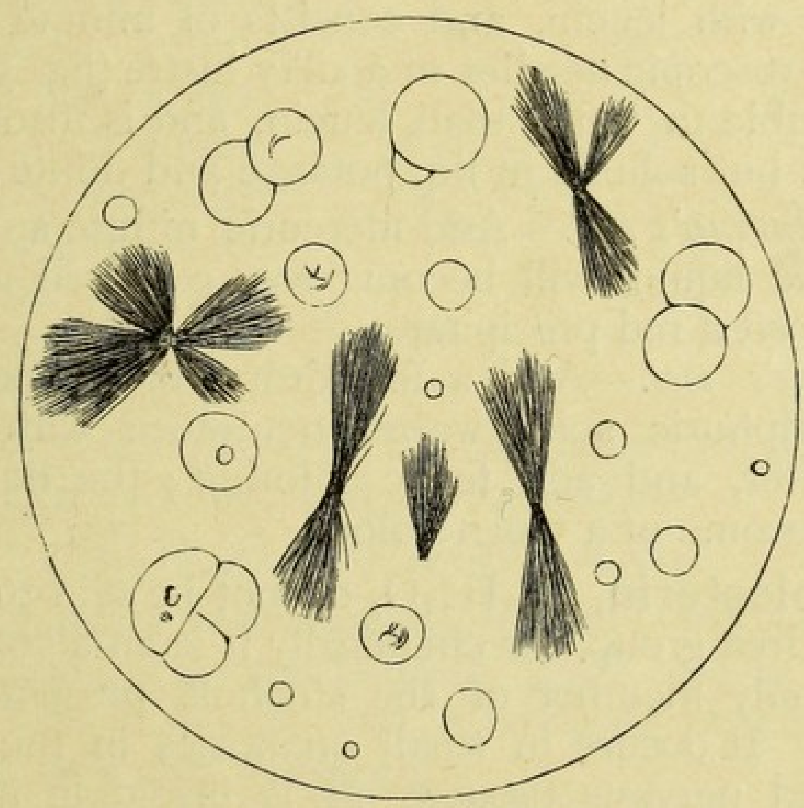

FIG. 5.—Crystals of leucin and tyrosin (Salkowski and Leube).

the alimentary canal, and in the urine in acute yellow atrophy and other diseases of the liver. These substances are formed during the decomposition of albuminous substances. They may be prepared by the artificial decomposition of albumen, fibrin, casein, gelatin, &c., but are most readily obtained by boiling horn-chips in dilute sulphuric acid. Leucin can also be obtained synthetically. Impure leucin appears under the microscope in the form of oily lumps clustering together (fig. 5); when pure it forms white flat crystals. It is soluble in water and alkalies, less so in alcohol.

Scherer's test.—Place a small portion on platinum foil with a drop of nitric acid and evaporate gently. A colourless residue will be left, which, on the addition of liq. potassæ, will become yellow and form an oily drop.

Tyrosin, $C_9H_{11}NO_3$, is generally found in connection with leucin, and consists of minute colourless microscopic needles of a silky lustre (fig. 5). It is less soluble in water than leucin, and is insoluble in alcohol, but soluble in liq. potassæ and dilute acids.

Hoffmann's test.—Add mercuric nitrate and boil; the liquids will become rose-coloured and deposit a red precipitate.

Piria's test.—Add a few drops of concentrated sulphuric acid, warm, neutralise with chalk, filter, and add ferric chloride; the liquid will become of a violet colour.

Cholesterin, $C_{26}H_{44}O$, cannot be said to belong to the Urea group, for chemically it is an alcohol, and is the only member of the alcohols present in the system. It occurs in small quantities in the blood, bile, and nervous tissues. It is insoluble in water and cold alcohol: soluble in ether, chloroform, and boiling alcohol. It occurs in white crystals, for the most part in rhombic plates (fig. 6). It is generally prepared from gall-stones by boiling with alcohol, filtering, and allowing to crystallise. With strong H_2SO_4 and a trace of iodine it becomes of a violet colour, which afterwards changes to green and then red.

III. CARBO-HYDRATES.—The principal carbohydrates found in the animal body are: 1. Grape sugar. 2. Maltose. 3. Milk sugar. 4. Inosit. 5. Glycogen. 6. Dextrin.

1. **Grape Sugar or Dextrose**, $C_6H_{12}O_6$, occurs in small quantities in the blood and urine, and in larger quantities in the contents of the alimentary canal. When pure it forms four-sided prisms, but is generally seen in irregular warty lumps. It is soluble in water and alcohol. It undergoes decomposition in the presence of certain ferments. It is precipitated by acetate of lead and ammonia.

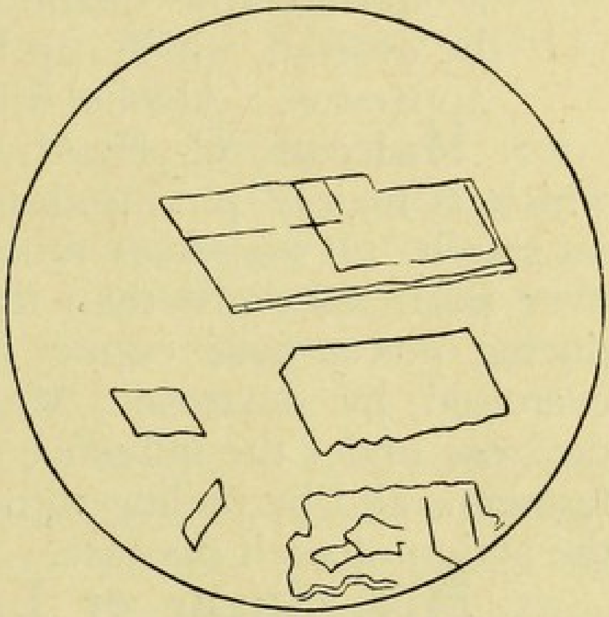

FIG. 6.—Crystals of cholesterin.

(*a*) *Alcoholic fermentation* takes place under the influence of yeast; alcohol and carbonic acid are formed:—

$$C_6H_{12}O_6 = 2C_2H_6O + 2CO_2.$$

(*b*) *Lactic fermentation.*—Under the influence of decomposing animal matters, lactic acid is formed in the first instance, and afterwards butyric acid, carbonic acid and hydrogen.

1st stage, $C_6H_{12}O_6 = 2C_3H_6O_3$.

2nd stage, $2C_3H_6O_3 = C_4H_8O_2 + 2CO_2 + 2H_2$.

The acidity of the contents of the large intestine is due to the presence of lactic acid.

Trommer's test.—Boil the solution with a few drops of solution of cupric sulphate and excess of caustic potass; if dextrose is present an abundant reddish-yellow precipitate of cuprous oxide will fall.

Moore's test.—Boil with caustic potass; if sugar is present the liquid will become first light yellow and afterwards brown.

Fermentation test.—Add a small quantity of yeast, and leave in a warm place for 24 hours; a considerable quantity of carbonic acid will be evolved, which can be collected in a suitable apparatus. Alcohol will be present in the liquid.

2. **Maltose**, $C_{12}H_{22}O_{11}$, is the form of sugar which is mainly produced by the action of diastase on starch. It possesses more rotatory power (+150) over polarised light than dextrose (+58). Its reducing power over cupric oxide is less than that exercised by dextrose. Maltose is converted into dextrose under the influence of some of the intestinal ferments, and by boiling with dilute acids, but not by the action of malt diastase.

3. **Milk Sugar or Lactose**, $C_{12}H_{22}O_{11}$, is found in milk. It differs from dextrose in being more insoluble in water, and not readily undergoing the alcoholic fermentation. It readily undergoes the lactic fermentation. It precipitates cuprous oxide from alkaline solutions in the same manner as dextrose. It is insoluble in alcohol.

4. **Inosit**, $C_6H_{12}O_6$, occurs in small quantities in the spleen, liver, and brain, and appears in the urine in uræmia. It undergoes the lactic but not the alcoholic fermentation.

5. **Glycogen**, $C_6H_{10}O_5$, is found in considerable quantities in the livers of well-fed animals, in smaller quantities in the white corpuscles of the blood, placenta, and fœtal tissues. It is an amorphous, white, tasteless powder, soluble in water, insoluble in alcohol. Its aqueous solution is opalescent.

Preparation.—Kill a well-fed rabbit shortly after a meal, quickly remove the liver, and after cutting it in slices, throw it into boiling water without loss of time. After boiling for a short time (to prevent the ordinary post-mortem change which glycogen undergoes into grape sugar) pound the liver, boil again and filter. The filtrate contains the glycogen and certain albuminous substances which must be removed. The latter are precipated with potassio-mercuric iodide in the presence of hydrochloric acid. The glycogen is then precipitated by adding alcohol.

Tests.—Dilute mineral acids (except nitric) convert it into grape sugar. Iodine gives a red colouration, which disappears on warming and reappears on cooling. (*Starch* gives blue with iodine, *dextrin* red, which disappears on warming, and does not reappear on cooling.)

6. **Dextrin**, $C_6H_{10}O_5$.—Starch is converted into dextrin by the action of ferments, the dextrin formed being in turn converted into maltose if the action of the ferment is continuous. Dextrin is found in the alimentary canal and also in the blood. It becomes of a red colour on addition of iodine; the colour disappears on warming and does not, as in the case of glycogen, reappear on cooling.

IV. Hydro-Carbons, or Fats.—The principal fats present in the animal body are :—

$$\text{Stearine}\ \left.\begin{matrix}C_3H_5\\(C_{18}H_{35}O)_3\end{matrix}\right\}O_3$$

$$\text{Palmitin}\ \left.\begin{matrix}C_3H_5\\(C_{16}H_{31}O)_3\end{matrix}\right\}O_3$$

$$\text{Olein}\ \left.\begin{matrix}C_3H_5\\(C_{18}H_{33}O)_3\end{matrix}\right\}O_3$$

These neutral fats, when submitted to the action of superheated steam, or heated with lead oxide, combine with water, and form glycerine and a fatty acid.

$$\overset{\text{Palmitin}}{\left.\begin{matrix}C_3H_5\\(C_{16}H_{31}O)_3\end{matrix}\right\}O_3} + 3\left.\begin{matrix}H\\H\end{matrix}\right\}O = \overset{\text{Glycerine}}{\left.\begin{matrix}C_3H_5\\H_3\end{matrix}\right\}O_3} + 3\ \overset{\text{Palmitic acid}}{\left.\begin{matrix}C_{16}H_{31}O\\H\end{matrix}\right.O.}$$

Stearin is best obtained from beef or mutton suet. It is the hardest of the fats, and crystallises in white shining plates. It has the highest melting-point (60° C.)

Palmitin is best prepared from palm oil ; it crystallises in needles and has a lower melting-point than stearin (40°C.)

Olein is prepared from olive oil, and is fluid at ordinary temperatures.

Glycerine, $\cancel{C_3 \left.\begin{matrix}H_5\\H_3\end{matrix}\right\} O_3}$, ~~or~~ $C_3\ H_5\ (OH)_3$, is a syrupy fluid with sweet taste and a neutral reaction ; it is soluble in water and alcohol, but not in ether. It dissolves many metallic oxides, and on heating decomposes, acrolein being formed.

V. The Albuminous Bodies or Proteids occur in almost all the tissues and fluids of the body. They derive their name from the white of egg, which is taken as a type of the group. They will not crystallise, and are obtained pure with difficulty. They are insoluble in alcohol and ether, soluble in strong acids and alkalis, undergoing decomposition in the process. With the exception of the peptones, they are coagulated by heat, and will not diffuse through animal membranes. They are not formed in the animal body, but enter the body in the form of food derived from the vegetable kingdom. Urea is the chief product of their oxidation within the body, carrying away all their N ; CO_2 and H_2O are also formed. They have the following average percentage composition :

O	21	per cent.
H	7·5	,,
C	54	,,
N	16	,,
S	1	,,

Reactions.—1. *Xanthoprotein Reaction.*—Heat with strong nitric acid, cool, and add ammonia. An orange colour is produced.

2. *Millon's Reaction.*—Add some Millon's reagent ($Hg(NO_3)_2 + HgNO_3$) and heat ; the fluid will become red, and if sufficient albumen is present, a precipitate will fall.
3. Add some liq. potassæ and a drop or two of solution of cupric sulphate ; heat : a violet colour is produced.

The albuminous bodies include several groups—

1. Albumin and its derivatives.
2. Globulins.
3. Fibrin.
4. Peptones.

1. **Albumin** is soluble in water, insoluble in alcohol and ether. It is coagulated at a temperature of 70° C. If dried at a lower temperature, it forms a tasteless yellow mass. Albumin is precipitated in the following ways :—

(*a*) By boiling and acidulating with nitric acid.
(*b*) By concentrated nitric acid in the cold.
(*c*) By the addition of acetic acid and potassic ferrocyanide.
(*d*) Boiling with acetic acid and strong solution of sodium sulphate.

Albumin exists in two forms—egg albumin and serum albumin.

They differ in that—

(*a*) Egg albumin is coagulated by ether, serum albumin is not.
(*b*) Coagulated serum albumin is soluble in strong HNO_3, egg albumin is not.
(*c*) Serum albumin injected beneath the skin does not appear in the urine, egg albumin does.

Alkali Albuminate.—If albumin in solution is treated with dilute caustic potash and gently warmed, some of its properties undergo change. The alkaline solution will no longer be precipitated by boiling. It is precipitated on neutralisation with acids, and is soluble in excess of the acid. It is not precipitated on neutralisation in presence of the alkaline phosphates.

Casein.—This substance closely resembles alkali albuminate, but differs from it in containing sulphur. It can readily be prepared from milk by saturating with magnesium sulphate, or by acidifying and gently warming; it is precipitated when milk comes in contact with the walls of the stomach.

Acid Albumin.—If albumin in solution is treated with HCl or other acids, it undergoes a change in its properties. It is no longer coagulated by heat. It is precipitated on neutralisation with an alkali, and is redissolved by excess; its precipitation is not prevented by alkaline phosphates. It is precipitated on boiling with lime-water. If muscle be dissolved in dilute HCl, a body termed *syntonin*, closely resembling, if not identical with, acid albumin, is formed.

2. **Globulins.**—These bodies differ from the albumins in being insoluble in water, precipitated by CO_2, or on saturating their solutions with NaCl. They are converted into acid albumin by HCl. They are soluble in dilute solutions of NaCl, the solution being precipitated by heat.

They include (*a*) globulin, (*b*) paraglobulin, (*c*) fibrinogen, (*d*) myosin, (*e*) vitellin.

(*a*) **Globulin** exists in the crystalline lens, and closely resembles paraglobulin in its properties, but differs from it in not assisting to form fibrin.

(*b*) **Paraglobulin** occurs in blood and serum, and in smaller quantities in some of the tissues. It gives rise to fibrin when mixed with any fluid, as hydrocele fluid, containing fibrinogen.

(*c*) **Fibrinogen** exists in blood, pericardial, pleural, and hydrocele fluids. It closely resembles paraglobulin, but, when thrown down by CO_2, it is less flocculent and more viscous.

(*d*) **Myosin** is present in dead muscle. It is not so soluble as fibrinoplastin. It is converted into syntonin by dissolving in HCl.

(*e*) **Vitellin** exists in yolk of egg ; it is soluble in dilute NaCl solutions, but differs from other members of the group in not being precipitated by saturating with NaCl.

3. **Fibrin** is obtained by whipping freshly-drawn blood. It forms tough, white strings, which are insoluble in water and dilute NaCl solution ; is converted into syntonin by digestion with HCl.

4. **Peptones** are distinguished from other albuminous bodies by not being precipitated by boiling, acids, or by potass. ferrocyanide and acetic acid. A trace of copper sulphate with excess of caustic soda produces a rose colour. They diffuse through animal membranes. They are precipitated by tannin, iodine, and acetate of lead.

Several different peptones exist.

VI. THE ALBUMINOIDS OR GELATINOUS BODIES. These substances, which occur as the principal constituents of many tissues, resemble the albuminous bodies in their composition, but differ from them in many of their reactions.

They include—

1. Mucin.
2. Gelatin.
3. Chondrin.
4. Elastin.

1. **Mucin** is found in fœtal connective tissue and in tendons. It occurs also in the mucous secretions, saliva, bile, gastric juice, &c., giving them their ropy consistence. It is not coagulated by boiling. It is

precipitated by acetic acid. It gives the proteid action with Millon's reagent and nitric acid, but not with sulphate of copper and liq. potass.

2. **Gelatin.**—Bones, connective tissues, tendons yield gelatin on boiling. When dry it is a colourless, transparent body; it swells up in cold, and dissolves in hot water; the solution, on cooling, forms a jelly. It is precipitated by tannic acid and mercuric chloride, not by acetic acid. It does not yield the proteid reactions with nitric acid, Millon's reagent, or copper sulphate.

3. **Chondrin** forms the bulk of the matrix of cartilage, and can be prepared by boiling cartilaginous substances in water, the solutions forming a jelly on cooling. It is precipitated by acetic acid and lead acetate.

4. **Elastin.**—The yellow elastic fibres present in the lig. subflava, and other parts of the body, consist of elastin. It does not dissolve in boiling water, but is soluble in boiling caustic potass.

CHAPTER II.

PHYSIOLOGICAL HISTOLOGY.

EPITHELIUM.

THE various free surfaces of the body—as, for example, the external surface of the skin, the mucous membranes, the internal membrane of the arteries, and the serous sacs—are lined by cells of different characters, which form the epithelium or endothelium. The latter term is applied by some to the flattened cells which line the serous sacs, blood-vessels, and lymphatics.

The epithelial cells differ very considerably in shape and size, but they agree in possessing nuclei and finely granular cell contents. This granular protoplasm has recently been shown to consist of a fine network, the meshes of which contain a hyaline material. The nucleus in like manner consists of a fine network, continuous with the network of the protoplasm, and has one or more nucleoli. Epithelial cells are connected together by a small quantity of a homogeneous albuminous substance, termed the intercellular cement ; it is stained of a dark brown colour by silver nitrate.

Epithelium may be divided into the following varieties :—

1. Tesselated or squamous.
2. Columnar.
3. Transitional.
4. Glandular.
5. Ciliated.

1. The **Tesselated** or **Squamous variety** is arranged either as a (*a*) single layer (fig. 7), or (*b*) in superimposed or stratified layers (fig. 8).

(*a*) A single layer of tesselated epithelium is found lining the pleura, pericardium, peritoneum, arachnoid, arteries, veins, capillaries, lymphatic vessels, acini of the lungs, anterior and posterior aqueous chambers of the eye, and looped tubes of Henle in the kidney. The cells consist of a thin plate with an oval nucleus, but differ considerably in shape ; those lining the serous sacs being polyhedral or nearly circular ; the cells lining the arteries and capillaries being elongated, and the lymphatics having epithelium, with an irregular or wavy border. The outline of these cells is readily shown by staining their intercellular cement with silver nitrate.

(*b*) The superimposed layers consist of strata of cells, which clothe surfaces specially liable to friction, They cover the true skin, forming the epidermis ;

they form the superficial layer of the mucous membrane of the cavity of the mouth, tongue, œsophagus, conjunctiva, and vocal cords, vagina, external aperture

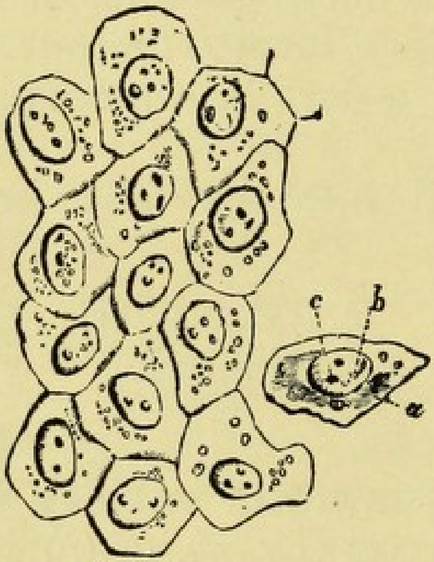

Fig. 7.—Pavement epithelium from a serous membrane; magnified 410 diameters (Quain's Anatomy). *a*, cell-body; *b*, nucleus; *c*, nucleoli.

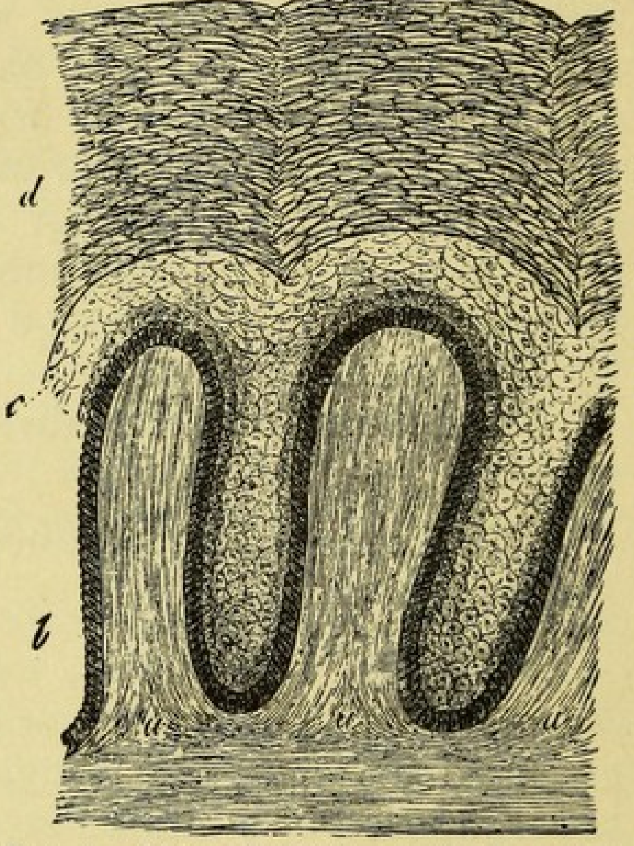

Fig. 8.—Skin of negro, vertical section (Quain's Anatomy). *a a*, papillæ; *b*, layer containing pigment; *c*, Malpighian layer or rete mucosum; *d*, horny layer of flattened cells.

and fossa navicularis of the urethra. The deeper cells of the dermis are more or less round, though the deepest are columnar, and form the rete mucosum; the superficial cells are flattened, overlap at their edges, and form the horny layer or stratum corneum, which covers the soles of the feet and palms of the hand. The deeper cells are not closely applied to one another at their edges, but are separated from one another by minute spikes or prickles, the spaces between the spikes forming channels. When the cells are isolated they appear to be surrounded by the spikes and are called '*prickle-cells.*'

2. **Columnar** (fig. 9).—This variety consists of cylindrical or club-shaped nucleated cells, the thick ends being towards the free surface. Their sides are often more or less flattened from mutual pressure or more or less irregular from the presence of lymphoid cells situated between adjoining epithelial cells. The protoplasm of the cell is granular from the presence of minute vacuoles ; it may also contain mucin and fatty globules. At times the outer ends of the cells are distended by mucus, forming the so-called 'goblet' cells (fig. 10). There is always a nucleus containing a fine network. The free border of the cell is more refractile than the rest of the protoplasm of the cell, and is finely striated. Columnar cells are found lining the alimentary canal from the œsophageal end of the

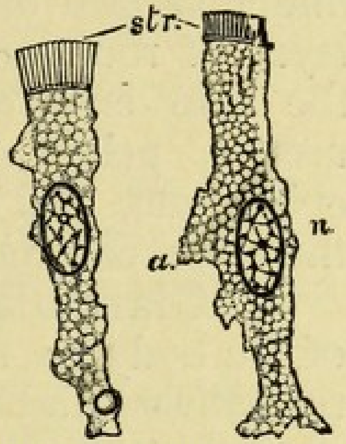

FIG. 9.—Columnar cells from the rabbit's intestine (Quain's Anatomy). *a*, an irregular projection ; *n*, nucleus with its network ; *str*, the fine striated border ; a fat-globule is visible in the left hand cell.

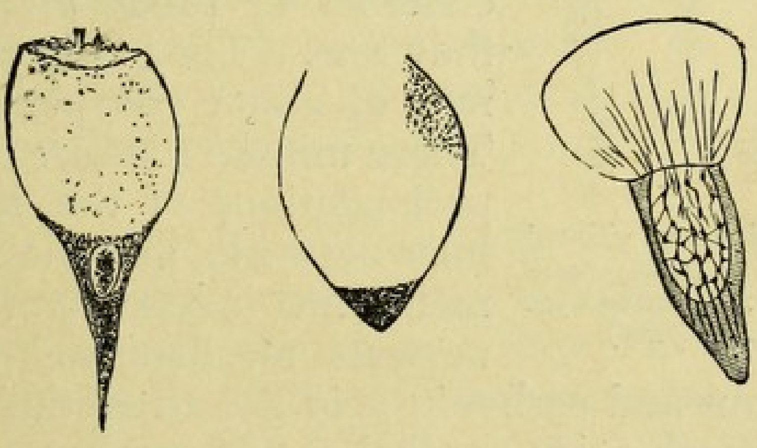

FIG. 10.—Goblet cells, highly magnified (Quain's Anatomy). The right-hand cell shows distinctly the intra-nuclear network, which radiates in the lower part of the cell, and also into the mucus-containing part.

stomach to the anus, lining the ducts of glands and the olfactory region of the nose.

3. **Transitional.**—This variety consists of flat-

tened cells on the surface, a middle layer of pear-shaped cells, their rounded ends fitting into the under surface of the flattened cells, and an inferior layer of rounded or pyriform cells fitting between the thin ends of the middle layer. The bladder, ureters, pelvis of kidney, are lined by transitional epithelium, and also the larynx and pharynx, where the columnar and flattened cells come in contact.

4. **Glandular.**—The acini of the various glands of the body, as the convoluted tubes of the kidney, the salivary and peptic glands, are lined by spheroidal or cubical cells. These cells are nucleated, and probably perform the important work of separating or elaborating from the blood the materials which form the secretion of the gland.

5. **Ciliated.**—In some parts of the body the epithelial cells are provided with minute rods which are constantly in motion, and serve to propel mucus or any minute particles in contact with them towards the orifice of the chamber or tubes whose walls they line. They vibrate at the rate of about 700 per minute. These minute rods are probably prolongations of the intra-cellular network, and their movements are independent of any nervous mechanism. Chloroform vapour and carbonic acid gas arrest their movements. Weak acids or alkalies and moderate electric currents stimulate them. Ciliated epithelium is for the most part columnar in shape (fig. 11).

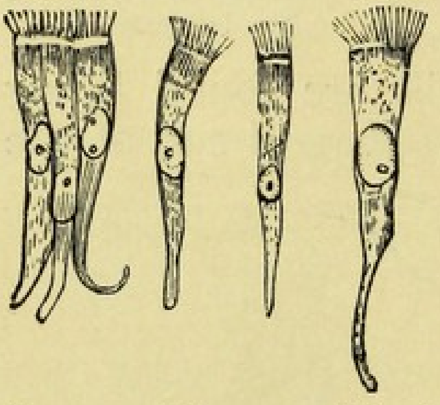

FIG. 11.—Columnar ciliated epithelium from nasal mucous membrane × 300 (Quain's Anatomy).

They are present in man—

(*a*) Lining the mucous membrane of the air-passages. Commencing near the nostrils, they line the nasal cavity (except the olfactory region), the antrum, ethmoidal and frontal sinuses, the nasal and lachrymal ducts, the upper part of the pharynx, the Eustachian tube, tympanic cavity, larynx, except the vocal cords, trachea, and bronchi till they enter the infundibula of the lungs.

(*b*) Lining the mucous membrane of the uterus, commencing at the middle of the cervix and continuing along the Fallopian tubes to their fimbriated extremities.

(*c*) Lining the vasa efferentia, coni vasculosi, and upper part of the globus major of the testis.

(*d*) Lining the lateral ventricles of the brain and central canal of the spinal cord in the child.

Many of the animalcula and algæ, as the paramecia, rotifera, vorticella, volvox, are provided with cilia as a means of locomotion, or for producing currents in the water, so as to carry their prey within their reach. Cilia are also found in the gills of the oyster and salt-water mussel, and doubtless serve to bring a fresh supply of oxygenated water in contact with the capillaries of their gills. In man, they probably prevent the accumulation of mucus or foreign particles on the surfaces they line, and possibly in the testicle help forward the immature spermatozoa.

They are most readily obtained for the microscope by snipping a small piece from the gills of the mussel, and covering with thin glass; they will continue to work for hours if evaporation be prevented.

PIGMENT.

PIGMENT is met with in various parts of the body, for the most part in epithelium and connective-tissue cells. It is met with in *epithelium cells* in the external layer of the retina and posterior surface of the iris;

in the deep layers of the cuticle in the dark races (fig. 8, *b*), the membranous labyrinth of the ear, and olfactory region. In *connective-tissue cells* which are irregularly branched, it is found in the outer layer of the choroid coat, in the iris and pia mater. It also occurs in some nerve-cells. The pigment itself consists of minute brown particles, which when they escape from the cells, exhibit the 'Brownian' movements. Pigment occurs in some pathological states, as in the rete-mucosum in Addison's disease and in melanotic tumours. The pigment of the choroid is evidently of use in absorbing any redundant light which enters the eye. Chemically it is characterised by the large percentage (nearly 60 per cent.) of carbon which it contains.

CHAPTER III.

THE CONNECTIVE TISSUES.

Connective or Areolar Tissue is present almost universally throughout the body, serving to connect the various organs with one another, as well as to bind together the parts of which an organ consists. The muscles are surrounded by a connective-tissue sheath, which penetrates into their substance, binding together the fasciculi and fibres. The same tissue is present beneath the skin and mucous membranes, and forms a sheath for the arteries, veins, and nerves. It is plentifully supplied with blood-vessels, and many nerves pass through its substance. Microscopically, four different elements may be seen—

1. Connective-tissue cells or corpuscles.
2. White fibrous tissue.
3. Yellow fibrous tissue.
4. Ground substance.

1. **Connective Tissue Cells** (fig. 12).—On examining the connective tissue of young animals, various cells will be seen with fine granular contents and nuclei lying in spaces in the ground substance. Some are branched, others flattened or rounded. Leucocytes may also be seen, which have perhaps migrated from the capillaries. The branched cells

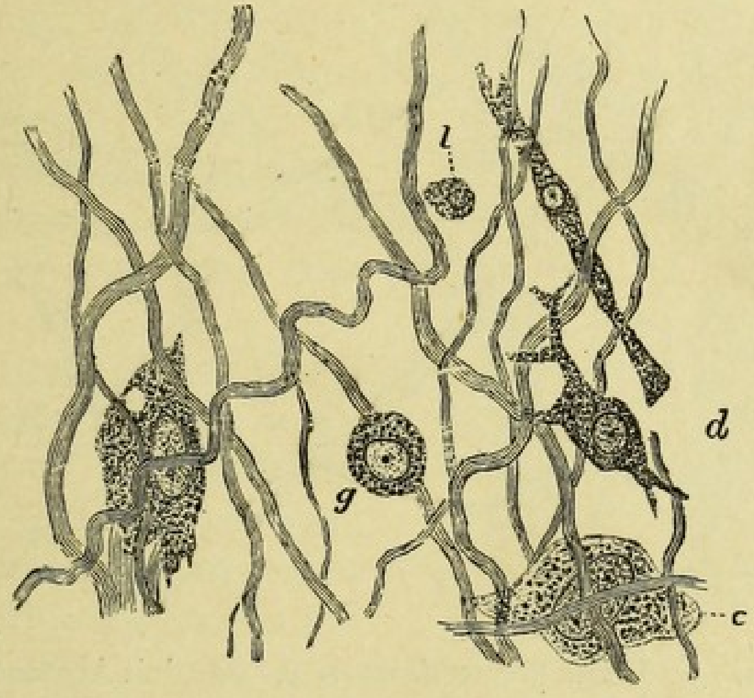

FIG. 12.—Connective tissue from a young guinea-pig (Quain's Anatomy). *d*, branched corpuscle; *c*, flattened cell; *g*, granular corpuscle; *l*, leucocyte.

generally join one another by their branches. The *corneal corpuscles* are thus branched. The cells in the fibrous tissue of tendons are square or oblong, and form continuous rows, as seen when the tendon is viewed longitudinally; when viewed in transverse section they appear irregularly branched, sending their branches between the bundles of the tendon.

2. **White Fibrous Tissue.**—When areolar or fibrous tissue is examined with a high power, it will be seen that it is principally composed of fine, wavy, parallel fibres; these are united in bundles by a very small amount of the ground substance (fig. 13).

Acetic acid causes the fibres to swell up and become indistinct. On boiling they yield gelatine.

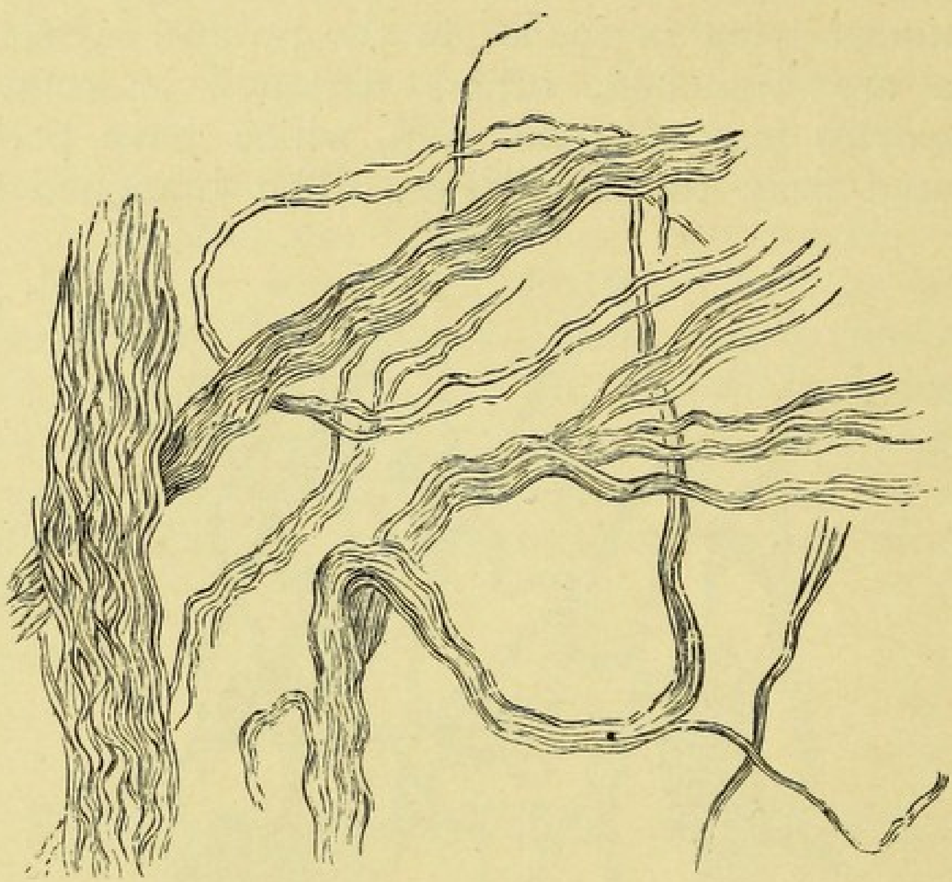

FIG. 13.—White fibrous tissue × 400 (Quain's Anatomy).

3. **Yellow Fibrous Tissue** forms a variable proportion of connective tissue, being especially abundant beneath the skin, mucous and serous membranes. Microscopically, it consists of yellow, elastic, curling, branching fibres, of a larger size than the fibres of white fibrous tissue. It is unchanged by acetic acid and the weaker alkalies. Chemically it yields elastin (fig. 14).

4. **Ground Substance.**—The intercellular material present in connective tissue consists of a homogeneous material, surrounding the cells and fibres cementing them together. It is stained by silver nitrate like the intercellular cement of epithelium.

Distribution of White Fibrous Tissue.—

Those connecting tissues of the body which require to be inelastic, tough, unyielding, are formed of pure white fibrous tissue without admixture of yellow. Such are the tendons, fasciæ, aponeuroses, most ligaments, the periosteum, the dura mater, pericardium, &c. They are white in colour, and will not readily stretch. Besides the ordinary wavy fibres, they contain connective-tissue corpuscles.

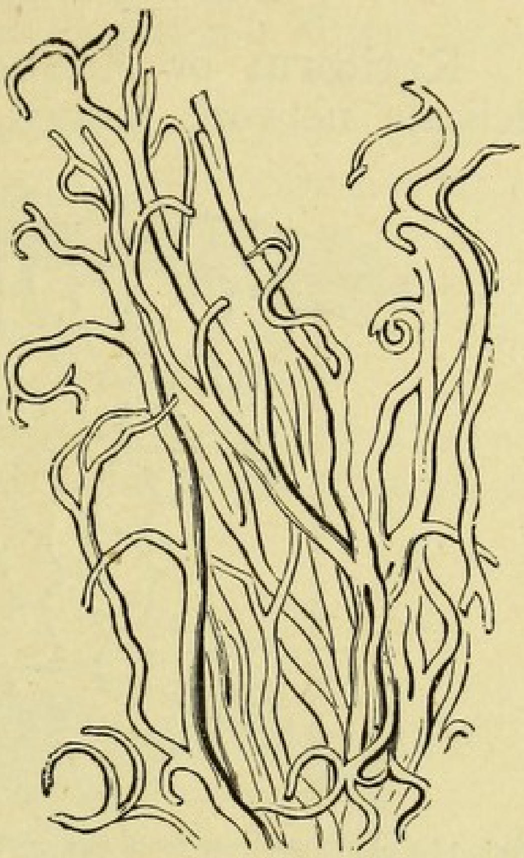

FIG. 14.—Elastic fibres from the lig. subflava × 200. (Quain's Anatomy.)

Distribution of Yellow Elastic Tissue.—In some parts of the body an elastic material is required to connect bones together or to form the walls of blood-vessels. Yellow elastic tissue enters largely into the following structures :—

1. Ligamenta subflava of the vertebræ.
2. The stylo-hyoid, thyro-hyoid, crico-thyroid ligaments, the vocal cords, and calcaneo-scaphoid ligament.
3. The midddle coat of the larger arteries and veins.
4. It is present beneath the mucous membrane of the trachea, and forms the walls of the infundibula.
5. The capsule and trabeculæ of the spleen, lymphatic glands, and erectile tissues.
6. Forming the ligamentum nuchæ of horse and ox.

RETIFORM TISSUE.

Retiform or **Adenoid Tissue** consists of a delicate network formed by connective-tissue cor-

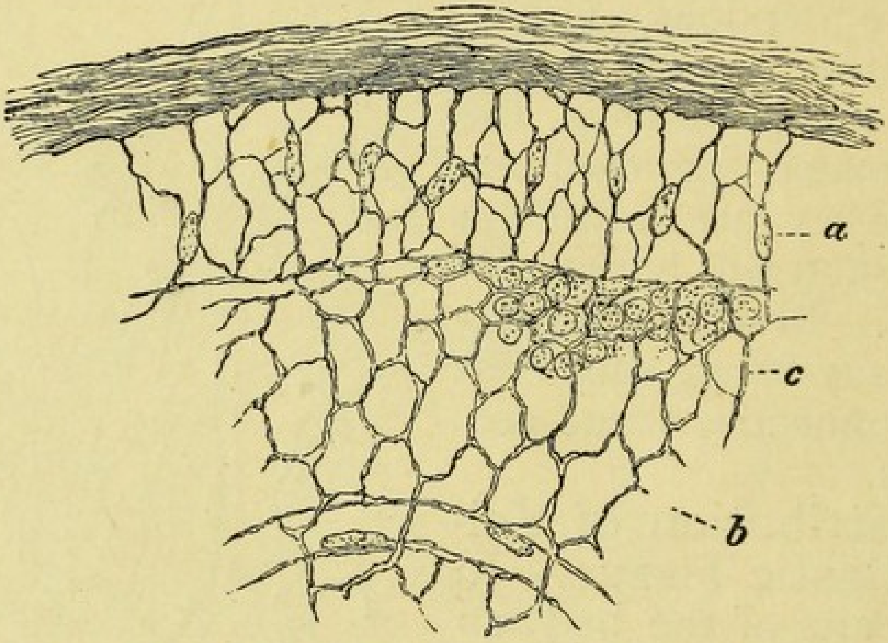

FIG. 15.—Thin section from the cortical part of a lymphatic gland (Quain's Anatomy). *a b*, network of fine trabeculæ; *c*, lymph-corpuscles still remaining in the meshes.

puscles joining their branches together. In some parts the corpuscles and their nuclei are very apparent, whilst elsewhere but little can be seen of nuclei at the intersections of the fibres. Retiform tissue forms the stroma or framework of *lymphoid tissue.*

In lymphoid tissue, the spaces in the network are occupied by leucocytes. It is found in lymphatic glands, solitary glands of the intestine, tonsils, spleen, &c.

ADIPOSE TISSUE.

Adipose Tissue is present in many parts of the body. It forms a layer beneath the skin, in the subcutaneous connective tissues, except beneath the skin of the eyelids and penis; it forms a layer of considerable thickness covering the buttocks, thighs, and abdomen, in well-nourished subjects. In the internal organs it is collected around the kidneys, heart, in the joints, and folds of the omentum, but it is absent from the cranium and lungs.

Structure.—Fat, to the naked eye, has a coarse or finely granular appearance from the presence of large or small *lobes*; these are again made up of *lobules*; each lobule has its *afferent arteriole*, *meshwork of capillaries*, *efferent vein*, and *fat cells*. The tubes and lobules are bound together by areolar tissue.

Fat Cells.—When examined microscopically the vesicles or cells are, in well-nourished bodies, round or

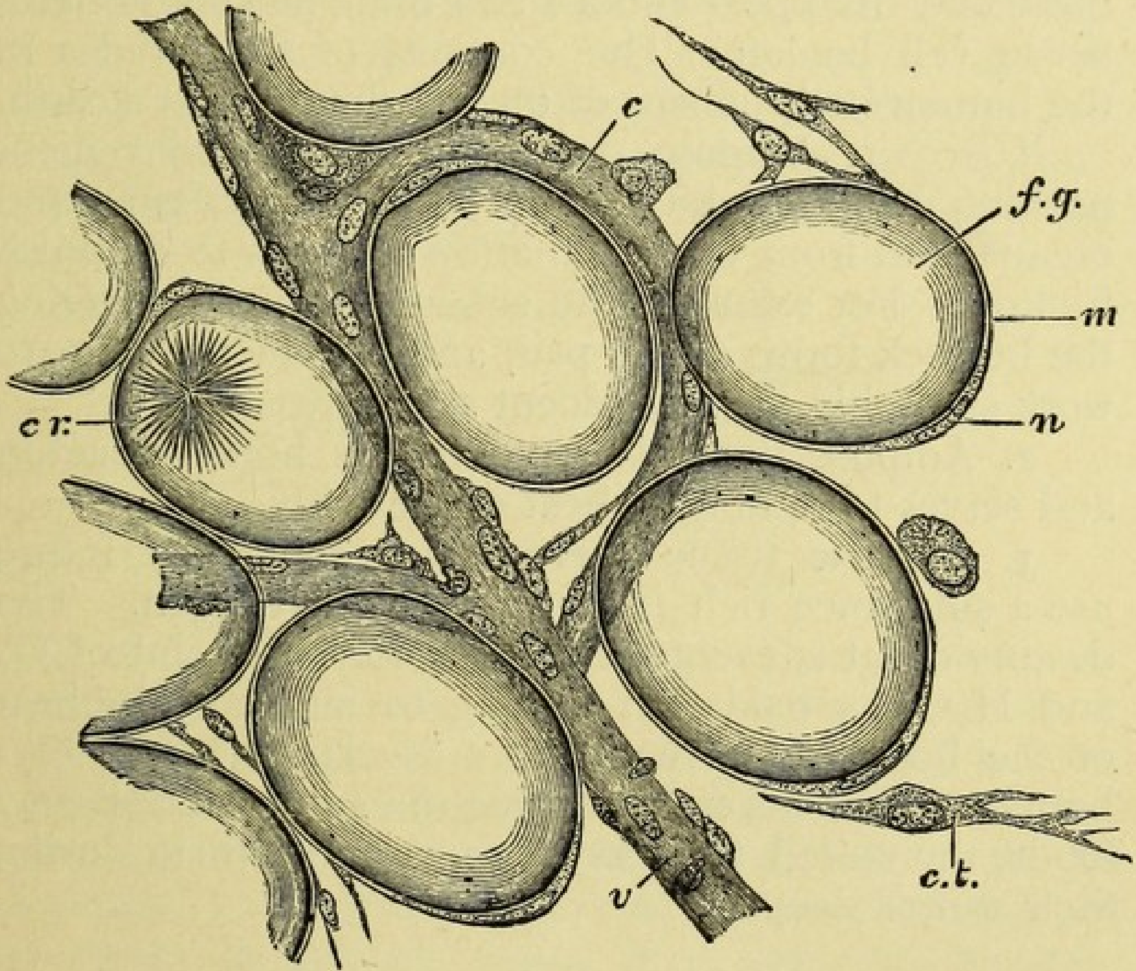

FIG. 16.—Fat cells, highly magnified (Quain's Anatomy). *f g*, fat globule distending a cell; *n*, nucleus; *m*, membranous envelope; *c r*, bunch of crystals; *c*, capillary; *v*, vein; *c t*, connective-tissue cell.

oval in shape, $\frac{1}{300}$ to $\frac{1}{600}$ in. in diameter (fig. 16). They are derived from ordinary connective-tissue cells, and consist (*a*) of a delicate envelope, the remains of the original protoplasm of the cell, which includes (*b*) a nucleus more or less flattened, and (*c*) fat globules distending the cell. After death a bunch of crystals may be seen within the cell. Under favourable conditions of nutrition, connective-tissue cells may be seen to contain oil globules in their protoplasm, others in which the globules are fused together and are commencing to push the nucleus to one side, distending the cell and converting it into a fat vesicle. In starvation the reverse takes place, the oil globules are absorbed, serous fluid takes their place, and finally these may disappear and a small branched connective-tissue cell be left. The contents of the vesicles in the human body consist of olein, palmitin, and stearin.

Uses.—1. Adipose tissue serves as a convenient packing material, which fits in between the tissues and organs, and from its fatty nature it serves to diminish friction. For example, the subcutaneous fat covering the buttock forms a soft pad, and allows the skin to work smoothly over subjacent structures.

2. Adipose tissue is an excellent non-conductor, and serves to retain the heat of the body.

3. Adipose tissue serves to store up for future use a substance rich in carbon and hydrogen. The destiny of fat is eventually to be converted into CO_2 and H_2O, its oxidation serving to maintain the heat of the body and give rise to muscular energy. Hybernating animals fatten during the autumn on starchy foods, the stored fat serving to maintain them during their winter sleep.

CHAPTER IV.

CARTILAGE AND BONE.

CARTILAGE is a bluish or yellowish-white, semi-translucent elastic substance, without vessels or nerves, and surrounded by a fibrous membrane, the perichondrium. This membrane is richly supplied with blood-vessels, lymphatics, and nerves. It is absent on the articular surfaces. Cartilage, on boiling for some hours, yields an albuminoid called chondrin, which, like gelatine, sets into a jelly on cooling, but differs from gelatine in not being thrown down by tannic acid.

Cartilage may be divided into

1. Hyaline . .	Temporary Costal Articular
2. Fibro-cartilage .	White Yellow.

1. **Hyaline Cartilage** (fig. 17) is present in many parts of the body. In the fœtus it forms a firm, elastic material for the skeleton, prior to the deposition of lime-salts and consolidation of the bones. In the adult it supplies an elastic material in the costal cartilages, to assist in forming the walls of the chest, its elasticity aiding in an important manner the expiratory act. It caps the ends of bones at the joints, and helps to diminish friction and lessen shock. It forms in large measure the walls of the trachea and bronchi, serving to maintain their rigidity and prevent collapse. It also forms the septum and

lateral cartilages of the nose ; the thyroid and cricoid cartilages in the larynx.

Structure.—The matrix or ground substance is finely granular and transparent, and, like the matrix

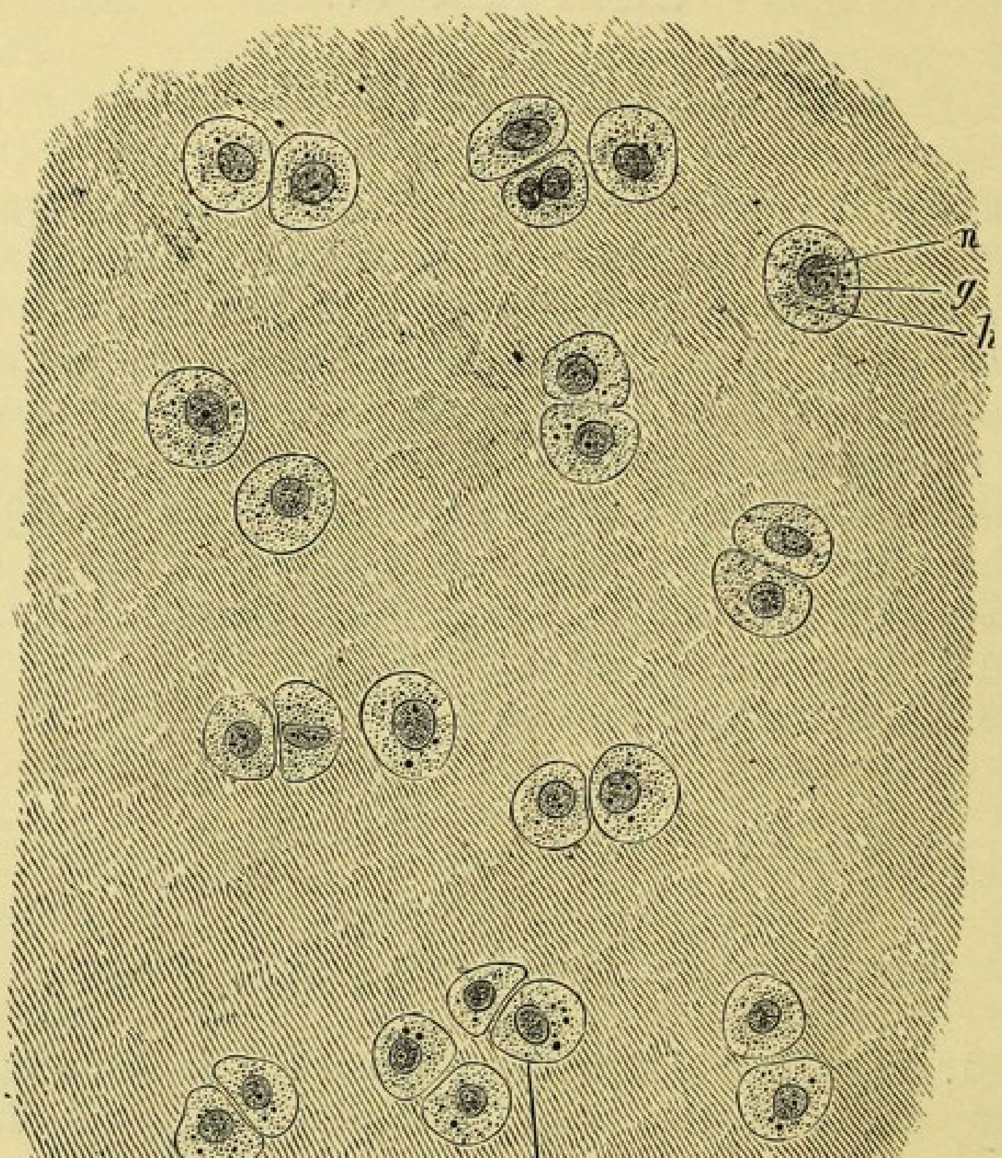

FIG. 17.—Hyaline cartilage (Quain's Anatomy). *a*, group of two cells ; *b*, group of four ; *h*, protoplasm of cell ; *g*, fatty granules ; *n*, nucleus.

of connective tissue, is stained brown by silver nitrate.

The cells occupy special cavities in the matrix, called the *cartilage lacunæ.* Each cavity is lined by a membrane, the *capsule*, which in growing cartilage is thickened by the addition of a layer of the hyaline matrix, distinct from the rest. The cells consist of round, oval, or elongated corpuscles with one or two nuclei: their protoplasm is finely granular. Each lacuna generally contains one cell, but it may contain 2–8 cells; in the latter case, cell-division is proceeding more rapidly than the formation of the ground substance.

Hyaline cartilage is modified in different situations:—

(*a*) **Temporary.**—Cartilage forms a support for the fœtus, and a bed for the deposition of the lime salts. The cells are small, for the most part angular, provided with tails, and uniformly scattered through the matrix, except where ossification is proceeding, when they arrange themselves in columns. The matrix is very finely granular.

(*b*) **Costal.**—The cells are large and collected into groups, and contain oil globules; near the exterior surface the cells are flattened and lie parallel with the surface. The matrix exhibits a tendency to the deposition of lime salts, beginning from the circumference of the cells, though no true bone is formed. The matrix contains some scattered fibres.

The cartilages of the nose, thyroid, cricoid, trachea, and bronchi resemble costal, though for the most part no fibres are to be seen in the matrix.

(*c*) **Articular.**—In the layer near the bone the cells are arranged in columns, though irregularly distributed near the surface. The matrix is not prone to calcify, like rib-cartilage. Near the articular surface the cells resemble the connective-tissue cells of synovial membrane.

FIBRO-CARTILAGE.

1. White fibro-cartilage.
2. Yellow fibro-cartilage.

White Fibro-cartilage differs from hyaline in having the matrix occupied by fibres of white fibrous tissue. It is consequently tougher and less elastic. Its microscopic characters resemble white fibrous tissue rather than cartilage, consisting of parallel wavy fibres with a few cartilage cells (fig. 18). It is distributed in the following manner :—

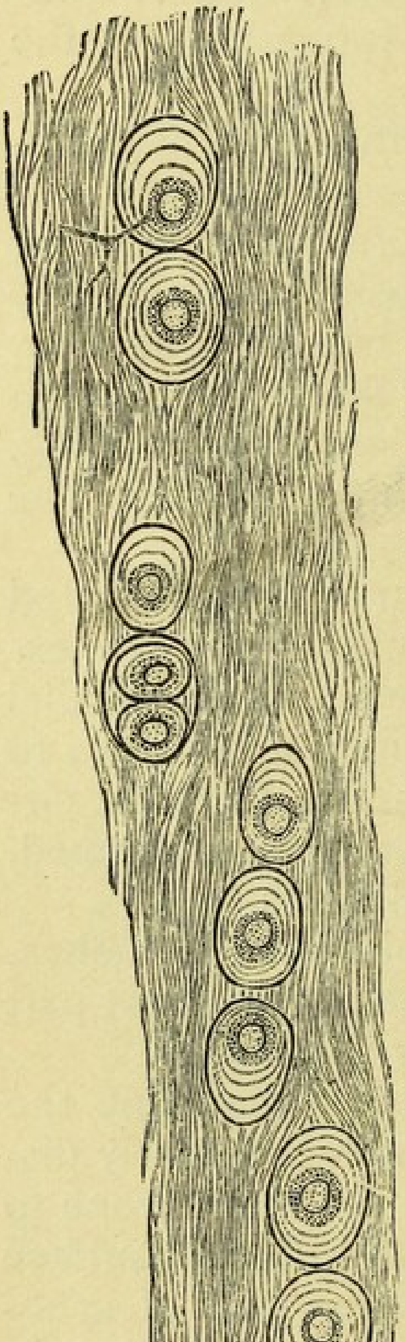

FIG. 18.—White fibro-cartilage, intervertebral discs (Quain's Anatomy).

1. *Inter-articular* fibro-cartilages form small pads occupying a movable joint, their surfaces being free and lined by synovial membrane. They greatly assist in deadening the effects of shock. They are present in the temporo-maxillary, sterno-clavicular, acromio-clavicular, inferior radio-ulnar articulations, and also in the knee-joint.

2. *Circumferential*, serving to deepen articular cavities, as in the glenoid cavities of the shoulder and hip-joints.

3. *Connecting*, which serve to connect the surfaces of bones together in immovable joints, and at the same time to diminish shock—as the intervertebral discs, and in the sacro-iliac synchondrosis.

4. *Lining Bony Grooves*, serving to deepen and render smooth the grooves in which certain tendons work, as the tendons of the peronei, extensors of the thumb.

Also forming the sesamoid cartilages developed in several tendons.

Yellow elastic Fibro-cartilage differs from hyaline in having its matrix pervaded with yellow elastic tissue. It is tougher, more flexible and elastic than the hyaline variety. Microscopical examination

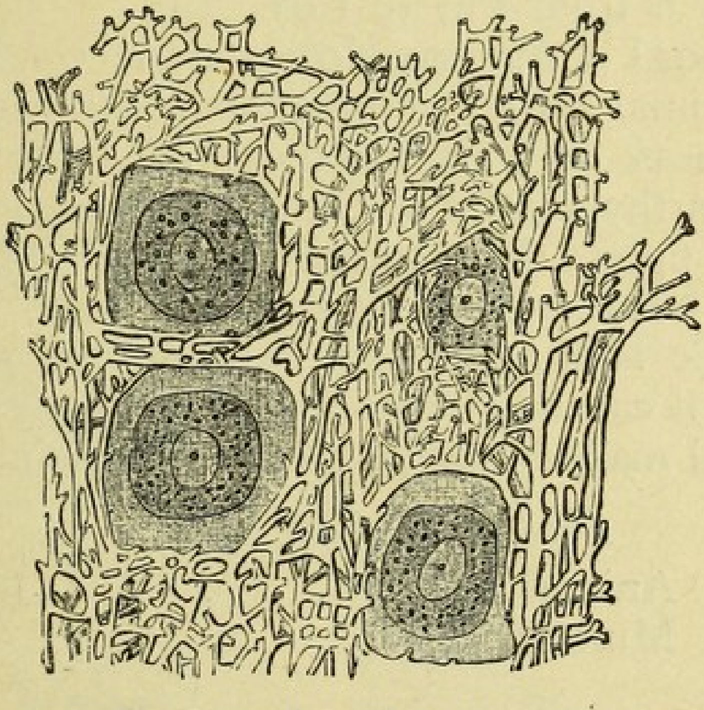

FIG. 19.—Elastic cartilage of ear (Quain's Anatomy).

of the epiglottis shows a fine network of elastic fibres, with numerous cartilage-cells scattered through its substance. In the external ear the network of elastic fibres is coarser (fig. 19). It forms the Eustachian tube, external ear, epiglottis, and cornicula laryngis.

BONE.

Bone is a tough, hard, elastic substance which forms the skeleton of the adult. The bones supply a framework for the support of the soft tissues of the body, form various cavities for the reception of important organs, as the brain, spinal cord, eyes, heart, and lungs, and act as levers for the action of the muscles and joints to aid in the locomotion of the body. The elasticity of bone is seen in the ribs and the rebound of the skull when dropped on the ground. Its specific gravity is from 1·87 to 1·97.

Chemical Composition.—Bone consists of a basis of animal matter, impregnated with earthy salts. The hardness and compactness of bone depends upon the earthy matter it contains, its elasticity and toughness upon the animal matter. The earthy salts may be removed by steeping bone in dilute hydrochloric acid; the bone will not be altered in shape, but it can be twisted and bent in any direction. The animal matter may be moved by calcining.

Percentage Composition.

Animal matter . .	33·3
Mineral „ . .	66·7
	100·0

The animal matter is a substance having some resemblance to but is not identical with cartilage, and yields gelatine on boiling. The earthy matters consist principally of calcic phosphate, calcic carbonate, and small portions of calcic fluoride, chlorides, and magnesian salts.

Structure.—To the naked eye a long bone is seen to be surrounded by a fibrous membrane—the periosteum—and on section its substance will be seen to consist of two different materials—the compact and cancellous tissues.

The **Periosteum** surrounds and adheres very firmly to the bone. It has two layers (*a*) the *outer* consists of fibrous tissue, which supports the vessels entering the bone, and sends filaments with them into the compact tissue ; (*b*) the *inner* or *osteogenetic*

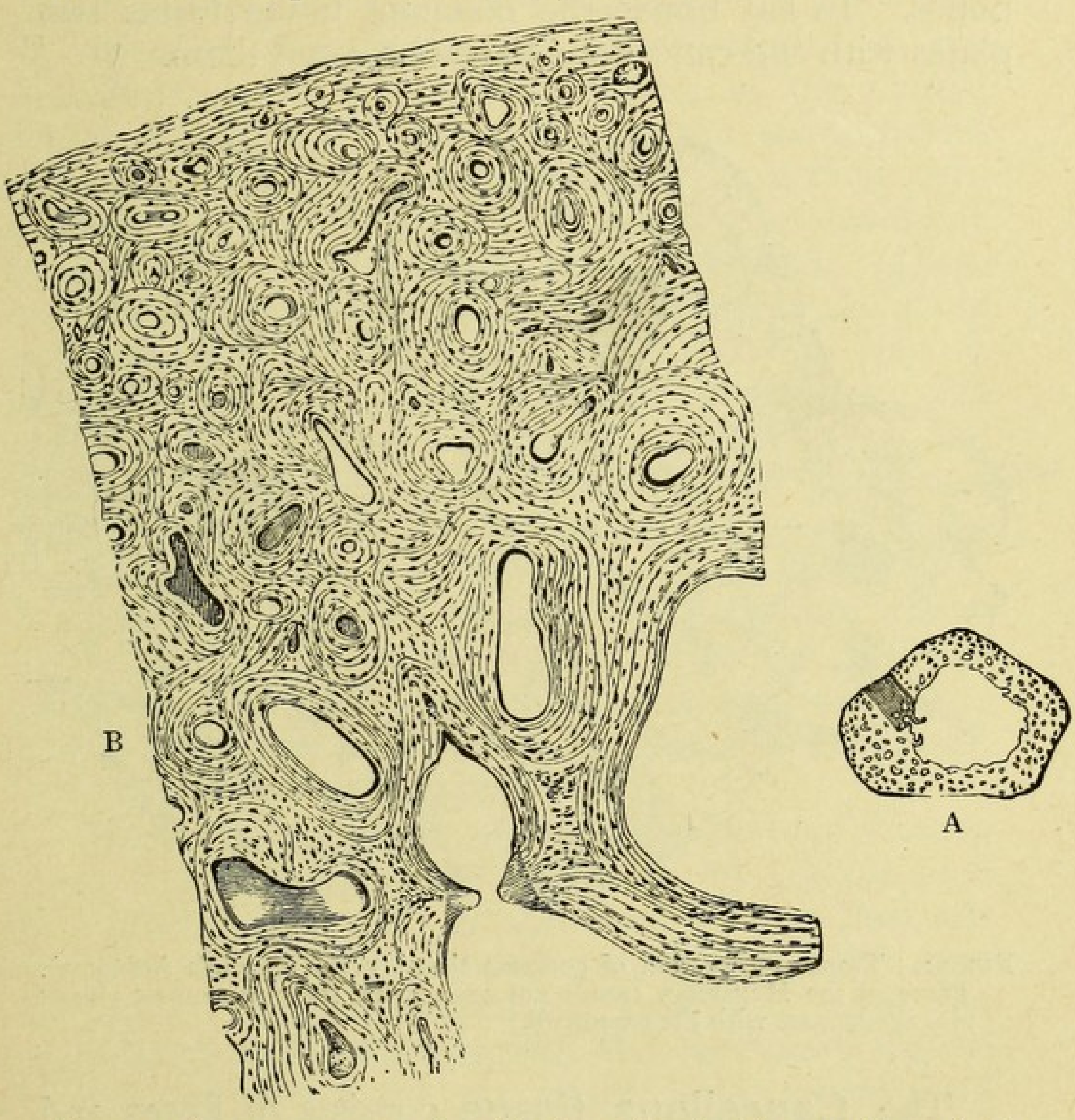

FIG. 20.—A, transverse section of a bone (ulna). The openings of the Haversian canals are seen, natural size. B, part of section A (the shaded portion), showing the Haversian canals, concentric lamellæ and lacunæ × 20 (Quain's Anatomy).

consists of elastic fibres, capillaries, and granular cells called *osteoblasts*. The periosteum also contains nerves and Pacinian bodies.

The **Compact tissue** is dense, white (pink during life), and hard, and is placed on the exterior of the bone; close examination shows it is porous and gradually shades away into the cancellous tissue. The relative amount of each differs in different bones. In flat bones the compact tissue forms two plates with the cancellous tissue between them.

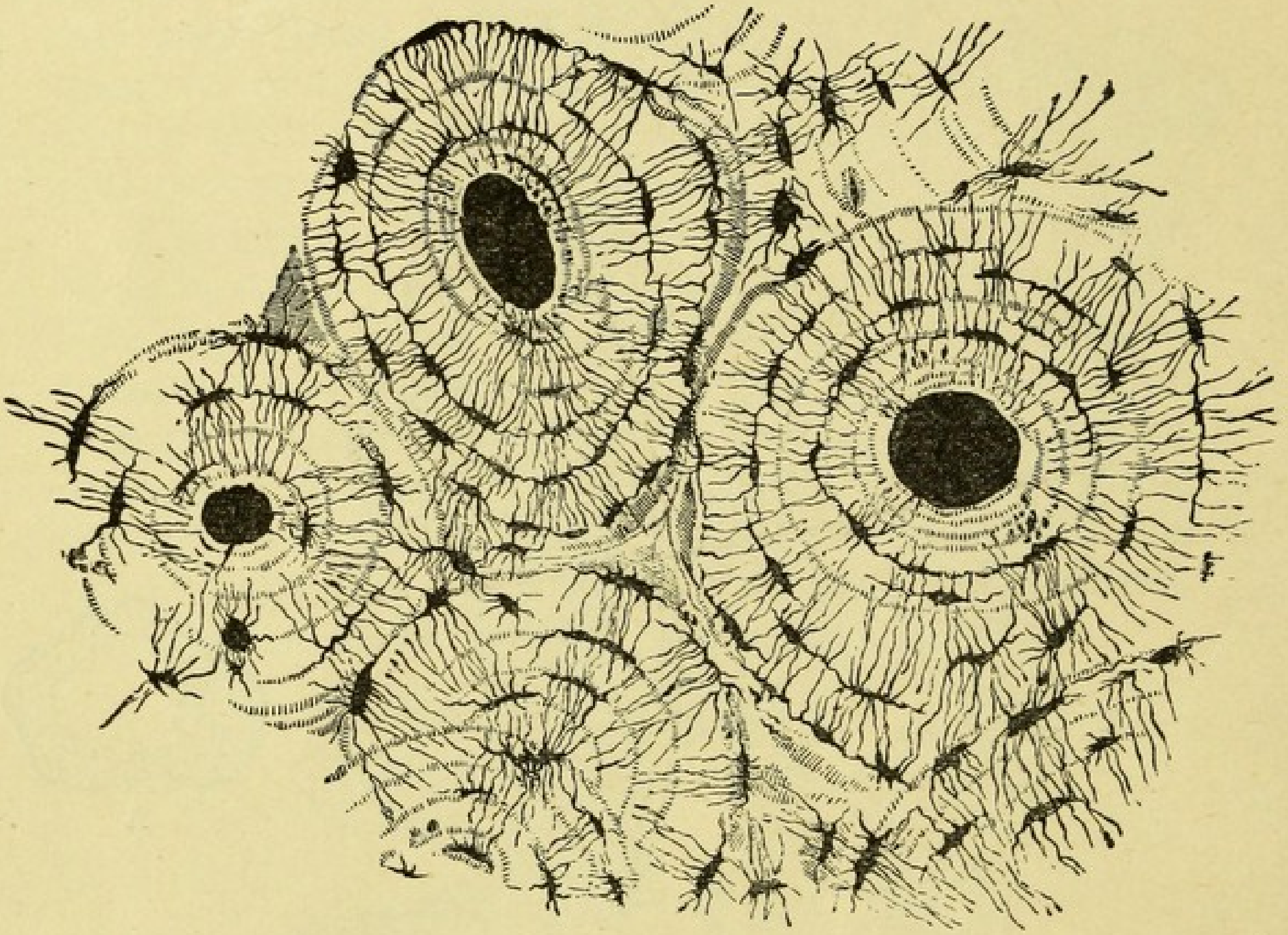

FIG. 21.—Transverse section of compact tissue × 150 (Quain's Anatomy). Three of the Haversian canals are seen, with their concentric rings; also the lacunæ with the canaliculi.

The **Cancellous tissue** consists of fibres and lamellæ which, joining together, form a latticework. The open spaces, during life, contain marrow and blood-vessels. The cancellous tissue is principally present at the expanded ends, and gives lightness as well as strength to the bone.

The **Marrow** is a soft vascular tissue contained in the hollow shaft and spaces of the cancellous tissue. It differs in different situations according to the cells it contains; within the shaft of the long bones and in the spaces of some spongy ones, it is called *yellow marrow*, and consists for the most part of fat-cells, fibre tissue, and blood-vessels; in the cancellous ends of the long bones, in the cranial diploë, the bodies of the vertebræ, the sternum and ribs, it is called *red marrow*, is of more fluid consistence, and has but few fat-cells, but contains some rounded and nucleated cells, the *marrow-cells*. These exhibit amœboid movements, and resemble the white corpuscles of the blood, but are larger, and have a larger nucleus. Amongst them are smaller cells of a reddish colour, which are believed to be transitional forms between marrow-cells and red blood corpuscles. There are also larger multi-nucleated cells, the *myeloplaxes* of Robin.

Minute structure.—On examining a thin transverse section of bone with a power of 100–200 diameters, the following structures may be made out:—Haversian canals, lamellæ, lacunæ, canaliculi, and osteoblasts (figs. 20 and 21).

Haversian canals.—These will be seen as dark spots or round apertures of $\frac{1}{200}$th to $\frac{1}{1000}$th inch in diameter, and in a longitudinal section they will be seen to be canals anastomosing freely with one another. They communicate externally with the periosteum and internally with the medullary cavity, and during life lodge an artery, vein, nerve, and lymphatic.

Lamellæ.—Numerous concentric rings will be seen surrounding the aperture of a Haversian canal (fig. 21). This appearance is caused by the transverse section of cylinders of bony tissue fitting one inside the other, which surround the Haversian canal. Besides the lamellæ surrounding the canals, there are others arranged round the medullary cavity, but near each surface, called the *circumferential* lamellæ.

Lacunæ, canaliculi, osteoblasts.—Between the lamellæ are numerous elongated dark spots, in reality cavities, which anastomose by numerous fine canals with one another, and also with those between neighbouring lamellæ. The spaces are the lacunæ, and the fine tubes are canaliculi. The lacunæ are occupied by the bone-cells, or osteoblasts ; these are nucleated cells, which send branches along the canaliculi (fig. 22).

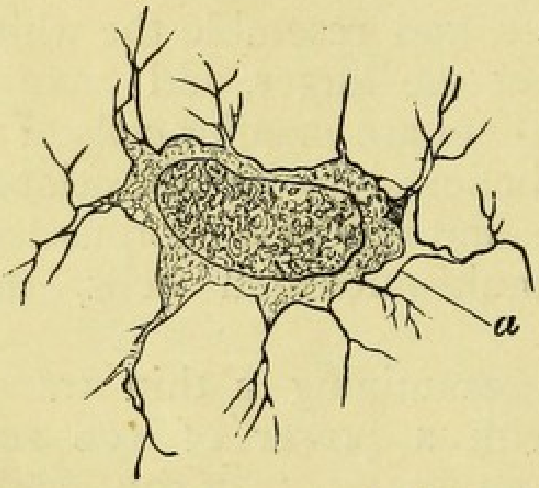

FIG. 22.—A bone-cell isolated (Quain's Anatomy). *a* wall of lacunæ, from which the osteoblast has shrunk away.

Perforating fibres. In sections of decalcified bone, fibres may be seen passing through the lamellæ in various directions, and bolting them together.

Blood-vessels.—In the long bones the 'nutrient artery,' or rather, the medullary artery, passes from the circumference obliquely through the compact tissue into the medullary canal. It sends branches to the marrow and to the Haversian canals.

Development of Bone.—Bone is formed by the deposition of lime salts either in cartilage or in membrane. The bones of the limbs, vertebral column, sternum, ribs, base of skull, are formed from cartilage ; the roof of the skull, the bones of the face, the lower jaw except the angle, are formed from membrane identical with the future periosteum. Bone *grows in length* by intracartilaginous and *in thickness* by intramembranous ossification.

Intracartilaginous Ossification.—In a long bone ossification begins in the centre of the bone, both in the cartilage and periosteum; later on, mostly after birth, other centres appear, which form the epiphysis, and finally these join the shaft. The processes by which bone succeeds cartilage may be stated as follows :—

1. According to Klein, the cartilage at the centre of ossification, becomes permeated with channels, containing vessels and osteoblasts derived from the inner layer of the periosteum.

2. In the neighbourhood of the vessels, the cells become enlarged, undergo division, and are arranged in radiating columns (fig. 24, *pz*).

3. The matrix between the columns of cells becomes permeated with lime salts, extending between and around cell groups, enclosing them in spaces called the primary areolæ, in which osteoblasts, marrow cells and vessels replace the cartilage cells (fig. 25).

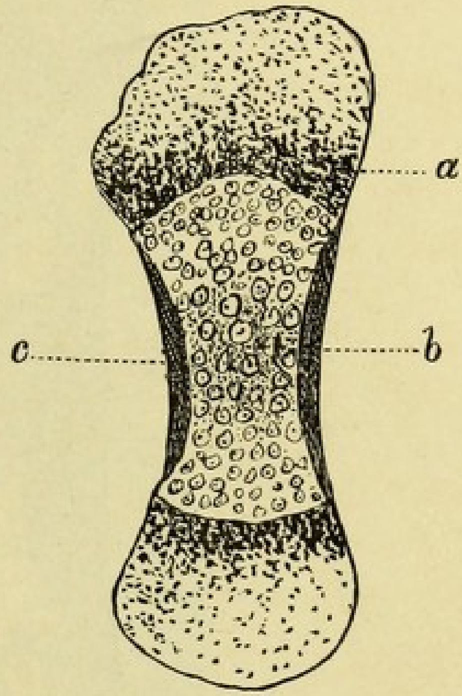

FIG. 23.—Section of first phalanx of the finger of a twelfth-week fœtus × 20 (after Kassowitz). *a*, proliferation of cartilage cells ; *b*, cells enlarged, calcification of matrix commenced ; *c*, periosteal bone being formed.

4. The osteoblasts arrange themselves on the surfaces of the walls of the cavities and gradually form bone-substance with lamellæ, Haversian canals and lacunæ. Thus a spongy or cancellous tissue is formed ; the calcified matrix diappears, and many of the spaces open into one another (figs. 24 and 25).

5. Simultaneously with the changes in the cartilage matrix a layer of osseous substance has been formed

beneath the periosteum, which continues to increase in thickness, being deposited around the osteoblasts, and finally compact bone is formed.

6. The spongy bone formed as described in (4) is

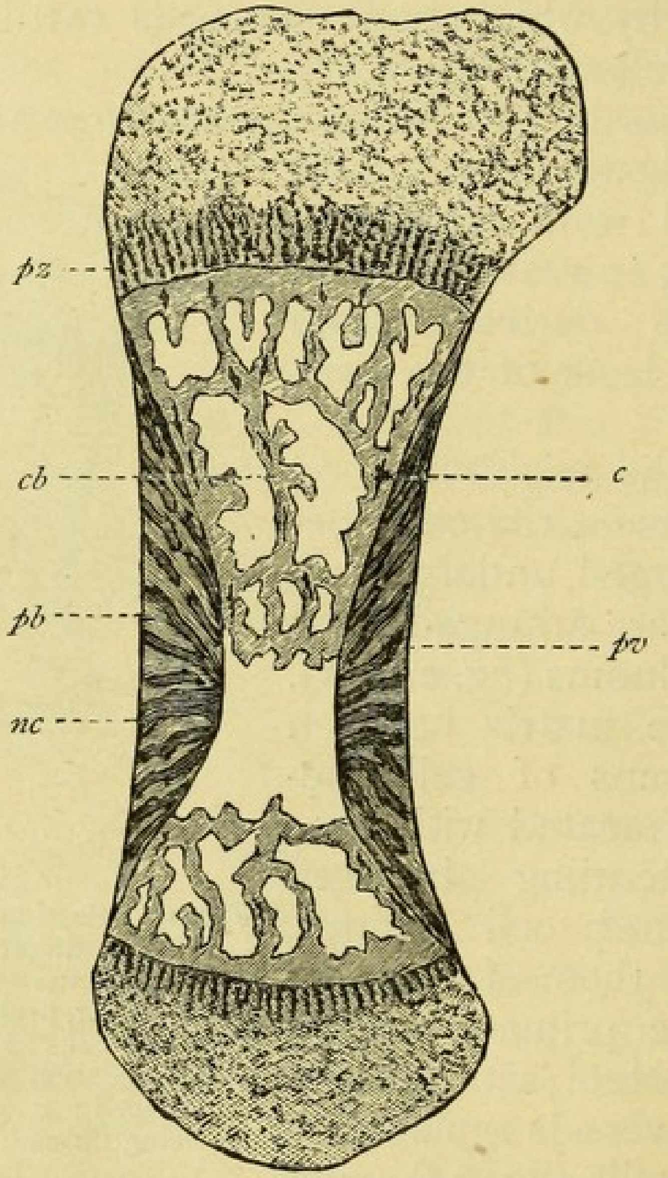

FIG. 24.—Section of the first phalanx of a new-born child × 10 (after Kassowitz). *p b*, periosteal bone; *c b*, bone formed from cartilage; *p z*, proliferation zone layer of cartilage in which calcification is proceeding; *c*, canaliculi; *n c*, nutrient canal; *p v*, periosteal vessels.

not permanent, the greater part of it being absorbed to form the medullary cavities. At birth the compact tissue which surrounds the shaft has been formed from the periosteum, whilst the cancellous tissue at

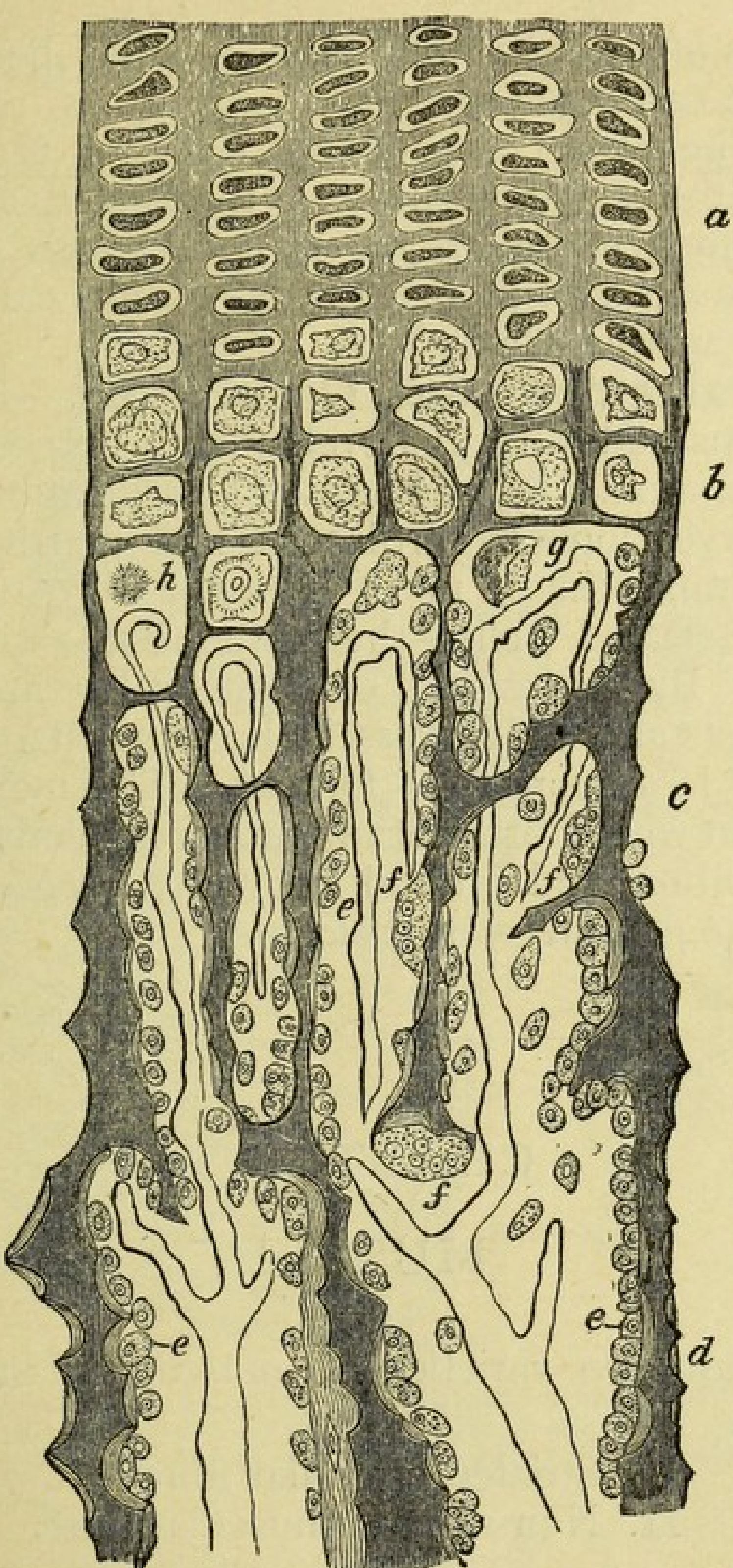

FIG. 25.—Longitudinal section of the developing femur of the rabbit × 350 (Quain's Anatomy). *a*, row of flattened cartilage cells; *b*, enlarged cartilage cells close to the advancing bone, the matrix between being calcified; *c d*, already formed bone, the trabeculæ being covered with osteoblasts (*e*) except here and there where a giant cell or osteoclast, *f*, is seen; *g h*, cartilage cells which have become shrunken and irregular. From the middle of the figure downwards, the dark trabeculæ which are formed of calcified matrix, are becoming covered with osseous substance deposited by the osteoblasts. The vascular loops are shown.

the ends of the bone and elsewhere has been formed from the cartilage (fig. 24).

7. The absorption of the walls of the primary areolæ (the calcified matrix) is effected by certain cells termed *osteoclasts* or the *myeloplaxes* of Robin. They are situated in depressions or pits called Howship's lacunæ (fig. 25, *f*).

Intramembranous Ossification.—In certain bones (named above) development proceeds direct from membrane, as in periosteal ossification, without the intervention of cartilage. The matrix, like the periosteum, is made up of layers of fibre tissue, with large nucleated cells—the osteoblasts—and blood-vessels. By deposition of lime salts around the osteoblasts and blood-vessels, bone substance, at first more or less spongy, is formed. The membrane or matrix, in which ossification proceeds, consists of indistinct fibres and ground substance, densely packed with large granular corpuscles.

CHAPTER V.

MUSCLE.

THERE are two varieties of muscular tissue in the body :—

I. Striated muscular fibre.
II. Non-striated muscular fibre.

I. **Striated Muscular Fibre** is found in the muscles attached to bone, such as the biceps, diaphragm, masseter, also in the muscles of the tongue, soft palate, pharynx, larynx, upper part of œsophagus, platysma, sphincter vesicæ, and muscles of the prostate.

For the most part, muscles which are under the control of the will, are striated, though exceptions are found in the constrictors of the pharynx, œsophagus, heart, &c. Striped muscle is of a dull red colour, and marked with longitudinal furrows on its surface.

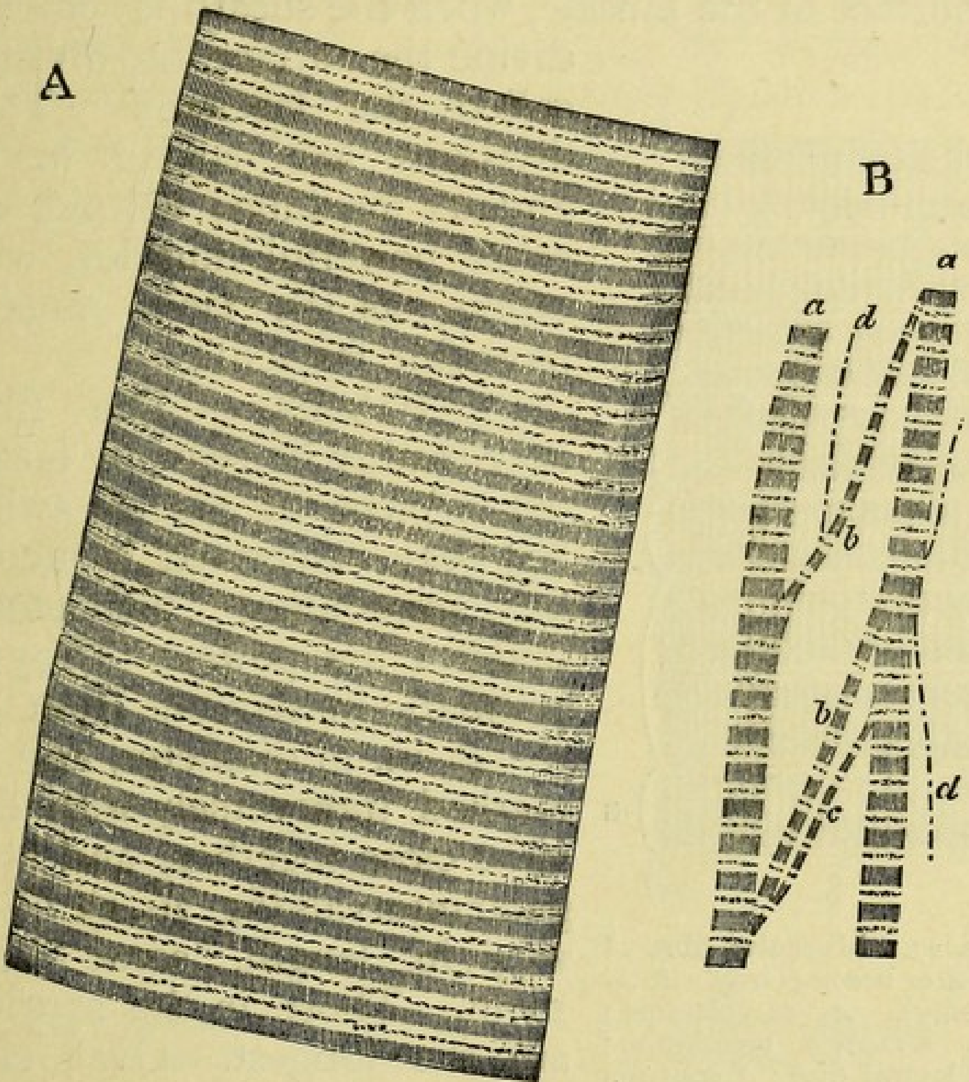

FIG. 26.—A, part of a muscular fibre (human) × 800 (Quain's Anatomy). B, separated portion of a muscular fibre × 800. *a a*, larger, and *bb*, smaller collections of fibrils ; *c*, smaller still ; *d d*, the smallest that could be detached.

A voluntary muscle consists of

1. Connective-tissue sheath.
2. Fasciculi.
3. Fibres and sarcolemma.
4. Discs, fibrillæ and sarcous elements.

1. **Sheath.**—Each muscle has its sheath of con-

nective tissue which surrounds it, binds the fasciculi together, and supports the blood-vessels called the *perimysium*; it sends fine prolongations in between the fibres called the *endomysium.*

2. **Fasciculi.**—The longitudinal furrows seen on the surface of the muscle, when the sheath is removed, divide the surface into divisions called the fasciculi. These divisions are coarse in the gluteus maximus, deltoid, and other powerful muscles, while others, as the facial muscles, have fine fasciculi.

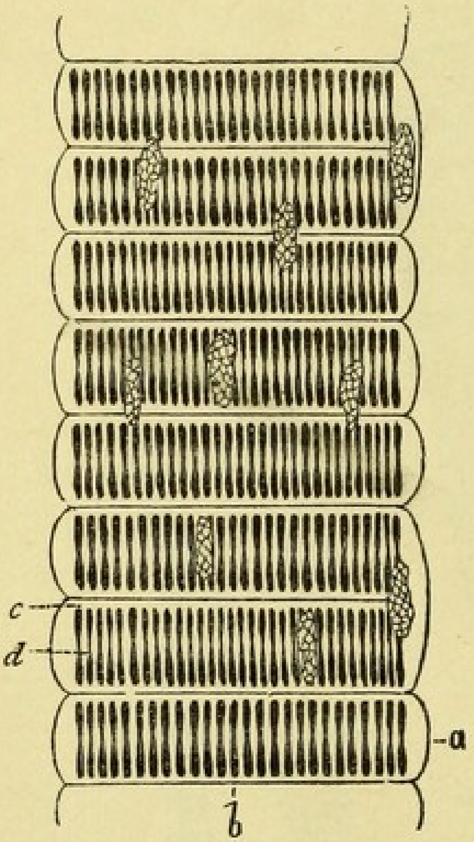

Fig. 27.—Muscular fibre of water beetle (Gray's Anatomy). *a*, sarcolemma; *b*, Krause's membrane; *c*, lateral disc; *d* contractile disc with sarcous elements.

3. **Fibres.** — The fibres may readily be seen by teasing out a piece of muscle (which has been macerated in alcohol or ammonium bichromate) under a low power. They are prismatic in section, from $\frac{1}{400}$ to $\frac{1}{700}$ in. in diameter, and are marked transversely with dark striæ close together, and at regular intervals (fig. 26, A). They vary in length, some being $1\frac{1}{2}$ in. Those in the sartorius are the longest. Oval, elongated nuclei are seen in the fresh muscle of the frog when treated with acetic acid. They are also present in mammalian muscles, being situated near the surface of the fibres, beneath the sarcolemma. The *sarcolemma* is a delicate homogeneous elastic sheath, which can be readily seen in the prepared muscle of the frog and water beetle, less readily in man; under favourable circumstances transverse lines will be seen, which appear to be connected with the sarcolemma and cross

the fibres in the intervals between the dark striæ. These are called Krause's membranes (fig. 27, *b*).

4. **Discs.**—If the living muscle of the water beetle (Hydrophilus) be examined under a high power, the compartments, as it were, formed by Krause's membranes joining the sarcolemma, will be seen to be occupied by discs. Occupying the centre of the compartment is a broad doubly refracting (anisotropous) disc, (fig. 27, *d*) on either side of which, and

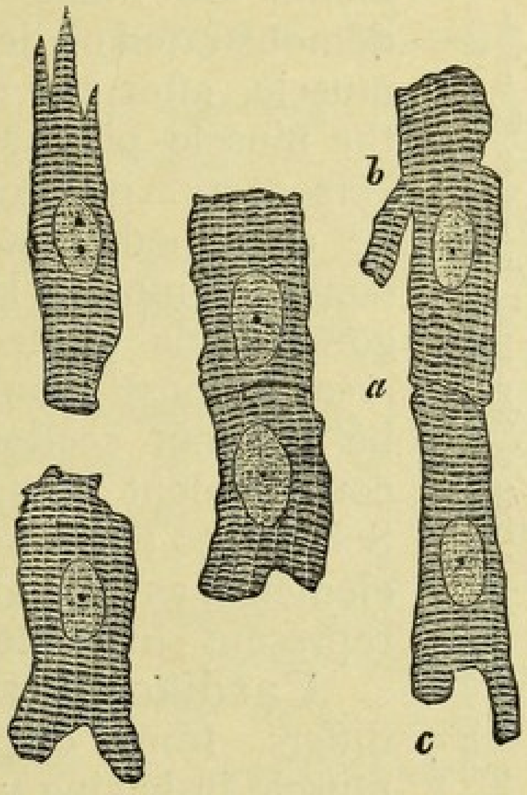

FIG. 28.—Muscular fibre-cells from heart × 425 (Quain's Anatomy). *a*, line of junction between two cells; *b*, *c*, branching cells.

separating it from Krause's membranes, is a transparent homogeneous, singly refracting (isotropous) sub stance; the former is often called the *contractile disc*, the latter the *lateral* disc (fig. 27, *c*). The contractile disc, though apparently homogeneous, in reality is composed of rod-shaped bodies, lying across the disc and separated from one another by a minute layer of homogeneous substance continuous with the lateral disc. These rod-shaped bodies correspond to the *sarcous* *elements* of Bowman, and when joined on to the rods of the neighbouring discs, form the *fibrillæ* (fig. 26.) When mammalian muscle is acted on by alcohol or chromic acid, the fibres readily split up into fibrillæ, and these again are marked transversely, dividing a fibril up into sarcous elements. These elements are much more readily demonstrated on dead than living muscle, after the coagulation of the muscle plasma. If a transverse section of living muscle-fibre be examined, it will be seen to consist of more or less small polygonal fields termed Cohnheim's areas; these would appear to be the cut sections of a sarcous element; but, according to Schäfer, to consist of a bundle of elements, as they are too large to represent single elements.

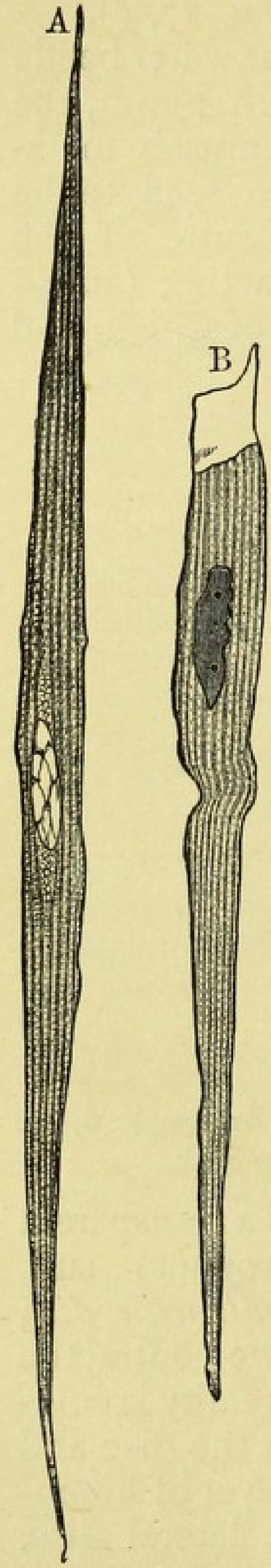

Fig. 29.—Muscular fibre-cells from the muscular coat of the small intestine (Quain's Anatomy). A, a complete cell, showing the nucleus with intra-nuclear network and fibrillation of the cell-substance. B, a broken cell, showing sheath at the upper end.

Cardiac Muscular Fibre differs from ordinary striated muscle in having very faint cross stripes and no sarcolemma; the fibres are also branched. If the fibres are acted on by osmic acid, they are seen to consist (in mammals) of oblong nucleated cells, some being forked at their extremities, and joined end to end (fig. 28).

II. **Non-Striated Muscular Fibre** is pale in colour, is not under voluntary control, and consists of bundles of contractile cells (fig. 29). It is found in many parts of the body—walls of stomach and intestines, blood-vessels, trachea, œsophagus, ducts, iris, &c. The cells are elongated or spindle-shaped, with an oblong rod-shaped nucleus, and are surrounded by a very delicate homogeneous sheath. They vary in length, and are $\frac{1}{2000}$ in. to $\frac{1}{3000}$ in. in breadth. The cells are held together by a transparent semi-fluid cement substance.

Chemistry of Muscle.

Muscle when removed from the body, or shortly after general death takes place, enters into the condition of *rigor mortis*. The chemical features of dead muscle, or muscle in a condition of rigor mortis, differ considerably from living muscle.

Dead muscle is acid in reaction, contains myosin, various albumins, sugar, extractive bodies, as kreatin, sarco-lactic acid, xanthin, hypoxanthin, inosit, salts, &c. (solids 25 per cent.) Its acidity is due to the presence of sarco-lactic acid. Potassium salts and phosphates are especially abundant.

Living muscle is faintly alkaline, contains no myosin, but a substance or substances from which myosin is formed on coagulation of the muscle-plasma, no sarco-lactic acid, glycogen instead of sugar, various albumins and extractives, as in dead muscle. The chemical changes taking place in muscle when passing into a condition of rigor mortis, consist in the formation of myosin and sarco-lactic acid, change of glycogen into sugar; carbonic acid is set free. Healthy living muscle even while at rest absorbs O and gives out CO_2. The exchange of gases is greatly augmented during contraction.

Physical Properties of Muscular Tissue.

The most important properties of muscles are *extensibility*, *elasticity*, *contractility*.

Extensibility.—Muscle is extensile, *i.e.* capable of being extended or stretched; when one set of muscles contract, the opposing muscles are extended.

Elasticity.—Muscle possesses very little elasticity; a very small weight will stretch it, but that little is very perfect, as it returns rapidly and perfectly to its original length. The muscles of the body are always in a state of extension, *i.e.* always slightly stretched.

Contractility.—Both muscle and nerve in a living state are irritable, that is, they respond when a stimulus is applied. The muscle responds by contracting, the nerve by transmitting the stimulus to its termination. This contractility is the characteristic property of muscle. If a muscle of a recently killed frog be laid bare, and any form of stimulus applied, such as the electrodes of a battery or coil, a hot wire, a chemical substance, or a mechanical injury, it will be thrown into a state of contraction. The stimulus may be applied to muscle itself, or to a nerve in connection with the muscle.

Rigor mortis.—This term is applied to the stiffening which muscle undergoes at death. In the human subject rigor mortis is complete in four to six hours after death, and lasts twenty-four hours to several days. In exhaustion of muscular power prior to death, as in animals hunted to death, or in soldiers killed on the field of battle, it sets in very rapidly. It commences in the muscles of the jaw, then affects those of the neck and trunk, next the lower and finally the upper limbs. The cause of rigor mortis is the coagulation of the myosin; the stiffening is arrested by the injection of a 10 per cent. solution of common salt. Muscle in this condition is thicker, shorter, and firmer than living muscle; it cannot be excited by any stimuli, it is acid in reaction, from the formation of lactic acid. It is opaque and the electric currents have disappeared.

Idio-muscular Contractions.—If in a patient suffering from phthisis or some wasting disease, a superficial muscle, as the pectoralis major, be smartly tapped, a local contraction, or *wheal*, is produced, which slowly travels along the muscle in the form of a wave. This phenomenon is only observed in exhausted muscle or muscles in which the nutrition is impaired. *Fibrillar contractions* may also be seen in wasted muscles, as in progressive muscular atrophy. These consist in the quivering of local muscular fibres, without any external stimulus being applied.

Phenomena of Muscular Contraction.

1. **Change in Form.**—When a muscle contracts it shortens—that is, its ends come nearer together, while the muscle itself becomes thicker; but there is no change of bulk: what it loses in length it gains in thickness; according to Landois the volume is slightly diminished.

2. **Chemical Changes during Contraction.** (*a*) Oxygen is used up. Living muscle is constantly consuming oxygen, but more carbonic acid appears than can be accounted for by the oxygen used. (*b*) Carbonic acid is set free, not accompanied by a corresponding consumption of oxygen. Probably some complex body splits up, producing these two acids. (*c*) Muscle is normally neutral or faintly alkaline; when it contracts it becomes acid, the acidity being due to the formation of sarco-lactic acid. Other changes doubtless take place, of which little is known.

3. **Negative Variation of Muscle Current.** Whenever a muscle contracts, a change takes place

in its electrical current. If a muscle when at rest, arranged so as to show its normal current, be made to contract or enter into a state of tetanus, the normal current will undergo diminution during the contraction. By refined methods it has been shown that the negative variation occurs during the 'latent period' of stimulation.

4. **Production of Heat during Contraction.** Venous blood coming from an active muscle is warmer than blood from muscle in a state of rest. The gastrocnemius of the frog shows an increase of about one-tenth of a degree C. for each contraction. The heat developed depends to some extent on the work done.

5. **Production of Sound during Contraction.**—A sound is emitted from a muscle during

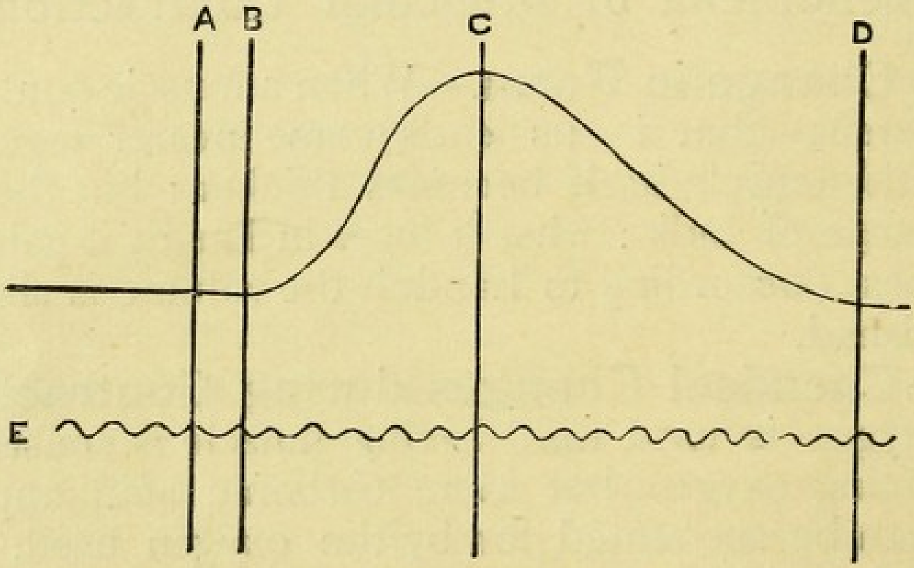

FIG. 30.—Muscle-curve obtained by pendulum myograph (Foster). A, moment when shock is sent into the nerve; B, the commencement; C, the maximum; D, the close of the contraction; E, curve made by chronograph.

contraction. By placing the ear over a contracting muscle a deep-toned sound will be heard.

Phenomena of a single Muscular Contraction.—If the sciatic nerve of a frog while still attached to the gastrocnemius, and recently removed from the animal, be placed upon the electrodes of an induction apparatus, and a single shock, either making or breaking, be made, the muscle gives a short, sharp contraction. If the muscle-nerve preparation be arranged in connection with a pendulum myograph, in which the tendon of the muscle is attached to a lever recording its movements on a moving surface, the lever rising during contraction and falling during relaxation, a curve similar to fig. 30 will be produced. The time occupied in tracing the curve is marked by the vibrations of a tuning-fork, recording on the same surface ; the apparatus also marks the exact moment when the induction-shock is sent into the nerve. By this means three facts will be demonstrated :—

1. There is a *latent period*, A to B (fig. 30), that is,

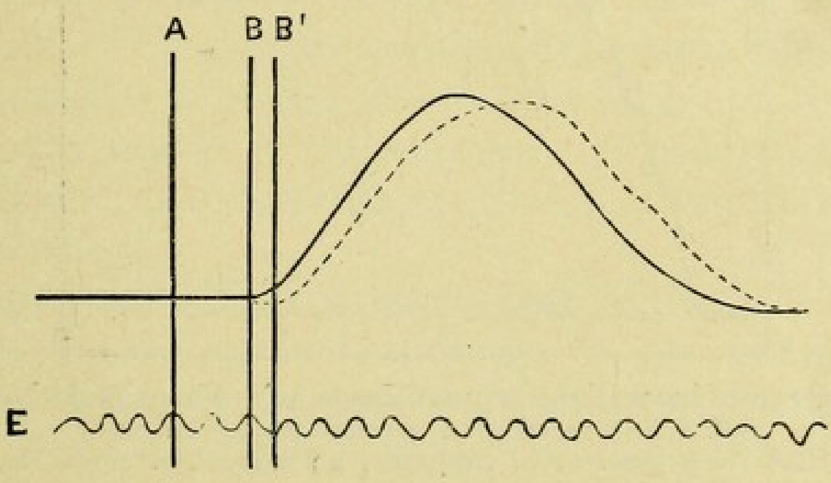

FIG. 31.—Diagrammatic muscle-curves representing electrodes placed on nerve (producing curve with dotted line) and on muscle (continuous line) (Foster). A—B′ represents whole latent period, including the time occupied by nerve-impulse in travelling along the nerve, and changes in the muscle ; B—B′ represents time occupied by impulse along nerve ; A—B represents latent period of muscle.

a short time elapses after the entrance of the shock into the nerve before the contraction of the muscle commences. This latent period is occupied by (1) the passage of the impulse along the nerve, and (2) certain changes taking place in the muscle itself before it begins to contract.

2. *There is a period of ascent or contraction* (B to C). This is slow at first, then more rapid, and slower again before the ascent is gained. The rapidity or slowness of the ascent at the various stages depends upon the weight to be raised and the exhaustion of the muscle.

3. *A period of descent or relaxation* (C to D). This is more prolonged than the ascent; it is more rapid at first than towards the end of relaxation. Exhausted muscles relax slowly.

If instead of placing the electrodes on the nerve they are placed upon the muscle itself, a muscle-curve (fig. 31) will be produced; the latent period A to B

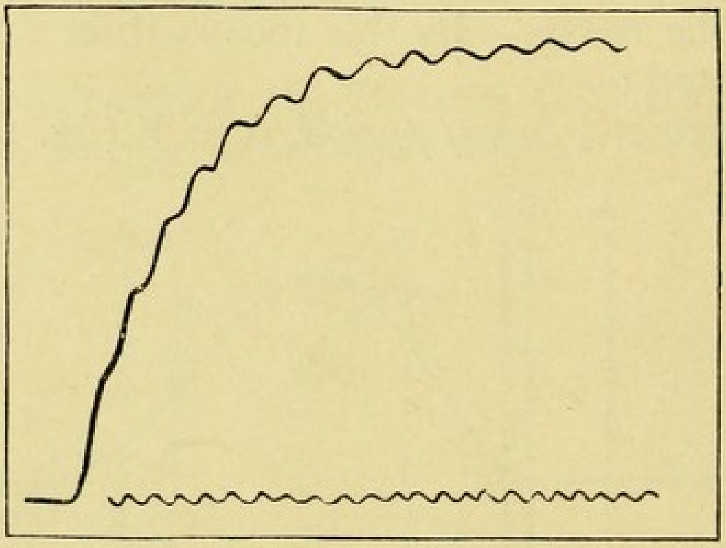

FIG. 32.—Curve of incomplete tetanus (Hermann). The stimulations succeed each other sufficiently rapidly to conceal the influence of each stimulation. Had they been more frequent, an unbroken curve would have been produced.

will be shorter than A to B′, in consequence of the time occupied by the impulse travelling down the nerve being eliminated, the latent period in this case representing preparatory changes in the muscle itself. Nerve-impulses in the frog travel at the rate of about 28 mètres per second; in man 33 mètres per second. The latent period of a frog's muscle varies from $\frac{1}{100}$th to $\frac{1}{200}$th of a second. It is shorter when the muscle is fresh and when under the influence of strychnia; it is prolonged when the muscle is heavily weighted, and in poisoning with curare.

Tetanus.—If single induction-shocks are made to follow each other slowly, a succession of curves are produced. But if they follow more rapidly, so that there is not time between the shocks for the muscle to relax, a condition of constant spasm is produced, known as tetanus. If the tetanus be incomplete, as in fig. 32, the waves produced by successive shocks are still perceptible. In complete tetanus, as produced by the magnetic interrupter in an induction machine, these are fused into one continuous curve. In the gastrocnemius of the frog twenty-seven shocks per second, and forty per second in man, are required to throw the muscle into a state of complete tetanus.

Action of Poison on Muscle.—*Curare* paralyses the terminations of the motor nerves, so that stimulation of the nerve produces no contraction, while direct stimulation of the muscle produces contraction. The sensory nerves are unaffected. It produces death by paralysing the respiratory muscles. Veratria has the same effect.

Properties of Non-striated Muscle.—When any stimulus is applied directly to an involuntary muscle, or to a nerve in connection with it, it contracts. The latent period is longer than in striated muscle ; the contraction takes place more slowly, but lasts longer. The force exerted, as in the uterus in parturition, or the bladder in expelling urine, is very great.

Effects of Muscular Exercise.

1. **On the Lungs.—Elimination of Carbon.** The most important effect of muscular exercise is to increase the number of the respirations, and thereby the quantity of air passing in and out of the lungs, leading to an increased absorption of oxygen, and elimination of carbonic acid. An adult, under ordinary

circumstances, during inspiration draws in 480 cu. in. per minute; if he walk four miles an hour, he draws in five times as much, or 2,400 cu. in.; if he walk six miles an hour, he draws in seven times as much, or 3,260 cu. in. Probably the excessive absorption of O and formation of CO_2 takes place in the muscles. For effects of exercise on CO_2 given off during respiration, see p. 126.

2. **On the Circulation.**—The increased work performed by the muscles requires increased activity on the part of the heart, to keep up the supply of arterial blood. The amount of increase is usually from 10 to 30 beats during exercise. After exercise the heart's action becomes slower. Excessive exertion may lead to hypertrophy of the left ventricle.

3. **On the Skin.**—The minute arteries of the skin become dilated, the perspiration is increased, more water, salts, and acids pass off from the system. The amount of perspiration may be more than double the usual amount. The evaporation reduces the temperature of the body, which would tend to rise. There is danger of a chill after the exertion is over, the skin still remaining wet while the heat of the body has declined.

4. **On the Voluntary Muscles.**—The muscles grow and become firmer in substance. If, however, the exercise be excessive, after growing to a certain extent, they will waste.

5. **On the Digestive System.**—The appetite increases with exercise, especially for meat and fats; this is doubtless the result of the wear and tear of the muscles and the increased elimination of carbon. Digestion is more perfectly performed, and the circulation through the liver and portal system quickened.

6. **On the Kidneys.**—The water of the urine and the salts are probably lessened in consequence of the increased perspiration. It has been shown by

various observers, including Parkes, that during active exercise the urea in the urine is not increased, but active exercise is followed by an increased appearance of urea. It appears, therefore, that to a certain extent, muscular exercise increases the elimination of urea, the urea making its appearance in the period of rest succeeding the exercise.

7. **On the Temperature.**—The temperature will not be increased ; the extra consumption of O, and the friction of the muscles, tend to raise the temperature ; but the evaporation from the surface of the skin will prevent much increased heat of body.

Various Muscular Movements.

Standing.—In standing the muscles fix all the joints of the vertebræ and lower extremities so as to form a rigid column ; any disturbance of equilibrium, *i.e.* any tendency to fall, is counteracted by muscular action. The head is fixed upon the vertebral column by the muscles of the neck ; the vertebral column is maintained in a state of rigidity by the erector spinæ and other muscles ; the hip, knee, ankle, and tarsal joints are fixed by the rigid contraction of their extensors and flexors.

Sitting.—In sitting, the body is supported on the tuber ischii, whilst the head and spine are fixed by their muscles, the muscles of the legs are relaxed and therefore at rest ; in leaning back on a support, the muscles of the back are also in part relaxed.

Walking.—In walking the legs move alternately, the movements being divided into two acts :—

1. One leg, the *active* one, is vertical and slightly flexed at the knee and supports the weight of the body ; the *passive* leg is extended, being behind the other, and touching the ground with the tip of the great toe.

2. For the forward movement of the body, the active leg is inclined forward and the knee straightened out (extended), the heel being lifted off the ground, so that only the tips of the toes touch the ground ; in the meantime the passive leg leaves the ground and swings with a 'pendulum-like movement' forward, touching the ground in front. The passive leg now becomes the active one, and act 1 is repeated.

Running.—In running the active leg as it is forcibly extended gives the impetus forward, and only one leg touches the ground at a time.

CHAPTER VI.

SKIN.

Consists of—

1. Epidermis or cuticle.
2. Dermis, corium or cutis vera.
3. Sweat glands, nails, hair, and sebaceous glands.

1. **The Epidermis** forms a protective covering over the whole surface of the body. It varies in thickness in different parts, being especially thick on the palms of the hands and soles of the feet, and wherever the skin is exposed to friction. It is moulded over the surface of the corium, covering the ridges and depressions and papillæ. It is made up of three principal layers : (*a*) the *horny layer*, or *stratum corneum*, is the most superficial, and consists of layers of flattened cells, which are dry and horny, without any nucleus ; (*b*) the *stratum lucidum*, composed of several layers of nucleated cells, which are more or less indistinct, and in section appear as an almost homogeneous layer ; (*c*) the *rete mucosum* or Malpighian

layer contains, in its upper part, layers of 'prickle' cells, and its inferior layer consists of a single stratum of columnar cells. Pigment is principally found in the lowest layer (fig. 8, *b*). **Nerves.**—According to Ranvier, fine varicose nerve-fibrils penetrate into the Malpighian layer, and end in knob-like swellings.

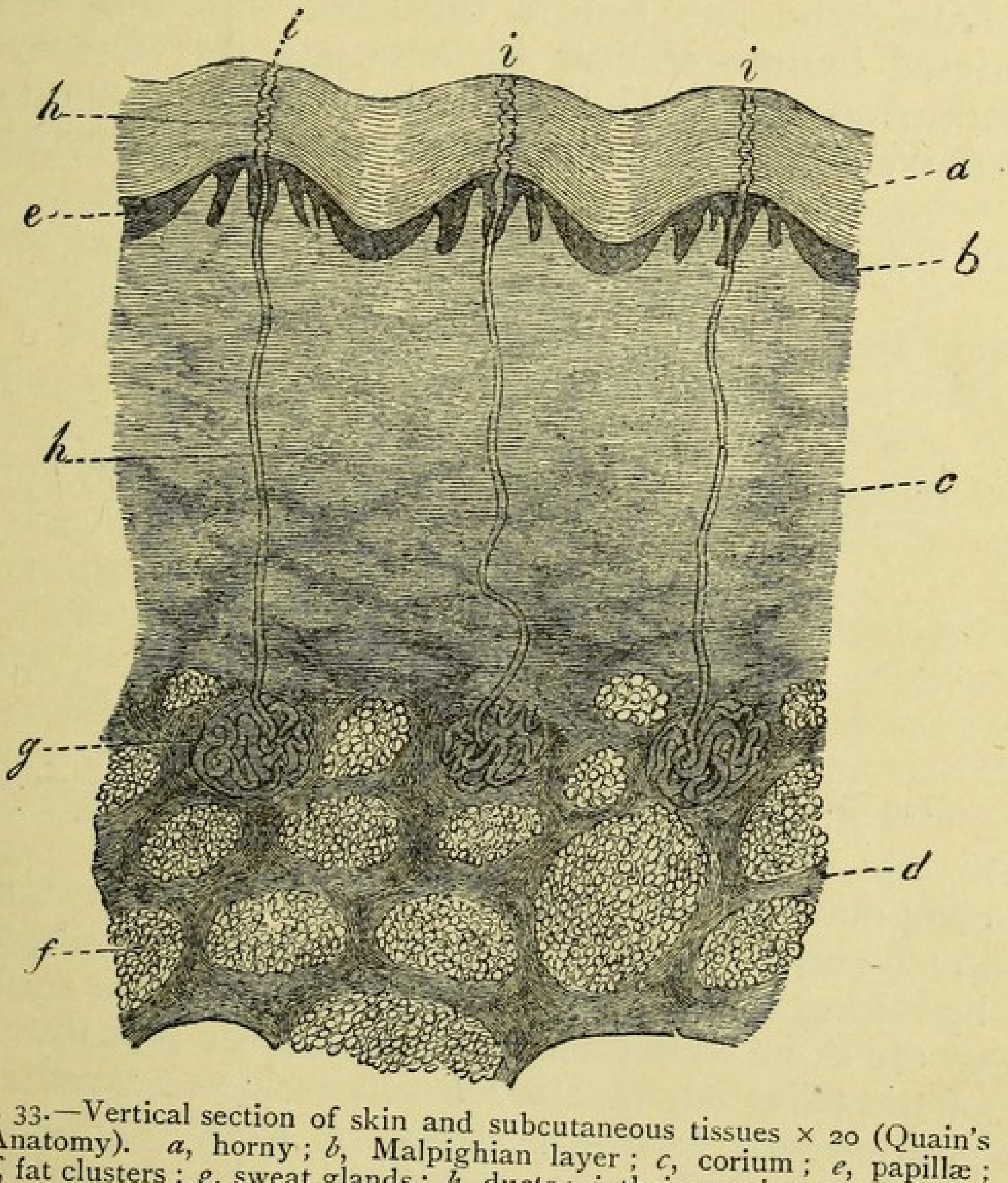

FIG. 33.—Vertical section of skin and subcutaneous tissues × 20 (Quain's Anatomy). *a*, horny; *b*, Malpighian layer; *c*, corium; *e*, papillæ; *f*, fat clusters: *g*, sweat glands; *h*, ducts; *i*, their openings.

2. **The Dermis,** or true skin, is made up of an interlacing network of connective tissue, formed of white fibrous tissue, yellow elastic tissue, corpuscles, vessels, and nerves. In some parts of the body, as

in the skin of the scrotum, perineum, penis, the cutis vera contains unstriated muscular fibres. There are also small muscular fibres in connection with the hair-follicles. Beneath the skin the subcutaneous tissues contain abundant adipose tissue. Numerous fine ridges are seen on the surface of the skin of the palm of the hand, and sole of the foot. The ridges are caused by rows of little elevations of the cutis vera, termed *papillæ*. These little eminences are more or less conical, or sometimes club-shaped ; they may be

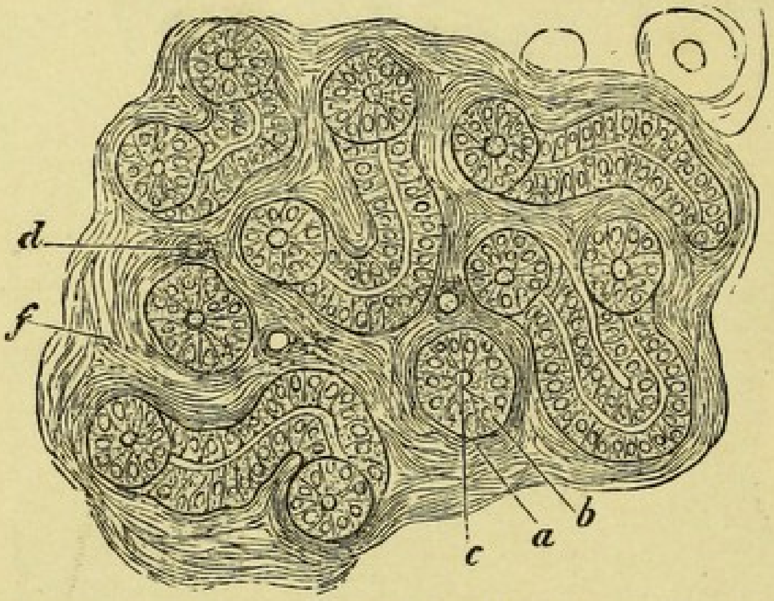

FIG. 34.—Section of a sweat gland (distal end) (Quain's Anatomy.) *a*, basement membrane ; *b*, lining cells ; *c*, lumen of tube.

compound, and contain a capillary loop, nerve, and touch-corpuscle ; they project into the epidermis, and by raising it up as it were, form a ridge on the surface of the skin. They serve to increase the sensitiveness of the part, lodging a touch-corpuscle in a favourable position for receiving sensations of touch (fig. 8).

3. **Sweat Glands** are situated in the subcutaneous tissue, and consist of a fine tube which forms the duct, continuous with a blind extremity which is coiled up into a ball of $\frac{1}{60}$ in. in diam., and is surrounded by a plexus of capillaries to form the gland (fig. 33). The distal part of the gland—namely,

some three-fourths of the coiled-up tube nearest the blind extremity—is of greater diameter than the rest, and is formed of a single layer of columnar cells, while between this and the limiting membrane is a layer of non-striated muscular cells (Klein); the lower fourth of the coil and also the sudoriferous canal as far as the rete mucosum consists of several layers of polyhedral cells, an external limiting membrane and also an internal limiting membrane; the epithelium of the duct is at its mouth continuous with the epithelium of the epidermis. The largest number of sweat glands are present in the palm of the hand; next, in the sole of the foot.

Nails.—The nail consists of a root and body. The root is that part of the nail which is covered by the skin, the body the external part which ends in the free edge. The *lunula* is the whitish portion of the body near the root, where the skin beneath is less vascular.

Structure.—The nail closely resembles the epidermis, and is, in fact, a modification of that structure, consisting of hard and thin layers of cells on the surface and round moist cells beneath, corresponding to the rete mucosum. Posteriorly the nail fits into a groove which lodges its root. The part of the cutis vera to which the root is attached is called the matrix, and is provided with large papillæ. The part to which the body of the nail is attached is called the *nail-bed.*

Hairs consist of a shaft and root. The *shaft* of the hair is cylindrical, and covered with a layer of imbricated scales, arranged with their edges upwards. The substance of the hair consists of fibres, or elongated fusiform cells, in which nuclei may be discovered. There are also present in some hairs small air-spaces, or lacunæ. In the coarser hair of the body there is the *medulla*, or *pith*, which is occupied by small angular cells and fine fat-granules.

The *root* of the hair swells out into a knob, and fits into a recess in the skin, called a *hair-follicle.* The follicle consists of two coats, an outer, or dermic coat, continuous with the corium, and an inner, continuous with the epidermis, and called the root-sheath (figs. 35 and 36). The *outer*, or *dermic*, consists of three layers : (*a*) formed of connective tissue, blood-vessels, and nerves ; (*b*) principally of corpuscles and a fibrous matrix ; (*c*) inner coat consists of a homogeneous membrane. The *inner*, or *epidermic coat* comes away when the hair is pulled out, and hence is called the root-sheath. It is made up of two layers, the outer root-sheath and inner root-sheath. The *outer root-sheath* corresponds with the rete mucosum, and is thicker than the inner, and is composed of large rounded cells. The *inner root-sheath* corresponds with the horny layer. It is composed of flattened cells. The deeper cells of the inner root-sheath form what is called Huxley's layer.

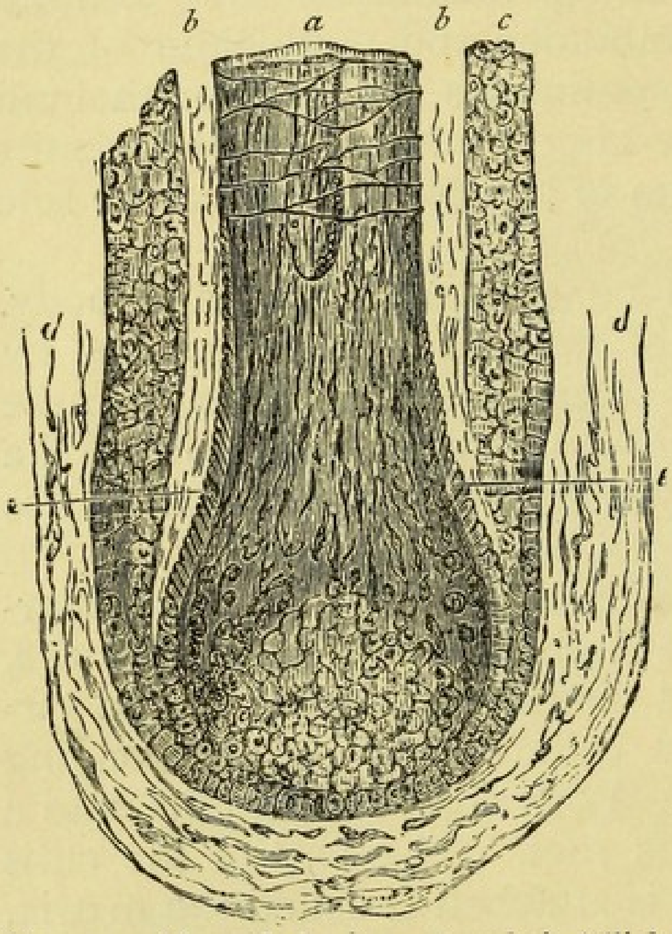

FIG. 35.—Magnified view of a hair-follicle (Quain's Anatomy). *a*, hair showing medulla, fibrous substance, and cuticle ; *b*, inner, and *c*, outer root-sheath ; *d*, dermic or external coat ; *e*, imbricated scales forming a cortical layer on the surface of the hair.

The bulbous root of the hair fits on to a papilla, which is very large in the tactile nasal hairs of the cat. Small bundles of involuntary muscular fibres connect the corium with the root of the hair, so that in contracting they elevate the hair.

The Sebaceous Glands consist of a small duct, which opens into the hair follicle, and is connected by its other end with a cluster of saccules lined with epithelium, which secrete fatty matters.

Functions of the Skin.—1. The skin everywhere clothes the external surface of the body, protecting the underlying parts from injury. 2. It affords support and protection to the terminations of the sensory nerves, which render it an important sense organ. 3. It is a bad conductor of heat, and thus serves to preserve the heat of the body. 4. It is supplied with a large extent of capillary blood-vessels, and thus by its means a large surface of blood is exposed to the cooling influence of surrounding bodies. The dilatation or contraction of the blood-vessels supplying the skin will help to regulate the heat of the body. 5. The sweat-glands which it contains make it an important excretory organ. 6. It plays a subsidiary part as an organ of respiration. 7. Under exceptional circumstances, absorption takes place from its surface.

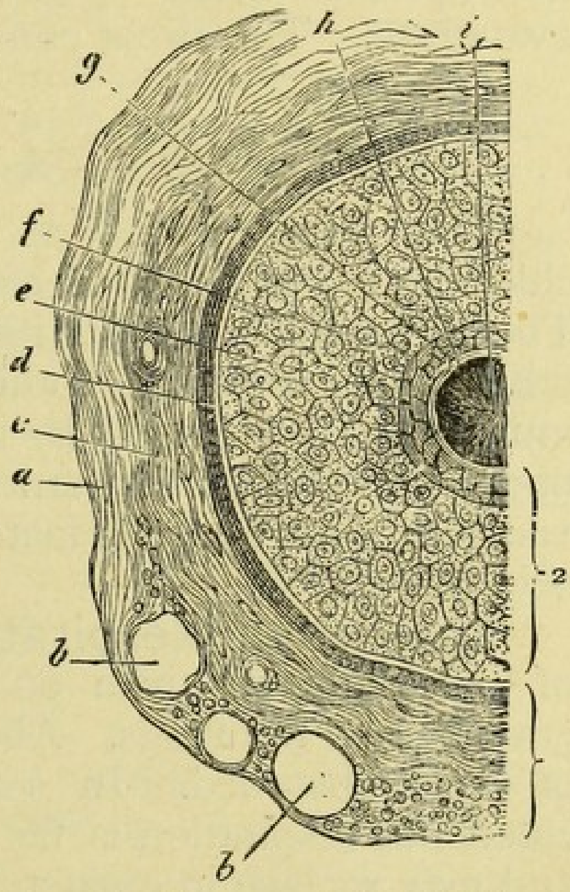

FIG. 36.—Section of hair-follicle (Quain's Anatomy). 1, dermic coat; *a*, outer layer of dermic coat; *bb*, blood-vessels; *c*, middle layer; *d*, inner or hyaline layer; 2, epidermic coat or root-sheath; *e*, outer root-sheath; *fg*, inner root-sheath; *h*, cuticle of root-sheath; *i*, hair.

The Perspiration is a clear, acid, colourless fluid with a peculiar odour. It contains nearly 2 per cent. of solid matter; its specific gravity is 1,004. The amount varies very considerably according to season, exercise taken, or fluid ingested. On an average there are about thirty ounces lost by the skin, though under exceptional circumstances the same amount might be lost in an hour. The sweat is constantly being exhaled from the body, either insensibly, or it collects in drops upon the skin, which gradually evaporate. The sweat consists of—

1. Salts.
2. Fatty acids.
3. Fats.
4. Nitrogenous bodies.

The salts consist of sodium and potassium chlorides; the acids of acetic, butyric, formic, &c. The nitrogenous bodies include urea, ammonia, and other more complex bodies. It is uncertain how much urea is excreted by the skin, if, indeed, any is, under normal circumstances. According to some, 100 grs. of nitrogenous material are thrown off by the skin daily.

Cutaneous Respiration.—About 10 grammes of CO_2 daily are given off by the skin, against 800 grammes by the lungs. About an equivalent quantity of O is absorbed. In some animals, as the frog, cutaneous respiration is far more active than in man, and may replace in great part pulmonary respiration.

Absorption through the skin may take place under exceptional circumstances. Mercury, arsenic, and many other reagents are absorbed by the skin when rubbed on the surface. The skin will absorb iodine if exposed to steam impregnated with that reagent, the iodine being again excreted by the urine.

Rabbits which have been covered with an impermeable varnish soon die. They become quickly cool, and have albuminuria. These effects are probably due to the absorption or non-excretion of the sweat, and to rapid loss of heat from dilatation of the cutaneous vessels.

The Nervous Mechanism of Perspiration. The *sweat-centres*, one for each side, are situated in the medulla oblongata, but probably subsidiary sweat-centres exist in the cord. They may be excited directly by (1) a venous state of the blood, hence the cold, clammy sweats seen in the later stages of certain diseases, as croup and pneumonia; (2) by hyperpyrexia, as when the temperature of the blood reaches 105° to 110° F. the sweating is profuse; (3) by certain drugs, such as calabar bean, nicotin, ammonium salts, opium, and ipecacuanha. Atropin appears to inhibit the sweat-centres. There appear to be *secretory nerves* which, when stimulated, increase the activity of the sweat-glands. *Vaso-motor* nerves regulate the supply of blood to the skin; they act in connection with the secreting nerves.

Sweating may be produced in the following ways: (1) by direct stimulation of the sweat-centres (*see above*). (2) By stimulation of the secretory nerves and vaso-dilator blood-vessels, as by the action of certain drugs, as pilocarpine, warmth to the surface, warm drinks, alcohol. (3) Reflexly by stimulation of certain sensory nerves. In the cat stimulation of the peripheral end of the divided sciatic produces sweating on the sole of the foot. (4) By mental stimuli.

There is a complementary action between the skin and kidneys; in summer, when the skin is active, less water is secreted by the kidneys; while in cold weather, when the skin is inactive, more water is secreted by the kidneys. In certain diseases where the kidneys are active, as in diabetes, the skin is harsh and dry.

CHAPTER VII.

THE BLOOD.

THE blood, as it exists in the living body, is a red, homogeneous, alkaline fluid, of saltish taste and faint odour; its specific gravity is 1052–1058. It consists of minute solid bodies, the corpuscles, floating in a liquid —the liq. sanguinis.

According to Hoppe-Seyler, 1,000 parts of horse's blood contain 326 parts of corpuscles, and 674 parts of liq. sanguinis.

When drawn from the blood-vessels it coagulates, fibrin is formed, and a separation takes place into clot and serum.

$$\text{Blood in living body}\left\{\begin{array}{l}\text{Liq. sanguinis}\left\{\begin{array}{l}\text{water}\\ \text{salts}\\ \text{albumin}\\ \text{elements of fibrin}\end{array}\right.\\ \\ \text{Corpuscles}\end{array}\right.$$

$$\text{Blood undergoing coagulation}\left\{\begin{array}{l}\text{Liq. sanguinis}\left\{\begin{array}{l}\left.\begin{array}{l}\text{water}\\ \text{salts}\\ \text{albumin}\end{array}\right\}\text{serum}\\ \left.\begin{array}{l}\text{elements of fibrin}\\ \text{Corpuscles}\end{array}\right\}\text{clot}\end{array}\right.\end{array}\right.$$

If the blood, as it flows from the blood-vessels, be stirred with a stick, so as rapidly to cause coagulation, we have—

$$\text{Blood}\left\{\begin{array}{l}\text{Liq. sanguinis}\left\{\begin{array}{l}\text{elements of fibrin}\quad\text{Fibrin}\\ \left.\begin{array}{l}\text{albumin}\\ \text{salts}\\ \text{water}\\ \text{Corpuscles}\end{array}\right\}\text{Defibrinated blood}\end{array}\right.\end{array}\right.$$

Red Corpuscles.—Human red corpuscles are circular biconcave discs of $\frac{1}{3200}$ in. in diameter (fig. 37). Examined singly with a high power, they are of a yellowish colour, and present a light transparent centre surrounded by an opaque rim, or *vice versâ*, according as the centre or edge is brought into focus. Examined edgeways their biconcave shape will be 77 readily seen. They have no nucleus or limiting membrane. The red corpuscles of mammals resemble those of man; the elephant has the largest, $\frac{1}{2700}$ in.; the musk deer the smallest, $\frac{1}{6300}$ in. They are oval in the camel tribe. In birds, reptiles, amphibians,

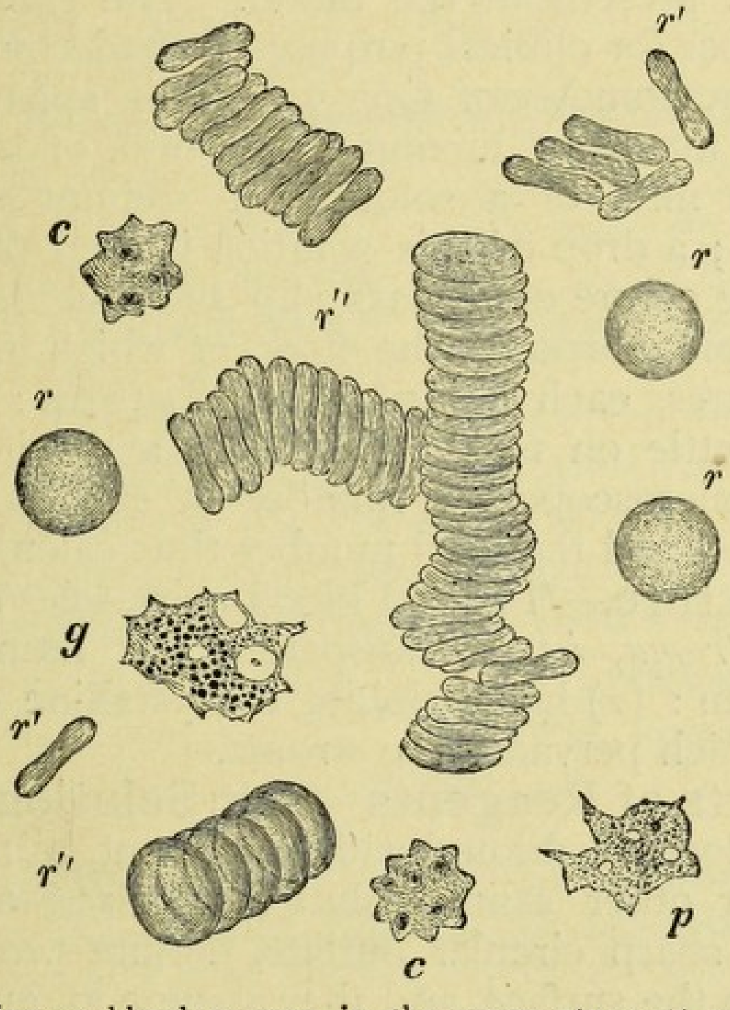

FIG. 37.—Human blood as seen in the warm stage × 1,200 (Quain's Anatomy). *r r*, single red corpuscles seen lying flat; *r' r'*, red corpuscles seen in profile; *r''*, red corpuscles arranged in rouleaux; *c c*, crenate red corpuscles; *p*, a finely granular pale corpuscle; *g*, a coarsely granular pale corpuscle. Both have two or three distinct vacuoles.

and fishes, the coloured corpuscles are elliptical discs, the proteus having the largest, $\frac{1}{400}$ in. by $\frac{1}{700}$ in.; they have also a prominent central nucleus. The red corpuscles are soft, elastic, and while pressure changes their shape, they readily regain it. When examined shortly after being drawn from the vessels, they adhere together by their surfaces, and appear like rolls of coins.

Number.—There are about 5,000,000 red corpuscles per cubic millimetre in the body in health. This number is diminished after hæmorrhages and in anæmia from whatever cause; in one case of anæmia recorded by Gowers there were only 1,290,000 per cub. mill. present in the blood. The estimation of the number for clinical purposes is made by means of the hæmacytometer of Gowers. This apparatus provides the means of mixing 5 cub. mill. of blood with 995 cub. mill. of a solution of sodium acetate of s.g. 1025; a drop of this solution is then placed in a cell in the centre of a glass slip such as are used for microscopic purposes, the floor of which is divided into squares, each being $\frac{1}{10}$ mill. square; the corpuscles settle on to these squares, and when placed under a microscope the number in each square can be counted and the total number thus calculated.

Structure.—The red blood-corpuscles consist of (1) the *stroma*, *i.e.* a transparent soft framework of protoplasm: (2) hæmoglobin, a crystalline colouring matter which pervades the stroma.

Effects of Reagents—Salt Solution.—When human blood is diluted with $\frac{3}{4}$ per cent. salt solution, serum, or other saline solution, the red corpuscles lose their sharp circular outline, minute prominences appear on the surface, and they assume an appearance termed '*horse-chestnut-shaped*,' from their resemblance to the prickly fruit of the horse-chestnut; they are also spoken of as being *crenated* (fig. 38, *f*).

Carbonic Acid.—If the horse-chestnut-shaped corpuscles be treated with carbonic acid gas, they again become smooth, though they do not regain their original biconcave form, but are more or less concavo-convex.

Tannic Acid.—If the horse-chestnut-shaped corpuscles are treated with 2 per cent. tannic acid, their hæmoglobin separates itself from the stroma of the corpuscles, and is extruded in drop-like masses. From this experiment it appears that the corpuscles are formed of a colourless *stroma* containing *hæmoglobin* (fig. 38, *g*).

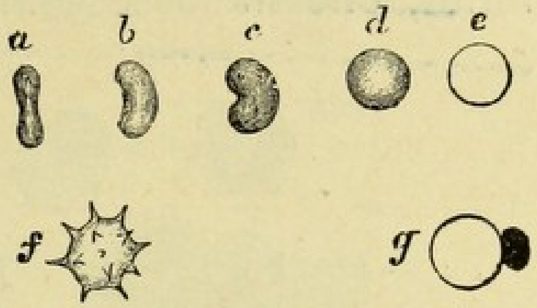

FIG. 38.—*a*–*e*, successive effects of water upon a red corpuscle; *a*, corpuscle seen edgeways, slightly swollen; *b*–*c*, one of the sides bulged out; *d*, spherical form; *e*, decolorised stroma; *f*, horse-chestnut-shaped effect of salt solution; *g*, action of tannin upon a red corpuscle.

Boracic Acid.—In newt's blood, treated with 2 per cent. boracic acid, the nucleus becomes of deeper colour at the expense of the disc, and a fine network of fibrils is displayed, which pervades both disc and nucleus. This fine network is occupied normally by hæmoglobin, and a homogeneous interstitial substance.

Water makes the corpuscles swell up and lose their hæmoglobin, their outline becoming very faint.

Chemical constituents of Red Corpuscles.

1. Hæmoglobin.
2. Globulin.
3. Salts.
4. Gases.
5. Water.

1. **Hæmoglobin** contains C.H.O.N.S.Fe., and forms 90 per cent. of (dried) red corpuscles. It is soluble in water and serum, crystallising in man and many mammals in elongated rhombic prisms, octahedral in the guinea-pig, and hexagonal in the squirrel. It can be obtained in crystals from the guinea-pig, dog, rat, or mouse, but with difficulty from the blood of sheep, ox, or pig (fig. 39).

Preparation.—The hæmoglobin is made to leave the corpuscles by shaking with ether or by alternately freezing and thawing the blood. The blood is thus rendered translucent or 'laky'; one quarter of its bulk of alcohol is added, and it is placed in a temperature of 0° C. to crystallise.

Hæmoglobin exists in the human blood in two forms, one in loose combination with oxygen—oxy-

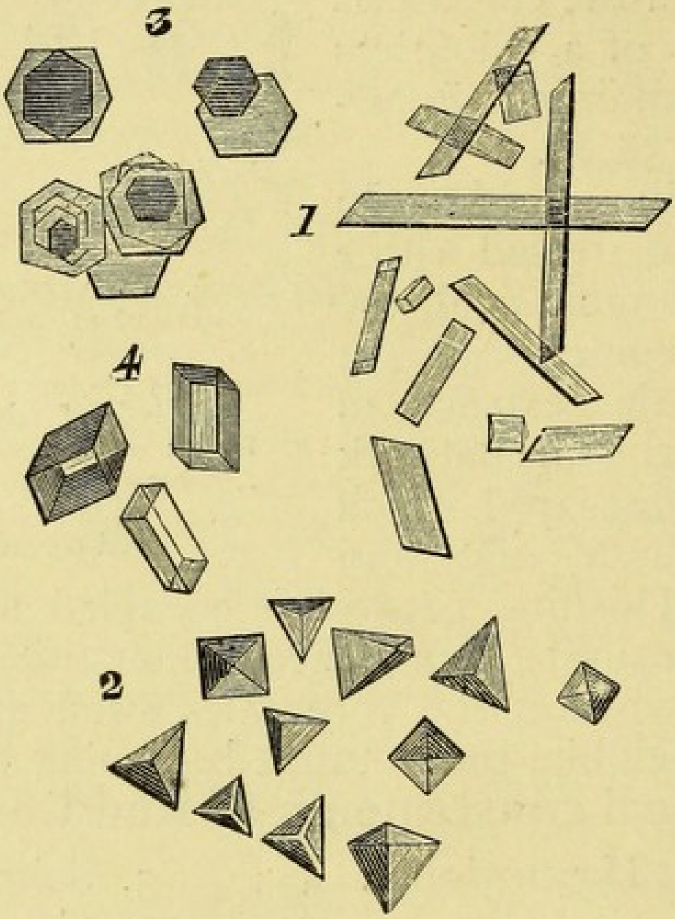

FIG. 39.—Blood-crystals, magnified, 1, human blood; 2, guinea-pig; 3, squirrel; 4, hamster.

hæmoglobin—and the other as reduced hæmoglobin. During the circulation of the blood, the O in combination with hæmoglobin is very readily given up to the tissues. If oxy-hæmoglobin be acted upon in solution with a reducing agent, as a solution of ferrous sulphate and tartaric acid with excess of ammonia, it is reduced and becomes of a purplish red colour. Oxy-hæmoglobin gives in the spectrum two narrow dark bands in the yellow and green, reduced hæmoglobin a single broad dark band intermediate in position between the two (fig. 40). Hæmoglobin readily decomposes, forming hæmatin and globulin. Hæmoglobin gives a characteristic blue colour when treated with tr. guaiaci and solution of peroxide of hydrogen.

Methæmoglobin is found in old blood-stains and in bloody urine ; it gives four bands in the spectrum (fig. 40, 5).

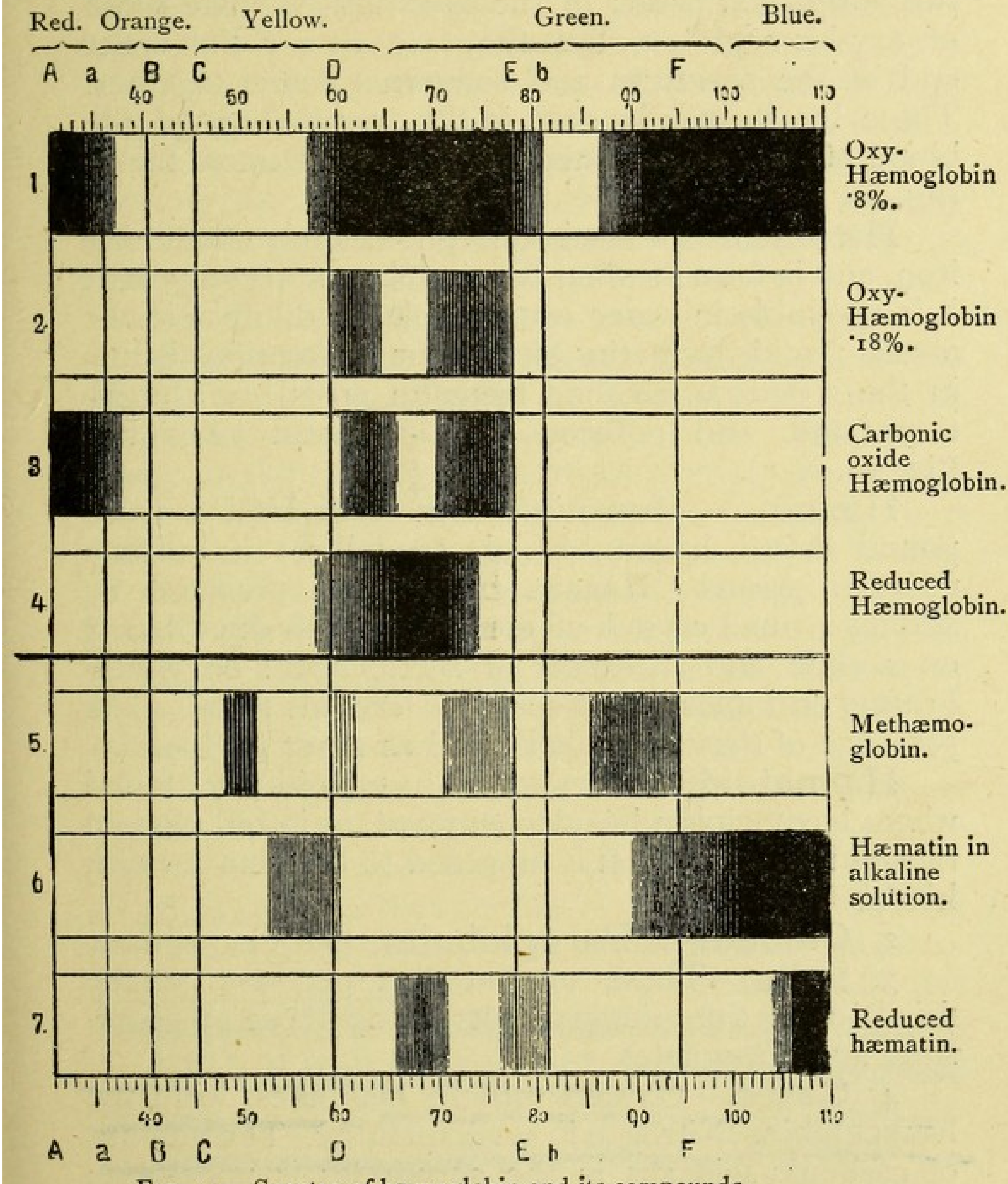

FIG. 40.—Spectra of hæmoglobin and its compounds.

CO-Hæmoglobin is a more stable compound than oxy-hæmoglobin, and is formed in the body when CO is inhaled, carbonic oxide displacing the oxygen in the hæmoglobin, the animal quickly dying. CO-hæmoglobin is of a florid red colour, and gives two absorption bands in the spectrum very like those of oxy-hæmoglobin, but they are nearer the violet end of the spectrum and somewhat nearer together. These bands may be seen in the examination of the blood of persons poisoned by coke or charcoal fumes (fig. 40, 3).

Hæmatin is a black amorphous body containing iron, and is formed when hæmoglobin is decomposed; it is insoluble in water but soluble in dilute acids or alkalis; acid hæmatin gives four absorption bands in the spectrum, alkaline hæmatin gives one absorption band, and reduced alkali-hæmatin gives two (fig. 40, 6, 7).

Hæmin. — Hæmatin forms with HCl a compound called hæmin, which crystallises in minute rhombic prisms. Hæmin crystals are prepared by adding a small crystal of common salt to dried blood on a slide and an excess of acetic acid: on gently heating and allowing to cool, the crystals form. The presence of these crystals is used as a test for blood.

Hæmatoidin.—Crystals of hæmatoidin are found where hæmoglobin has decomposed, as in old clots of blood in the body. It is supposed to be identical with bilirubin.

2. **Globulin** or **Paraglobulin.** See *Coagulation.*

3. **Salts.**—These amount to 1 per cent. of the dried solids, the principal salts being those of potassium and phosphates.

4. **Gases.**—Oxygen loosely combines with the hæmoglobin. Nitrogen in small quantity. The amount of carbonic acid gas in the corpuscles is uncertain; by far the greater part exists in the serum (*see* p. 76).

5. **Water** forms 56·5 per cent. of the corpuscles.

Origin of the Nucleated Red Blood Cor-

puscles in the Embyro.—From cells in the vascular area of the mesoblast. These mesoblastic cells become branched, and their processes join together, so that an irregular network of granular corpuscles is formed. The nuclei multiply, some form corpuscles which acquire a reddish colour, others remain to form the epithelium of the capillaries. The first-formed red corpuscles are nucleated cells, exhibit amœboid movements, and multiply by division. These primary nucleated corpuscles are gradually succeeded by ordinary red corpuscles, and before the end of intra-uterine life the nucleated ones have disappeared.

Origin of the Red Blood Disks.—1. In the fœtus the red blood disks are formed in the interior of mesoblastic or connective-tissue cells. The protoplasm of the cell acquires a reddish tinge, then round red bodies appear, the cells become elongated, and join others forming a network; eventually a system of capillaries is formed, and the blood disks join the general circulation. 2. Origin from white corpuscles. 3. In the marrow of bones. Peculiar cells are seen in the marrow filling the spaces of the cancellous tissue of the ribs, flat bones, and the ends of the long bones, which are apparently intermediate forms between marrow-cells and red blood corpuscles. They closely resemble the nucleated red corpuscles of the embryo. 4. In the spleen, though this is doubtful. 5. Several authors have described small bodies termed 'hæmatoblasts,' which are believed by some to be transitional forms between the white and red corpuscles.

Fate of Red Corpuscles.—Probably broken up in spleen. Hæmoglobin probably forms bile-pigments.

WHITE CORPUSCLES OR LEUCOCYTES (fig. 37).—The white corpuscles in human blood are spheroidal,
3 μ finely granular masses of $\frac{1}{2800}$ inch in diameter. In a cubic millimetre of human blood there are about 10,000 white corpuscles. Some of them are of less size,

being smaller than the red corpuscles. They have a lower specific gravity than the red. They have no cell-wall, and their substance consists of protoplasm. According to Heitzmann, their granular appearance is due to a fine intercellular network, having small dots at the intersections of the network. In the meshes of the network there is a hyaline substance. They possess one or two nuclei, which are readily brought out by acetic acid. When examined in a fresh state, especially if placed on a warm stage, they exhibit spontaneous change of shape like the amœbæ, these movements being termed amœboid. The movements consist in a protrusion of processes of protoplasm, which are retracted and other processes protruded.

Both in human and newt's blood there are some colourless corpuscles which contain coarser granules than others; these are called *granular corpuscles*. The white corpuscles will take up coloured foreign particles, as vermilion. They are found in various tissues of the body, as in the meshes of the retiform tissue of lymphatic glands, tonsils, solitary glands, &c. In inflammation they pass through the walls of the capillaries into the tissues. They are present in the blood in the proportion of 1 per 300 red corpuscles after a meal, and 1 per 800 during fasting; they are much more numerous in some diseases, as in leucocythæmia.

Composition :—

1. Several albuminous substances.
2. Lecithin and glycogen.
3. Salts, mainly potassium and phosphates.
4. Water.

Origin.—Probably from the lymphoid tissues of the body, i.e. lymphatic glands, solitary glands, spleen, &c., by division of the leucocytes existing there. The thoracic duct and lymphatics are constantly pouring white cells into the blood, derived from the mesenteric and other lymphatic glands.

Fate.—They are converted into red corpuscles. During inflammation they pass through the capillary walls, and are converted into pus-cells; it is also probable they are utilised in other ways than in forming pus, possibly being converted into the cell-elements of new tissues, or taking the place of worn-out cells throughout the body.

Blood-plates.—These are colourless, oval disks, found in the blood, and named blood-plates by Bizzozero. They are best seen in the blood of the guinea-pig.

LIQ. SANGUINIS is a clear yellow alkaline fluid in which the corpuscles float. It may be obtained by allowing the slowly coagulable blood of the horse to stand in a tall vessel surrounded by ice. The temperature of 0° C. prevents coagulation, the corpuscles subside, and the clear fluid may be removed by pipette. Its composition may be described as serum *plus* the elements of fibrin.

SERUM.—When blood has coagulated, and the clot separated, a thin yellow transparent alkaline fluid is left, of specific gravity 1028.

It consists of—

1. Albumin . . .	78·8 parts
2. Paraglobulin . . .	4·0 ,,
3. Extractives . . .	3·9 ,,
4. Fatty matters . .	1·7 ,,
5. Salts	8·6 ,,
6. Water and gases . .	903·0 ,,

1. **Albumin** exists in combination with the sodium as an albuminate. It is in the form of serum-albumen, differing from egg-albumen in not being coagulated by ether. On boiling the serum, the albumen coagulates; the fluid, after being deprived of its albumen, is called *serosity*.

2. **Paraglobulin,** one of the fibrin-factors, is

present, all the fibrinogen disappearing during coagulation.

3. **Extractives** include kreatin, kreatinin, urea, uric acid, and traces of grape sugar.

4. **Fatty Matters** in minute division, and combined with sodium as soaps.

5. **Salts,** principally sodium salts, in combination with Cl and CO_2, smaller quantities of potassium and calcium phosphates and sulphates.

6. **Gases.**—CO_2, partly free, and partly in combination with the sodium.

Gases of the Blood.

In human blood it has been calculated that 100 vols. of blood contain :—

	O	CO_2	N
Arterial blood	20 vols.	39 vols.	1–2 vols.
Venous blood	8–12 ,,	46 ,,	1–2 ,,

measured at 0° C. and 760 mm.

Oxygen is present in arterial blood in the proportion of 20 per cent.; in venous blood the amount necessarily varies according to whether the blood has passed through an organ in a state of activity or in a state of rest. In asphyxia oxygen may be entirely absent from the blood. Nearly the whole of the oxygen is in loose chemical combination with the hæmoglobin of the corpuscles. The oxygen of the blood can be expelled from it by means of the mercurial air-pump; no oxygen escapes till the pressure is reduced to 125 mm., or about $\frac{1}{6}$th of the ordinary atmospheric pressure; the gas is then rapidly given off and the blood becomes dark. The oxygen can also be expelled by passing other gases, CO, NO, N or H, through the blood. It can also be extracted by reducing agents, as ammonium sulphide and Stokes's fluid, (sulphate of iron, tartaric acid with excess of ammonia).

Carbonic acid.—This gas is present in arterial blood in the proportion of about 39 per cent.; in venous in variable amount, according to the vein from which it is taken and the activity of the organ yielding it; it averages 46–50 per cent. CO_2 is present in the liq. sanguinis in combination with sodium; a part, the 'loose' CO_2, so-called on account of its being readily given off in the mercurial air-pump, is in combination with sodium as the hydro-sodic carbonate ($NaHCO_3$); and part also as 'fixed' CO_2, as it can only be expelled by an acid, being in the form of sodic carbonate, Na_2CO_3. When hydro-sodic carbonate is exposed to diminished pressure in the air-pump, CO_2 is given off as follows:—

$$2NaHCO_3 = CO_2 + Na_2CO_3 + H_2O.$$

Carbonic acid is also present in small quantities in the red corpuscles in loose chemical combination (Ludwig).

Nitrogen exists simply dissolved in the blood.

Coagulation of the Blood.

Blood drawn from a living animal into a beaker first becomes viscid and then is converted into a jelly. This jelly is of the same bulk as the previous blood. Finally, the jelly contracts, forming the clot, and a yellow clear liquid, the serum, oozes out. In man blood becomes viscid in two or three minutes, forms a jelly in five or six minutes later, and a few minutes later still the serum begins to appear. In the horse coagulation goes on more slowly, so that the corpuscles have time to sink before the jelly stage is reached; so that a yellowish stratum is formed on the top, free from red, but containing white corpuscles, called the 'buffy coat.' This buffy coat appears in human blood in certain inflammatory conditions.

Many circumstances favour or postpone the coagulation of the blood. The principal are—

Circumstances favouring Coagulation.

1. Contact with foreign matter.
2. Moderate temperature, 100° to 120° F.
3. Stasis of blood in the vessels, or injury to or inflammation of the lining membrane.

Circumstances retarding Coagulation.

1. Contact with lining membrane of the blood-vessels.
2. Cold (0° C.) indefinitely postpones.
3. Addition of neutral salts, or the caustic alkalies.

Contact with foreign matter quickly determines coagulation, while contact with the endothelium of the blood-vessels exercises a restraining influence. If the jugular vein of a horse be ligatured at both ends and cut out, the blood will remain fluid for one or two days, but will clot on being withdrawn. Blood will remain fluid for several days in the excised heart of the turtle. Horse's blood allowed to stand sursounded by ice will remain fluid indefinitely. Blood drawn into a saturated solution of sodic phosphate will remain fluid, but will clot if diluted. The share taken by the corpuscles in coagulation is uncertain. Fluids containing white corpuscles clot more firmly and quickly than those containing red only.

The immediate cause of coagulation is the formation of fibrin, of which blood yields about ·2 per cent. Fibrin is formed by the union of two albuminous bodies present in the blood—paraglobulin and fibrinogen. A third body, supposed to be of the nature of a ferment, is essential, or at any rate favours the process.

Fibrin.—This substance may be obtained by stirring some freshly-drawn blood with a stick or bundle of twigs. It is a white stringy body, insoluble in water or alcohol, soluble in alkalies, lactic, phosphoric, and acetic acids. HCl converts it into syntonin.

Paraglobulin may be obtained from serum of diluted liq. sanguinis, by passing through it a stream of CO_2 or saturating it with NaCl. It is thrown down as a granular white precipitate.

Fibrinogen may be obtained in a similar manner by passing CO_2 through hydrocele or pericardial fluid, or saturating with NaCl.

The Ferment is obtained by adding defibrinated blood to twenty times its bulk of alcohol; a precipitate of albuminous bodies with the ferment is thrown down. Distilled water dissolves out the latter, and if added to a solution containing fibrinogen and paraglobulin, coagulation quickly ensues.

Amount of Blood in Body.—Probably about $\frac{1}{13}$th of the body-weight as estimated by the hæmoglobin of the blood. By calculating the amount of blood escaping from the body of a decapitated criminal, by weighing the solid residue, after the addition of the blood washed out of the blood-vessels by injection of water, Lehmann estimated the amount of blood as being 1 in 8.

In a new-born child it is 1 in 19.

Quantitative Composition of Human Blood as a Whole:—

Water	790	parts
Fibrin	2	,,
Hæmoglobin	140	,,
Albumen, &c.	60	,,
Salts	8	,,
	1000	

CHAPTER VIII.

THE CIRCULATION.

THE circulation is carried on by means of the—

1. **Heart,** beating about seventy per minute, alternately receiving blood from the venous system, and discharging it into the pulmonary artery and aorta.

2. **Arteries,** with elastic and muscular walls, forming channels for the blood to the system, assisting the heart in maintaining the circulation, and regulating the supply of blood to different parts.

3. **Capillaries.**—Canals of minute calibre, with thin permeable elastic walls, allowing both liq. sanguinis and white corpuscles to pass through their walls into the surrounding tissues.

4. **Veins,** forming channels back to the heart, provided with muscular walls and valves, and being sufficiently capacious to hold the total blood of the body.

THE HEART.

The heart consists of four chambers with contractile walls, situated in the chest, and surrounded by a fibro-serous sac—the pericardium—in which it works.

The Pericardium.—This membranous sac is attached below to the diaphragm, while its upper and narrower part surrounds and is attached to the great vessels connected with the base of the heart. It consists of an external fibrous layer, and an internal serous sac. The *fibrous* layer is a tough, dense membrane, attached below to the central tendon and muscular fibres of the diaphragm; above it is attached to the great vessels, and is continuous with their external coats. The *serous* covering consists of a parietal layer, which is united to the inner surface of the fibrous layer, and a visceral, which is reflected round the great vessels enclosing the aorta and pulmonary artery in a common sheath. In structure the serous layer resembles other serous membranes.

General Description of the Heart.—In form, the heart resembles a cone, its *base* being directed upwards, backwards, and to the right, its *apex* downwards, forwards, and to the left. In part it is covered by the lungs, especially during inspiration. Its *apex*-beat is felt at the fifth intercostal space, two inches below the nipple, and one to the inner side of the left nipple line. In order to map the outline of the heart on the chest-wall, define the *base* by drawing a transverse line across the sternum corresponding with the upper border of the third costal cartilages, continuing it ½ in. to right of sternum, and 1 in. to left. *Lower border.*—Draw a line from the apex-beat through the sterno-xiphoid articulation to the right edge of sternum. *Right border.*—Continue last line with an outward curve to join the right end of the base line. *Left border.*—Draw a line curving to left (inside nipple) from the apex-beat to the left end of the base line.

Cavities of Heart.—The heart contains four chambers, two auricles and two ventricles.

The Right Auricle receives the blood from the superior and inferior venæ cavæ at its upper and lower posterior angles. The septum between the two auricles forms the posterior wall, and presents the *fossa ovalis* (fig. 41, 3′), the remains of the *foramen ovale*), which is surrounded by a border (except below), the *annulus ovalis.* Between the two orifices of the venæ cavæ is the *tubercle* of *Lower* (fig. 41, 3), and in front of the opening of the inferior vena cava is the

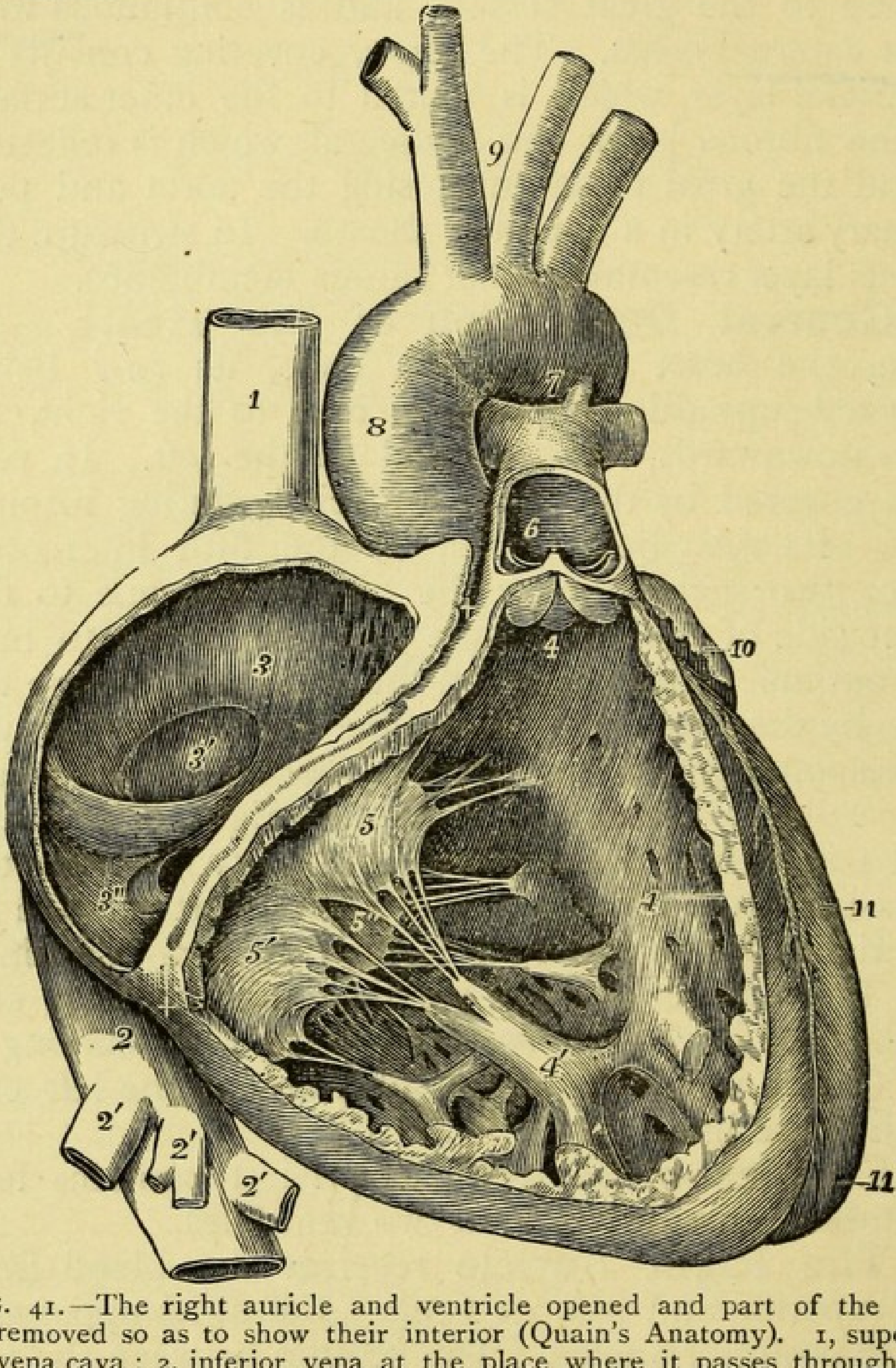

FIG. 41.—The right auricle and ventricle opened and part of the wall removed so as to show their interior (Quain's Anatomy). 1, superior vena cava ; 2, inferior vena at the place where it passes through the diaphragm ; 2′, the hepatic veins cut short ; 3, tubercle of Lower ; 3′, fossa ovalis, the Eustachian valve is just below ; 3″, opening of the great coronary vein and valve ; 4, 4, right ventricle ; 4′, large anterior columnar cornea ; 5, the anterior ; 5′, the inferior ; 5″, septal segment of the tricuspid valve ; 6, interior of the pulmonary artery ; 7, 8, aorta ; 9, innominate and left carotid artery ; 10, left auricular appendix ; 11, 11, left ventricle.

Eustachian valve. The *coronary vein* opens into the auricle between the inferior cava, and auriculo-ventricular opening, and is guarded by the *valve of Thebesius* (fig. 41, 3″). The auricular appendix is a tongue-shaped appendage, which projects from the anterior angle, and covers the root of the aorta. The cavity of the auricle is smooth, except that of the auricular appendix, which presents the muscular bands called *musculi pectinati.* The openings into the right auricle are the following:—(1) Openings of venæ cavæ; (2) auriculo-ventricular opening; (3) orifice of coronary sinus; (4) openings of one or two small veins of right ventricle; (5) foramina Thebesii, which are small depressions, some of them transmitting minute veins.

The Right Ventricle forms the right border and chief part of the anterior surface of the heart. At its base are two orifices guarded by valves, the *auriculo-ventricular* and the *pulmonary artery.* The inner surface presents muscular elevations termed *columnæ carneæ,* some of which are attached by their extremities to the wall of the ventricle, others are attached along their whole length, while a third set are connected by their bases to the ventricular wall, and are connected by their other extremities to the segments of the tricuspid valves, by means of the *chordæ tendineæ* (see fig. 41).

The Left Auricle is situated at the posterior part of the base of the heart. It receives two pulmonary veins on each side, and opens into the left ventricle through the mitral valve. The interior of the left auricle is smooth like the right, its appendix presenting musculi pectinati.

The Left Ventricle forms the left margin of the heart, the greater part of the posterior, and a small part of the anterior surface. Its walls are some three times as thick as the right ventricle, its musculi papillares are larger, and the chordæ stronger. Like the right ventricle, it has two orifices, *auriculo-ventricular*, guarded by the mitral, and the *aortic*, guarded by the *semilunar valves*.

Endocardium.—The internal membrane lining the heart closely resembles the lining membrane of the arteries. It consists of a single layer of tesselated epithelium, with a connective-tissue layer beneath.

Valves of Heart.—The *mitral* and *tricuspid* valves are situated at the auriculo-ventricular orifices, and prevent the passage of blood into the auricle during the ventricular systole. They consist of flaps or cusps, two in the mitral, and three in the tricuspid, connected by their bases to the auriculo-ventricular orifices ; their free margins and lower surfaces give attachment to the chordæ tendineæ which connect them with the musculi papillares. They are formed of a duplicature of the lining membrane of the heart, strengthened by connective tissue. During the ventricular systole, the pressure of the blood in the ventricles presses their free edges or rather their marginal surfaces together, the musculi papillares regulating the tension of the chords and preventing the valves from becoming retroverted into the auricles.

The *semilunar valves* guard the aortic and pulmonary openings. They consist of three semicircular folds attached by their convex margin to the wall of the artery at its junction with the ventricle, and are formed by a reduplication of the lining membrane strengthened by fibrous tissue. In the centre of each free margin is a little nodule, the corpus Arantii, the the three meeting in the centre when the valves are closed. On each side of the corpora Arantii is a thin semilunar marginal surface, where the fibrous tissue is absent, called the lunula ; these surfaces come in contact when the valves close. After the systole of the ventricles, the tension of blood in the aorta and pulmonary artery closes the valves by distending them and pressing the marginal surfaces together. The semilunar valves during the ventricular systole are pressed back against the walls of the aorta, and hence, according to Brücke, prevent the filling of the coronary arteries which arise from the sinus of Valsalva during the ventricular systole, the coronary arteries being filled after the closure of the valves and during the diastole of the ventricle.

Sounds of the Heart.—*First sound.*—Best heard at the apex-beat. It is synchronous with the ventricular systole, commencing immediately the ventricle begins to contract, but ceases before its completion. It is louder, longer, duller, than the second sound. Various explanations have been given as to its cause; none of them are entirely satisfactory. It has been ascribed to :—

1. Closure of auriculo-ventricular valves.
2. Muscular sound of contraction of ventricles.
3. Cardiac impulse against chest-wall.

The closure of the auriculo-ventricular valves seems the most probable cause, as when these valves are diseased the normal first sound is replaced by a murmur. The last explanation (3) is improbable.

The *second sound* is short and sharp ; it is heard best at the junction of the third right costal cartilage with sternum, and corresponds to the closure of the semilunar valves. Between the first and second sounds the pause is very short, but between the second and succeeding first, the pause is longer, and is about equal in duration to the time occupied by the first and second sounds together (fig. 42). In certain abnormal conditions of the circulation, as in Bright's disease, or in mitral obstruction, or regurgitation, a double first or second sound may be heard.

Doubling or reduplication of the first is less common than that of the second. According to Potain, normally there is a reduplication of the second sound at the end of inspiration and beginning of expiration.

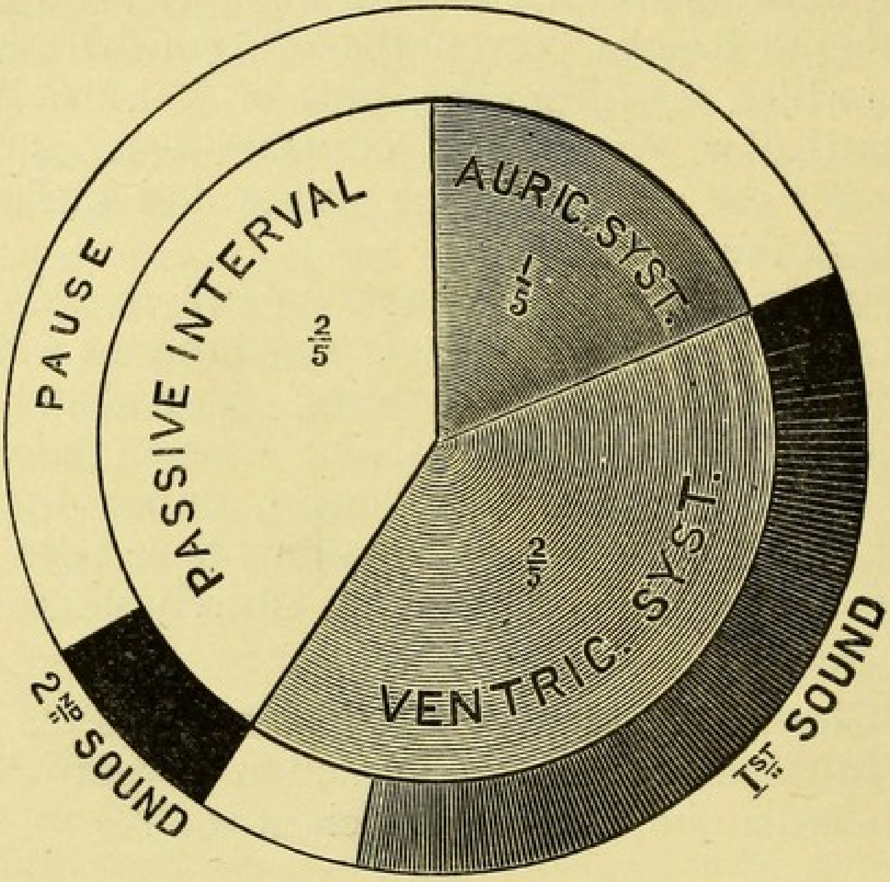

Fig. 42.—Diagram illustrating sequence of events in a cardiac revolution.

The sounds have been likened to the pronunciation of the syllables *lŭbb*, *dŭp*.

A Cardiac Revolution.—A complete cardiac cycle includes three acts, viz :—

Systole of the auricles, *systole of the ventricles*, and *pause* (see fig. 42).

During the pause (includes the passive interval) after the contraction of the ventricles, the venæ cavæ and pulmonary veins are pouring blood into the auricles, a portion of the blood escaping through the auriculo-ventricular valves into the ventricles.

The **auricular systole** commences in the muscular fibres surrounding the great veins, the contraction running through vessels and auricles in a peristaltic wave, emptying the contents of the vessels into the auricle, and then emptying the auricle itself, the appendix being the last part to contract, the ventricles becoming filled. Regurgitation into the great veins is hindered by (1) Peristaltic contraction of the muscular walls of the veins, their mouths becoming narrowed; (2) Aspirating power of thorax during inspiration; (3) Valves at junction of subclavian and internal jugular veins. Regurgitation into the coronary sinus is prevented by the valve of Thebesius.

Then follows immediately the **systole of the ventricles.** The ventricles become tense and hard, change from a rounded to a more conical form; the heart twists on its long axis from left to right, and ejects the ventricular contents—5 to 6 oz. of blood—into the aorta or pulmonary artery; the auriculo-ventricular valves close at the commencement of the ventricular systole, while the semilunar valves open. The ventricular systole is not so simple as it at first sight appears; the first stage or act consists in the sudden hardening of the ventricular walls at the commencement of their contraction; the second is the forcible ejection of their contents, followed by closure of the semilunar valves; thirdly, there succeeds a quiescent period, when they remain empty and contracted. The first stage, which is synchronous with the 'cardiac impulse,' is registered on the cardiographic tracing (fig. 43) by the sudden rise of the lever, *b e*; the other two are included in that part of the tracing between *e* and *f*. The semilunar valves open and the auriculo-ventricular close at *e*, at the commencement of the active contraction, and the semilunar valves close and the auriculo-ventricular open at *f*, at the end of the systole. The time occupied by a complete beat is about ·8 sec. It will be divided in the following manner, supposing that beat occupied one second :—

Contraction of auricles	$= \frac{1}{5}$ sec.
Dilatation of auricles	$= \frac{4}{5}$ sec.
Contraction of ventricles	$= \frac{2}{5}$ sec.
Dilatation of ventricles	$= \frac{3}{5}$ sec.

or,

Auricular systole	$= \frac{1}{5}$ sec.
Ventricular systole	$= \frac{2}{5}$ sec.
Pause	$= \frac{2}{5}$ sec.

(See fig. 42.)

The **passive interval** which follows the ventricular systole corresponds with the auricular diastole, blood pouring from the great veins into the auricle.

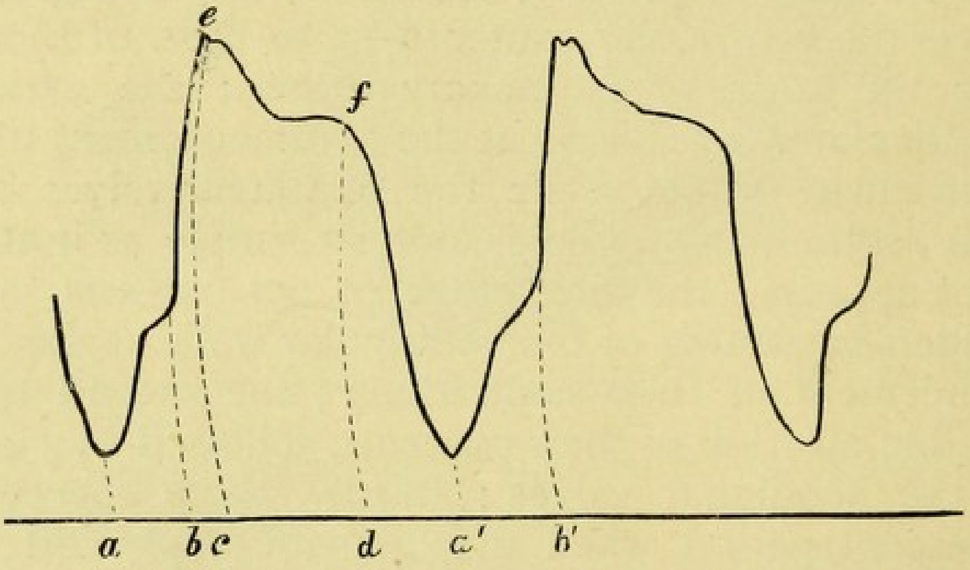

FIG. 43.—Tracing obtained by a cardiograph placed directly on the ventricle of a cat's heart (Foster) *a—b*, corresponds to the distension of the ventricle, during the auricular systole ; *b—c*, the time during which the ventricles change their shape from a flattened to a rounded form ; *e*, marks the closure of the auriculo-ventricular and opening of the semilunar valves ; *c—d*, the expulsion of the ventricular contents and time during which the ventricle remains contracted ; *d—a'*, relaxation of the ventricles. The semilunar valves probably close at *f*.

Cardiac Impulse.—The impulse of the heart may be both seen and felt in the 5th intercostal space, midway between the left edge of the sternum and a line drawn vertically through the nipple. It is most marked during expiration, and disappears or diminishes at the end of inspiration, inasmuch as the heart's apex is separated from the chest-wall by lung. It is caused by the sudden hardening of the left ventricle during the systole, and probably also in part by the heart twisting slightly on its axis, the apex being brought more forward.

A tracing can be obtained from the cardiac impulse in a man by means of a cardiograph. Fig. 44 shows the curve registered by the impulse of the heart of a healthy man; *a b* corresponds to the auricular systole, the ventricles being filled with blood; *b c*, *c e*, corresponds with the apex-beat and ventricular systole; *d* and *e* mark the closure of the aortic and pulmonary valves, the aortic closing $\frac{1}{20}$ sec. before the pulmonary; *e f* marks the diastole of the ventricles.

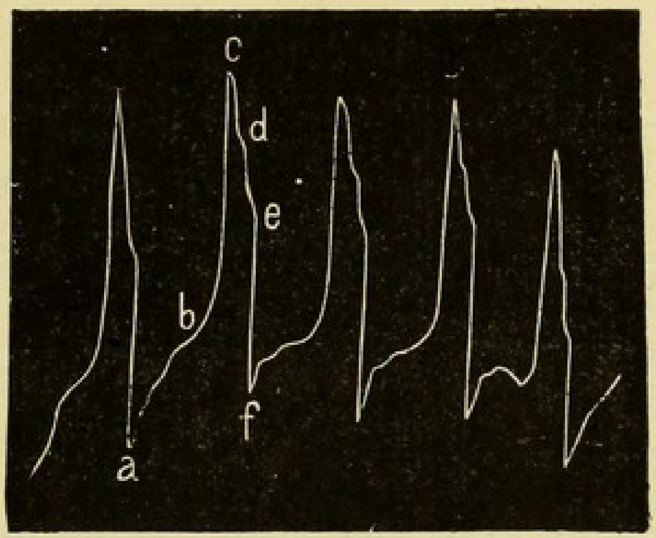

FIG. 44.—Tracing obtained by cardiograph from apex-beat of a healthy man. *ab*, contraction of the auricles; *bc*, contraction of ventricles; *d*, closure of the aortic; *e*, closure of pulmonary valves; *ef*, diastole of ventricles. (Landois and Sterling.)

Work done by the Heart.—It has been calculated that the daily work of the right ventricle is equal to 15,000 kilogramme-mètres; the left ventricle is equal to 60,000, so that the total work of the heart in twenty-four hours may be estimated at 75,000 kilogramme-mètres, or about one-fifth of the total work performed by the body. This is about the amount of work performed by a man in the ascent of Snowdon (Foster).

Frequency of Cardiac Pulsations.—In the adult 65–75 (average 72) per minute. In the fœtus, 150–200. At birth it is 140; end of second year, 110; end of fifth, 100; end of fourteenth, 86; at twenty-one, 75. It is affected by position, being five beats more when sitting than lying down, and ten more in standing than sitting, a result due to the greater number of muscles brought into a state of contraction. The number of beats is increased by active exercise, during digestion, and by excitement. Increased resistance to the flow of blood at first increases, then, if continued, diminishes the number of beats. Diminished pressure, as in a large hæmorrhage, increases the number of beats. A slow pulse differs from a quick pulse rather in the length of the diastole, than from any change in the systole.

Endocardial Pressure.—Goltz and Gaule found the maximum pressure in the left ventricle of a dog amount to 140 mm. of mercury, 60 mm. in the right ventricle, and 20 mm. in right auricle. Immediately after the systole a negative pressure of −52 to −20 mm. was observed in the left ventricle, in the right ventricle about −17 mm., and in the right auricle −12 to −7 mm. While to some extent this negative pressure is due to the aspirating power of the thorax during inspiration; yet, as a considerable negative pressure is observed after the chest is opened, it would appear that the suction-power or active dilatation of the ventricles, and in a lesser degree the auricles, is of considerable service in carrying on the venous circulation.

Innervation of the Heart.

The nervous mechanism of the heart consists of—

1. Intra-cardiac ganglia.

2. Extra-cardiac—(*a*) inhibitory centre, (*b*) accelerating centre.

3. Inhibitory nerves, *i.e.* vagi.
4. Accelerator nerves, *i.e.* sympathetic.

1. **Intra-cardiac Ganglia—Automatic Action.** If the heart of a mammal be removed from the living body it will continue to pulsate for a few moments, but the movements quickly cease, though they can be prolonged for a short time if some arrangement be made for supplying it with arterial blood. If a frog's heart be removed from the body it will continue to beat for hours, or even days, if it is kept moist, or, better still, supplied with a fluid containing O and also some nutrient fluid, as serum-albumen. It has been assumed that this automatic action of the heart is the result of the motor ganglia which the heart contains.

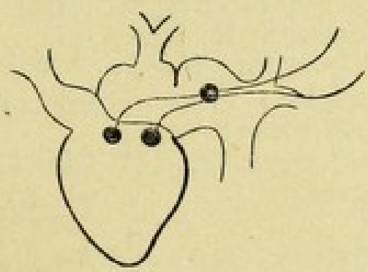

FIG. 45.—Diagram of the frog's heart.

This, however, is not universally true, as when a ligature is placed between the sinus venosus and the rest of the heart (auricles and ventricles), the latter part ceases to beat, although it contains Bidder's ganglia (see figs. 45 and 46). Moreover, parts of the heart, such as the venæ cavæ and upper part of the sinus venosus will pulsate when separated from the rest of the heart, though no ganglia have been demonstrated in them ; and the heart of the snail contains no nervous elements, yet it beats rhythmically. While it is unsafe, in the present state of our knowledge, to make any dogmatic statement about the functions of the cardiac ganglia, it would seem they are capable of originating rhythmical pulsations and retaining this power after the muscular fibres themselves have ceased to contract automatically. The ganglia appear also to be more sensitive to outside stimuli than the muscular fibres. The principal facts known concerning the cardiac ganglia have been studied in the frog's heart. The frog's heart consists of two auricles above and a single ventricle below; the latter is continuous in front with the aortic bulb, which divides into two aortæ—right and left. Posteriorly the right auricle receives the sinus venosus, a small chamber formed by the junction of the two superior venæ cavæ and inferior vena cava. The cardiac branches of the vagi pass to the sinus venosus, where they are connected with some nerve-cells which form *Remak's ganglia*; branches proceed along the auricular septum to two ganglia situated in the auriculo-ventricular groove, called *Bidder's ganglia* (see figs. 45 and 46).

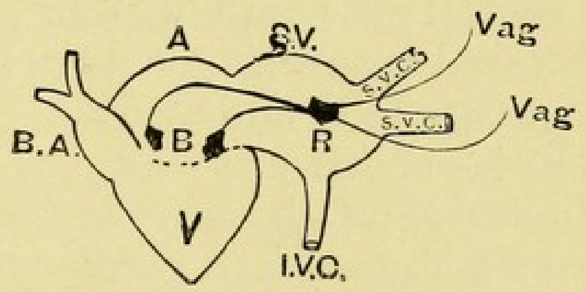

FIG. 46.—Scheme of nerves of frog s heart (Landois and Sterling). R, Remak's and B, Bidder's ganglia; S.V, sinus venosus; A, auricles; V, ventricle; B A, bulbus arteriosus; Vag, vagi; I V C, inferior vena cava; S V C, superior vena cava.

The most important experiments in connection with the ganglia of the frog's heart are the following:—

Stannius's Experiment.—If the sinus venosus be separated from the auricles by tying a ligature round the line of junction between the two (see fig. 47, 1); the sinus venosus, and veins continue to beat, while the auricles and ventricles stand still in diastole. If an incision be made at the auricular-ventricular groove, so as to separate the ventricle from the auricles, Bidder's ganglia being included with the ventricle, the ventricle commences to pulsate again. Thus the sinus venosus and ventricle are pulsating, though with a different rhythm, while the auricles are motionless. (See fig. 47, 2). This experiment has been thought to prove that both Bidder's and Remak's ganglia are *motor* in function, while the auricles contain *inhibitory* ganglia.

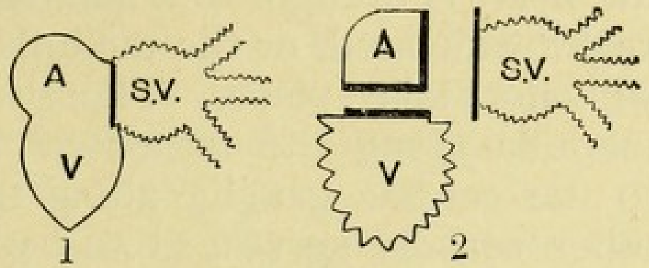

FIG. 47.—Stannius's experiment (Landois and Sterling). A, auricle; V, ventricle; S V, sinus venosus; the zigzag lines indicate which part continues to beat; in 2 the ventricle beats at a different rate.

Section of the Heart.—If the ventricle be separated from the auricles by means of scissors, the cut being made *below* the auriculo-ventricular groove, so that the upper part of the ventricle goes with the auricles, Bidder's ganglia being included, the auricles will continue to beat rhythmically, while the lower part of the ventricle is motionless. If the heart be divided longitudinally, each half—an auricle and half a ventricle—will pulsate.

2. **Extracardiac Centres.**—The *inhibitory centre* is situated in the medulla, and is constantly in action. It is capable of being influenced by the excitation of various sensory nerves. The *accelerating centre* is also in the medulla; it is not constantly in action. These centres are largely influenced by afferent nerves from various parts of the body. Thus a ghastly sight, good news, an inflamed pericardium or peritoneum, may profoundly influence the pulsations of the heart through its regulating centres in the medulla (see p. 257).

3. **Inhibitory action of Vagus.**—If the vagus of a frog or rabbit be excited by an interrupted current, the heart's action will become slower, and the blood-pressure in the arteries will be diminished; or if the current be strong, it will be arrested in diastole. Section of the vagi is followed by an acceleration of the cardiac beats. If atropin be injected, even a strong current passed along the vagi will not diminish the cardiac beats.

Reflex Inhibition.—If the intestines of a frog be struck sharply, or the mesenteric nerves stimulated, the heart is brought to a standstill in diastcle. If the vagi are divided, or the medulla destroyed, this effect will not take place. The stimulus ascends to the medulla along the mesenteric nerves, and descends to the cardiac ganglia along the vagi. Irritation of other sensory nerves, as the posterior auricular, will have a similar effect.

4. **Accelerator Nerves.**—The sympathetic nerves which pass from the cervical cord to the last cervical and first dorsal ganglia, and from thence to the heart, are called the accelerator nerves. Stimulation of these nerves with the interrupted current causes quickening of the heart's action, and their division renders the heart's action slower. The blood-pressure in the arteries is not increased by exciting the accelerators, unless the peripheral resistance is increased by contraction of the arteries. These nerves seem to act by shortening both diastole and systole.

THE ARTERIES.

Structure.--The arteries have three coats—

1. Internal { Epithelial. Sub-epithelial. Elastic.
2. Middle { Muscular. Elastic.
3. External—Connective tissue.

1. **Internal** (fig. 49 *a*, *b*).—This coat may be readily stripped off the inner surface of the artery as a transparent, colourless, elastic and brittle membrane. It is formed of—

(*a*) An epithelial layer, consisting of a single layer of thin, elongated cells, with nuclei (fig. 48).

(*b*) Sub-epithelial layer, composed of branching corpuscles lying in cell-spaces of homogeneous connective tissue.

(*c*) Elastic layer, consisting of a fine membrane marked with interlacing network of fibres and perforated with round openings, and termed fenestrated membrane of Henle (fig. 49 *b*).

2. **Middle or Muscular** (fig. 49 *c*).—In the small and medium-sized arteries the middle coat consists of pure non-striated muscular fibre, arranged transversely round the artery with only a slight admixture of elastic tissue. In the larger arteries yellow elastic fibre predominates, and, indeed, the aorta consists of nearly pure yellow elastic tissue.

3. **External coat,** or tunica adventitia (fig 49 *d*), consists of fine connective tissue, with a variable amount of elastic tissue arranged longitudinally.

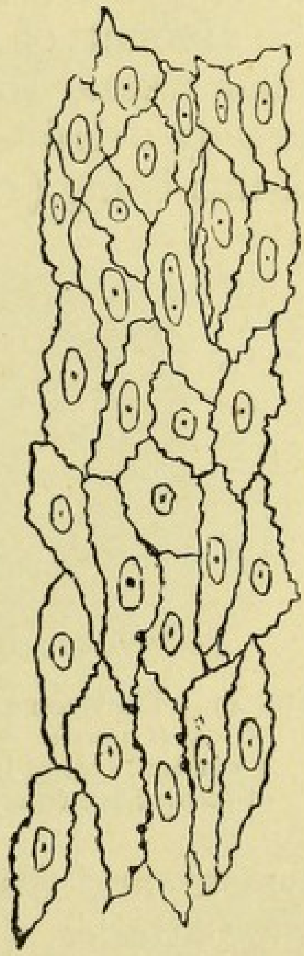

Fig. 48. — Epithelial layer lining the posterior tibial artery of man × 250 (Quain's Anatomy).

Circulation in the Arteries. The arteries are elastic and contractile tubes which convey the blood from the heart to the capillaries. The larger arteries are exceedingly elastic, but feebly contractile; the small arteries are contractile on account of the muscular tissue in their walls, while they are less yielding and elastic than the larger arteries. Their *elasticity* allows them to dilate during the systole of the heart, thus diminishing any risk of rupture, and their elastic recoil during the diastole when the aortic valves are closed, assists in maintaining the circulation, and converts what would be an intermittent supply of blood to the capillaries into a constant stream. The *contractile* power possessed by the smaller arteries is of great importance (1) in regulating the supply of blood to an organ. Thus during digestion the minute gastric arteries dilate and supply the peptic glands with a larger supply of blood than during fasting. The arterial muscular tissue is regulated by the vaso-motor nerves. (2) It assists in arresting hæmorrhage, when an artery is completely divided by occlusion of the divided ends. (3) It enables the arterial system to accommodate itself to the amount of blood in the body. At each ventricular systole some 5 oz. of blood are forced into an already overfilled aorta and arterial system; the effect of this being (1) to increase the tension in the arterial

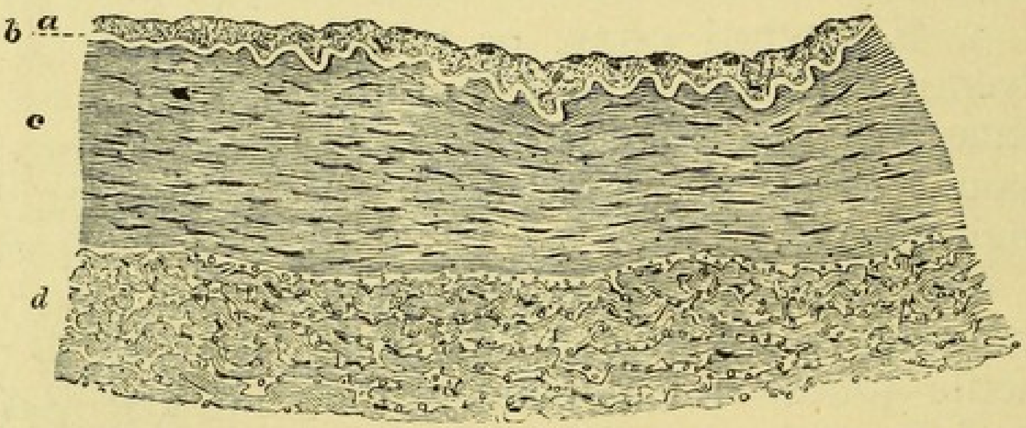

FIG. 49.—Transverse section of part of the wall of the posterior tibial artery × 75 (Quain's Anatomy). *a*, epithelial and sub-epithelial layers; *b*, elastic layer of inner coat; *c*, muscular layer; *d*, outer coat, consisting of connective-tissue bundles.

system and distend the elastic walls of the aorta and large arteries, (2) to send a wave-impulse along the blood in the arteries, which is gradually lost before reaching the capillaries and which can be felt in the radial as the pulse. If the arteries were rigid tubes, the intermittent action of the heart would cause an intermittent flow of blood from the arteries to the capillaries. The effect of the ventricular systole is to distend the walls of the aorta, to store up force during the systole to be utilised in continuing the circulation during diastole, the recoil of the elastic walls assisting to convert the intermittent blood-stream into a continuous one. If a large vessel, as the carotid, is divided, an intermittent stream of blood flows out, but a wound of a small artery yields a steady stream.

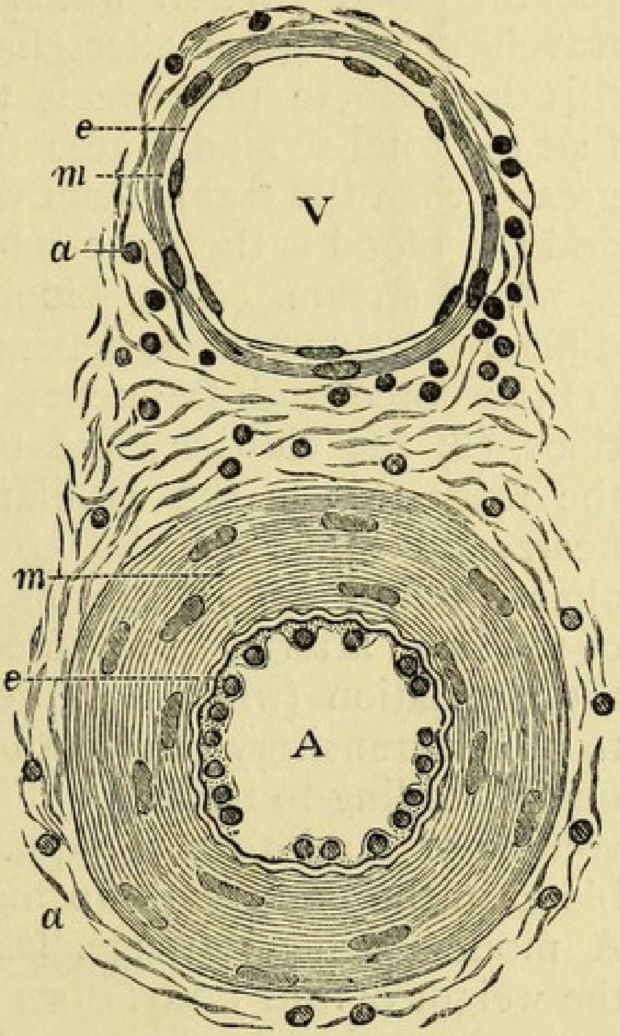

FIG. 50.—Transverse section through a small artery and vein (Gray's Anatomy). A, artery; V, vein; *e*, epithelial lining; *m*, circular muscular fibres with nuclei; *a*, external or connective-tissue coat.

Arterial Pressure.—The pressure of blood in the arteries is measured by connecting the carotid artery of a rabbit or dog with a **U**-shaped tube containing mercury. If a float on the mercury be made to carry a small camel's-hair brush or pen, the oscillations of the mercury caused by the varying tension in the blood-vessels can be recorded by the brush or pen writing on a revolving surface. Such an arrangement is called a kymograph. The pressure in the arteries undergoes variations which correspond—(1) with each systole of the left ventricle, (2) with the movements of respiration (*see* p. 130).

The mean pressure in the carotid of man probably amounts to about 150–200 mm. (6–8 in.), in the aorta

250 mm. (9·8 in.), and in the brachial 110–120 mm. (4·3–4·7 in.) of mercury.

The arterial pressure or tension decreases in passing from the larger to the smaller arteries in spite of the increased friction which results from the blood travelling through smaller channels. The reason for this decrease in pressure is to be found in the fact that the total sectional area of the smaller arteries is greater than the trunk from which they were derived, and the blood is therefore travelling as it were through a wider stream. The blood-pressure varies under different circumstances, depending upon three factors: (1) the force and frequency of the heart's contractions, (2) the elasticity and tone of the arteries, (3) the resistance in the capillaries. The force of the heart and tonus of the arteries may vary to suit altered conditions of the circulation. Thus ligature of the large arteries or an injection of saline fluid into the circulation (when the pressure is normal) leads to only a transitory rise in the pressure, the pressure quickly falling to normal. The injection of a greater volume of fluid than is equal to the volume of the blood in the body leads to high pressure and death. A moderate hæmorrhage, less than 3 per cent. of the weight of the body, does not lower the pressure; more than this leads to a lowering, and perhaps death.

Velocity of the Flow.—The rate of movement of the blood in the arteries has been measured principally in the carotids of the horse, dog, and rabbit. In the horse Volkmann found the velocity to be 300 mm. per sec. in the carotid, 165 mm. in the maxillary, and 56 mm. in the metatarsal. Various instruments are employed for this purpose, the *Stromuhr* of Ludwig and the *Hæmatachometer* of Vierordt being the principal. In order to measure the time occupied by the circulation of any portion of blood, ferrocyanide of potassium is injected into the jugular vein, and the blood from the peripheral end of the same vein tested from time to time. In this way a complete circulation has been found to take place in 15 secs. in the dog, and 23 secs. in the human subject (*Hermann*).

The Pulse.—The impulse or shock caused by the overfilling of the aorta during the ventricular systole is the cause of the pulse. This pulse-wave travels at the rate of 5–10 metres (15–30 ft.) per second along the arteries, and is lost at the capillaries. This pulse-wave must be carefully distinguished from the blood-current, the latter travelling only some 300 mm. (12 in.) per second; the former stands in the same relation to the moving blood as does a wave on the surface to the current of a slowly flowing river. The duration of the ventricular systole being $\frac{2}{5}$ second, before the end of the systole the pulse-wave would have travelled about 12 ft. if that were possible, so that the beginning of each wave is lost at the periphery before the end of it has left the ventricle. The more rigid the arteries the faster the wave travels; the more distensible the more slowly it travels. If

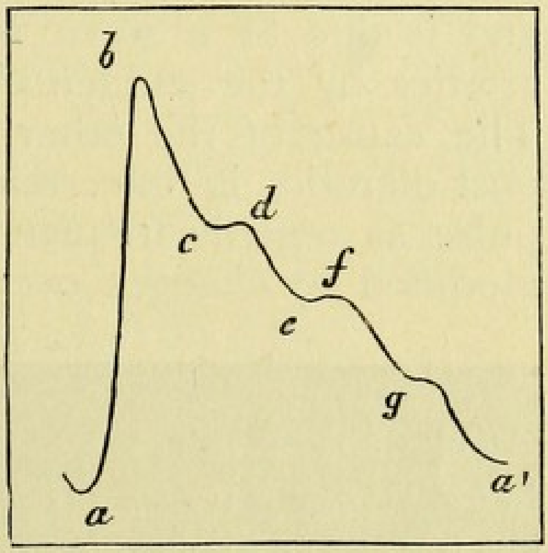

FIG. 51.—A normal pulse-trace magnified. *a b c*, primary wave; *c d e*, predicrotic wave; *e f g*, dicrotic wave; *e*, aortic notch; *a—e*, systole; *f—a'*, diastole of the ventricles.

the finger be applied to the radial artery, the artery will be felt to expand beneath the finger some 75 times a minute; under some circumstances the pulse-wave will feel to be double or dicrotic. This dicrotism is shown by the sphygmograph to be constant in health, but is more marked when the tension in the arteries is low, and the arterial walls more distensible than usual, as in febrile conditions of the system.

In a sphygmographic tracing, fig. 51, the up-stroke *a—b* is caused by the pulse-wave as it travels along distending the artery and raising up the lever of the sphymograph. The down-stroke *b—a'* is more gradual than the up-stroke, and is caused by the descent of the lever consequent on the artery regaining its normal calibre. The descent is marked by several minor waves. The largest of these, *efg*, is called the dicrotic wave, and is due to a wave or vibration sent along the arteries by the sudden closure of the aortic valves. The cause of the other minor waves, the pre- and post-dicrotic, is uncertain. The character of the pulse as regards frequency, volume, tension, &c., is modified by changes occurring (1) in the beat of the heart, (2) or changes taking place in the arterial walls or capillaries. Thus in the low tension of some fevers due to a relaxed condition of the arterial system, there is a sharp short ventricular contraction, giving a straight up-stroke (fig. 52, *a—b*) to the primary wave, and a prominent dicrotic wave, *efg*. The same result occurs after a warm bath, the arteries relaxing and the tension becoming low. In Bright's disease

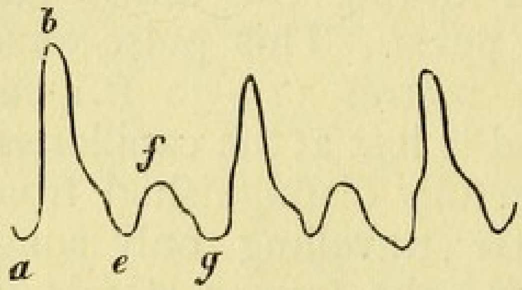

FIG. 52.—Tracing of a dicrotic pulse (fever).

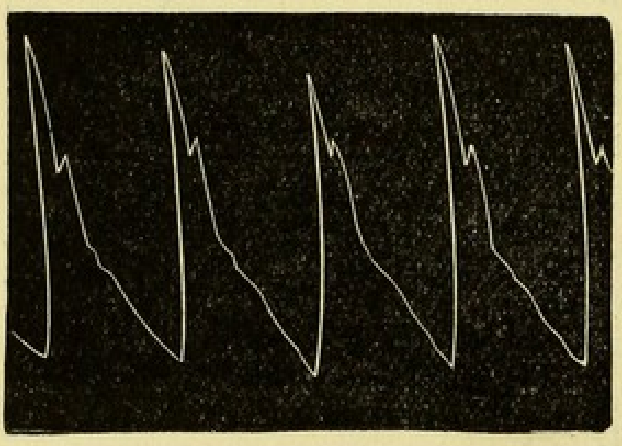

FIG. 53.—Aortic regurgitation (Landois and Sterling).

the tension is high and the ascent of the primary wave is gradual, not so high, and the secondary waves small. The same effect is produced by a cold bath.

In aortic regurgitation (fig. 53) the up-stroke is sudden and high, in consequence of the dilatation and hypertrophy of the left ventricle, a larger volume of blood than usual being propelled into the arteries; the down-stroke is abrupt and the dicrotic wave very slightly marked on account of the imperfect closure of the aortic valves.

Pulse-rate.—In health the normal pulse-rate in an adult is 70 in a male and 80 in a female; in the newly-born it is 130–140; at three years of age it has fallen to 100; at ten years of age to 90; at twenty-one years to 70; after middle-life it is slightly higher.

The pulse-rate is higher in standing than in sitting; it is increased by muscular exercise, by increase of the blood-pressure, by fever, by hæmorrhage, by various emotions. In some diseases, as in meningitis, it is slower than normal. It is usually slower during sleep than when awake.

THE CAPILLARIES.

Structure.—The smaller arteries end in a fine network of vessels, which differ in structure from the arteries and veins, in that their walls contain no muscular elements, but consist of a single layer of elongated epithelium continuous with that of the arteries; the epithelium is rendered apparent by injection of solution of silver nitrate, and exposing to light, the reagent darkening the intercellular material and rendering the outline of the cell apparent (fig. 54). The nuclei can be stained with logwood. In the vessels slightly larger than the capillaries a layer of elongated muscular fibre cells is added.

Size.—Their average size in the human body is about $\frac{1}{3000}$ of an inch, but they differ in different parts of the body. They are comparatively large in the marrow of bone, skin, and mucous membrane; small in lung, muscle, and brain. The network is close in lung and muscle.

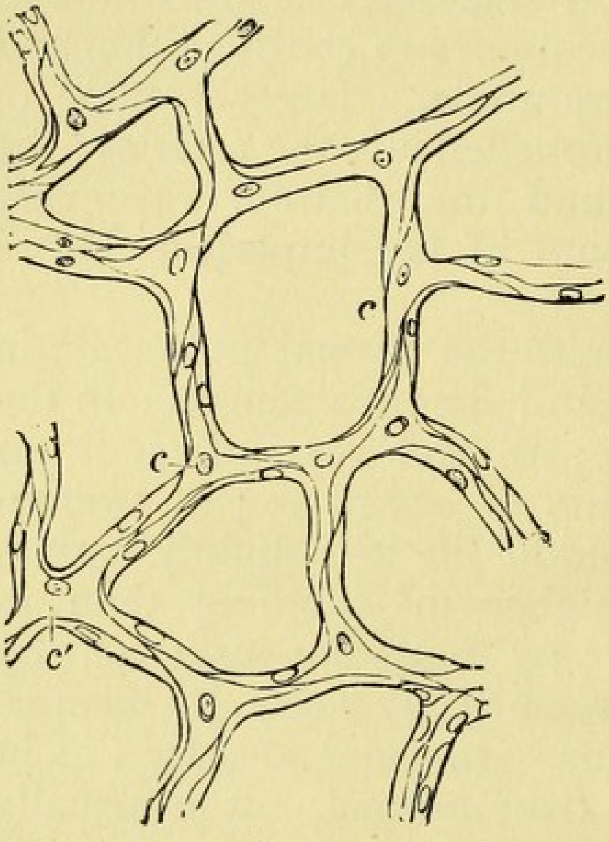

Fig. 54. — Capilary vessels from the bladder of a cat (Chrzonszczewsky).

Circulation in Capillaries. — The velocity of the blood in the capillaries is very much less than in arteries or veins, being about ·57 mm. to ·75 mm. per second (1·4–1·8 inches per minute.) But a very small portion of the capillary system is traversed by any one blood corpuscle. The flow is constant, not intermittent, as in the larger arteries. Under some abnormal circumstances, as in hypertrophy of the left ventricle and a rigid condition of the arteries, an intermittent flow or pulse may occur in the capillaries. This may be demonstrated by pressing the finger on the forehead; alternations of redness and pallor are noted at the border of the pressure-mark. The red blood corpuscles, for the most part, travel in the mid-stream, the white corpuscles moving more slowly along the side. The thin capillary walls allow the liq. sanguinis readily to pass through, and so bring the blood in direct contact with the tissues, and also nourish parts by irrigation, in which there are no capillaries, as cartilage and the cornea. Under certain circumstances, as in inflammation, when the capillaries are distended, the white corpuscles push through the capillary wall into the tissues passing through the intercellular substance between the endothelial plates. This is termed *Diapedesis*. The capillary circulation can be readily seen when the web of a frog's foot is spread out beneath the microscope. It may also be seen, suitable precautions being taken, in the mesentery of some of the smaller mammals. The capillary walls, though they contain no muscular element, are apparently contractile. The calibre of the capillary channels is distended when a large supply of blood reaches the part and the channels shrink when the supply is less. It appears that sometimes they can change their form independently of any engorgement with blood, the endothelial cells, which form their walls, being apparently slightly contractile. The movement of blood in the capillaries is dependent upon the action of the heart, modified by the arteries.

VEINS.

Distribution.—The veins carry the blood from the capillaries to the heart. They ramify through the body like the arteries, but they are more numerous, anastomose more freely, and are of greater capacity. They usually accompany the arteries; but there are exceptions, as the hepatic, sinuses of the skull, and veins of spinal cord.

Structure.—The veins have thinner walls than the arteries. They have the following coats :—

1. **Internal.**—This coat closely resembles the inner coat of the arteries (figs. 55 and 50).

2. **Middle.**—This coat is thinner and less muscular, and contains more white fibrous tissue than the middle coat of the arteries. The muscularity of the middle coat is best marked in the splenic and portal,

and least marked in the hepatic part of the inferior vena cava and subclavian veins (figs. 50 and 55).

3. **External.**—This coat consists of connective tissue and elastic fibres. In certain veins this coat contains a considerable quantity of muscular tissue, as in the abdominal cava, iliac and renal. The striated muscular fibre of the heart is prolonged for some distance on the walls of the pulmonary veins and venæ cavæ. Muscular tissue is wanting in most

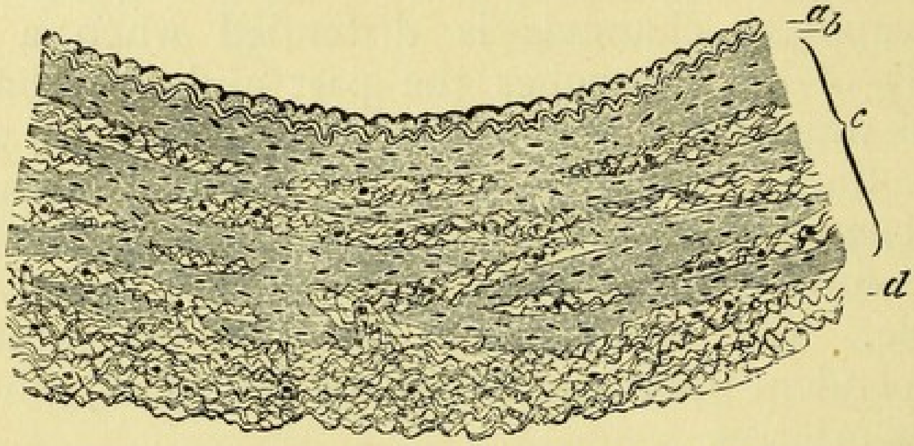

FIG. 55.—Transverse section of part of the wall of one of the posterior tibial veins (Schäfer). *a*, epithelial and subepithelial layers ; *b*, elastic layer of inner coat ; *c*, middle coat of muscular and connective tissue ; *d*, connective-tissue coat.

of the veins of the brain and pia mater, retina, venous sinuses of dura mater, and cancellous veins of bone.

Valves.—The valves consist of semilunar folds of lining membrane, strengthened by including connective tissue. They consist for the most part of two flaps or pockets, which come in contact by their free margins, and prevent reflux of blood towards the capillaries. The veins of the extremities, neck, and scalp have numerous valves, while they are absent for the most part in the deep veins of the abdomen, chest and cranium. Many other veins are destitute of valves. Such are the venæ cavæ, portal, hepatic, renal, uterine, pulmonary, and sinuses of skull. There are a few in the intercostal and azygos.

The forces which propel the blood in the veins are—

1. Vis a tergo—heart's action.
2. Vis a fronte—aspiration of the thorax.
3. Muscular contraction.

(1) The *vis a tergo* or force exerted by the heart in assisting the flow of blood in the venous system is probably not great, the velocity of the blood in the small veins being small.

(2) The *vis a fronte*, or force supplied by the suction action of the chest during inspiration is much more considerable. When an ordinary inspiration is taken, not only is air drawn into the air-passages by the expanding chest, but the blood in the great veins external to the chest is sucked towards the right auricle. This effect is more powerful if a deep inspiration is taken. During an ordinary expiration the sucking action becomes *nil*, while during a powerful expiration, as in blowing or coughing, the expiratory effort obstructs the flow of blood into the chest and causes congestion of the venous system.

(3) During muscular exercise the veins are compressed by the contracting muscles, the effect being to drive the blood towards the heart, the valves preventing its return towards the capillaries.

The velocity of the blood in the venous system is small when compared with the arteries, though greater in the large veins near the heart than in the smaller veins. It is about 200 mm. per sec. (7 to 8 inches) in the jugular vein of the dog. The pressure in the crural vein of the sheep has been shown to be 11·4 mm. of mercury (·4 inches), while in the subclavian it was − 1 mm. to − 5 mm. during inspiration, the mean pressure being − ·1 mm.

Venous Pulse.—The flow of blood in the veins is, unlike the flow in the arteries, continuous and not intermittent. In the large veins, however, the aspirating power of the thorax draws the blood to the chest during inspiration, and thus leads to more or less intermittency. In case of regurgitation through the tricuspid valve, there is a 'back-stroke' seen in the veins of the neck, sometimes called a 'venous pulse.'

Innervation of the Blood-vessels.

1. Vaso-motor centres—medulla, cord, ganglia.
2. Vaso-motor nerves, *i.e.* (*a*) vaso-constrictor, (*b*) vaso-dilator.

Vaso-motor Centres.—The principal vaso-motor centre is situated in the medulla. Nothing is known of this centre anatomically, its position having been determined by experiment. Excitation with the interrupted current of the medulla of a frog will cause the vessels in the web of the foot (when seen beneath the microscope) to contract. The same result can be witnessed in the rabbit by exposing a small artery. Section of the cord below the medulla causes the vessels to dilate. The latter experiment shows that the muscular fibre of the arteries is in a continual state of contraction or *tonus*. Various subsidiary vaso-motor centres are situated in the spinal cord. Besides the vaso-motor, or rather vaso-constrictor nerves, there are vaso-inhibitory or vaso-dilators. Such are the chorda tympani to vessels of the submaxillary glands, and the nervi erigentes to the arteries of the erectile tissue of the penis. The vaso-motor centre can also be influenced by various afferent nerves: this may occur through the higher nerve-centres, as in blushing; excitation of the central end of various sensory nerves will bring about contraction of arteries; while the vagus contains, especially in the superior laryngeal branch, fibres which excite and also fibres which, when stimulated, lead to inhibition of the vaso-motor centre.

Action of Poisons, &c., on the Circulation.

1. *Nicotine*, *Curare*, and *Conia* paralyse the communications of the vagus with the inhibitory ganglia. Stimulation of the vagus is unable to slow the heart ; this effect, however, follows stimulation of the sinus venosus.

2. *Muscarin* and *Jaborandi* stimulate the whole inhibitory apparatus, and so cause the heart to stop in diastole. Atropia antagonises them.

3. *Calabar bean* also increases the excitability of the inhibitory mechanism, but will not stop it in diastole.

4. *Atropia*, *Hyoscyamine*, *Daturine* paralyse the whole inhibitory mechanism. Excitation of the vagus and sinus venosus are without effect.

5. *Veratria*, *Digitalin*, *Delphinia* and *Antiar* affect the muscular fibre and arrest the heart in powerful systole. (See Hermann's 'Physiology,' translated by Dr. Gamgee.)

CHAPTER IX.

LYMPHATIC SYSTEM.

Distribution.—The lymphatic vessels may be said to take their origin in every tissue of the body supplied with blood ; they carry back into the vascular system any excess of the plasma of the blood which has transuded from the capillaries, and which is not required for the nutrition of the tissues. The lymphatics or lacteals which originate in the mucous membrane of the alimentary canal, perform the important office of taking up certain of the products of digestion and conveying them into the vascular system after their passage through the mesenteric glands. The lymphatic capillaries commence in various ways in the tissues; by their junction they form the larger lymph vessels; these finally join either the left or right thoracic duct, and by their means the contents of the lymphatic vessels enter the subclavian veins.

Modes of Origin.—The lymphatics have varied modes of origin—(1) in *plexuses* or *networks* of capillaries; (2) in *lacunæ* or *clefts* in connective tissue; (3) in *lymph spaces* or *cavities*. 1. **Plexiform.**—Networks of capillary lymph-vessels are present beneath the skin, and mucous membrane of the stomach and intestines, some of the plexuses being joined by small blind vessels, as in the villi. 2. **Lacunar.**—Various spaces or interstices in the connective tissue of various organs are connected with the lymph capillaries. These clefts are generally without a complete endothelial lining, but the endothelial cells forming the wall of the lymph-capillaries are directly continuous with the connective tissue cells in the clefts or lacunæ. 3. **Lymph spaces or cavities.**—In some parts the lymphatic capillaries commence in spaces or sinuses lined by a single layer of squamous epithelium, or rather, endothelium, with sinuous outlines, similar to the endothelium lining the lymph-vessels. Such are found beneath the skin and mucous membranes, in the diaphragm, lungs, liver, &c. Resembling these, only very much larger, are the serous sacs, such as the pleural, pericardial, and peritoneal cavities; also the synovial cavities and the subdural and subarachnoid spaces. The cavities are directly connected with the lymphatics by minute holes—the *stomata* surrounded by a layer of polyhedral cells. By means of these openings fluids and solid matters can enter the lymphatics.

Lymphatic capillaries. — These consist of channels, for the most part larger than the capillaries of the vascular system, their walls consisting of a single layer of flattened nucleated epithelium, with sinuous outlines. Sometimes a small artery is completely surrounded or ensheathed in a lymphatic capillary ; the space surrounding the artery is termed the *perivascular lymph space.*

Lymphatic vessels. — The capillaries empty themselves into vessels which closely resemble veins. These are lined by a single layer of elongated nucleated flattened cells with sinuous outlines ; outside the epithelial coat is a thin layer of longitudinal elastic tissue, the middle coat consists of muscular tissue, and the external of a mixture of connective and muscular tissue. They are provided with valves so closely approximated as to give them a beaded appearance. The valves resemble those described with the veins.

Thoracic duct.—All the lymphatics of the body, except those of the right side of the head, right thorax, right upper extremity, and right side of the heart, empty themselves into the thoracic duct. The thoracic duct commences opposite the second lumbar vertebra, this part being dilated and termed the receptaculum chyli, and terminates in the subclavian in the neck near its junction with the jugular.

Functions.—Liq. sanguinis exudes from the capillary blood-vessels to supply the tissues with materials for their nutrition. The excess of liq. sanguinis thus supplied enters the lymphatic capillaries, passes through the lymph glands into the thoracic duct, and thence into the venous circulation. The liq. sanguinis that has passed out of the capillaries accumulates in the connective-tissue spaces, or lacunæ, from which the lymphatics arise.

The lymphatics which arise in the villi of the small intestines are termed lacteals, and during digestion absorb fatty matters, and to a smaller extent soluble matters and albumen from the contents of the intestine. During the digestion of food, the columnar epithelium covering the villi may be seen to be distended with oil globules (though some observers assert the oil globules pass between the cells), these globules passing from the epithelium into the retiform tissue, and thence into the fine lacteal present in the villus.

Lymph has been described as blood minus the red corpuscles. It is a yellow alkaline fluid of sp. gr. 1045 and 6–7 per cent. of solids. Water 98.63

It consists of— Solids 1.37

White corpuscles.	Extractives. —
Elements of fibrin. 0.11	Salts. 0.88
Albumen. 0.23	Water. 98.63
[illegible] 1.05	

It has been obtained for examination from the thoracic duct during a fasting period, or from some large lymphatic vessel. The white corpuscles are more numerous in lymph which has passed through lymph glands. They vary in size; the larger contain two or three nuclei and show more active amœboid movements than the smaller ones.

Chyle may be described as lymph plus fatty matters. It may be obtained from the thoracic duct during a period of digestion. It is an opaque milky fluid which clots when drawn from the duct: the clot exhibits a pink colour. It contains 8–9 per cent. of solids.

It consists of—

White corpuscles.	Albumen. 7.1
Immature red	Extractives. 1.0
Fatty matters. 0.9	Salts. 0.4
Elements of fibrin. trace	Water. 90.5

Water 90.5 per cent
Solids 9.5

Examined microscopically, white corpuscles are seen in abundance in chyle drawn from the upper part of the thoracic duct. Many of these white corpuscles are of a reddish colour, and are probably in process of being converted into red.

The fatty matters consist of oil globules of various sizes and finely divided matter of a granular appearance, which forms the molecular basis of chyle. Chyle undergoes changes in its passage from the villi to the thoracic duct; these changes are effected through the agency of the mesenteric glands. They consist in a diminution of the molecular basis and an increase of the white corpuscles and elements of fibrin. Some of the white corpuscles appear to be of a reddish colour.

Movements of the Lymph.

1. *Vis a tergo.* Pressure of blood in the blood-vessels.

2. Contraction of muscular fibres in their walls and in the villi.

3. Compression by muscular action of voluntary muscles.

4. *Vis a fronte.* Aspiration of thorax.

1. If a ligature be applied to the thoracic duct, the chyle will tend to accumulate behind it, or if a tumour compress it the lacteals will become dilated and tortuous. This shows the existence of some *vis a tergo.* The liq. sanguinis leaves the capillaries under considerable pressure, and accumulating in the spaces of the tissues readily passes into the lymphatic vessels. Increase of pressure in the arteries causes increased tension in the lymphatics.

2. The muscular fibres in the walls of the lymphatic vessels act after the manner of the lymph-hearts in the frog. The contraction of the muscular

fibres of the villi assists in emptying the contents of the contained lacteal.

3. Contraction of the voluntary muscles compresses the lymphatic vessels in the same way as the veins, driving the lymph forwards, the valves preventing reflux.

4. The enlargement of the chest during inspiration sucks the blood in the large veins towards the heart; the rapid motion of the blood in the subclavian over the orifice of the thoracic duct will tend to make the contents of the duct discharge into the vein, thus supplying the *vis a fronte.*

Lymphatic glands.—The basis of all lymph-glands is the so-called *lymphoid tissue,* which consists of retiform or adenoid tissue with lymph corpuscles occupying the meshes of the network (fig. 56). Lymphoid tissue therefore consists of (*a*) a network of fine fibres; (*b*) small nucleated cells at the intersections of the network, which may be separated from the fibrils of the network; (*c*) lymph-corpuscles occupying the meshes. Some of the corpuscles are small with a large nucleus, and are probably the newest formed; others are larger and probably older, with two or three nuclei, and exhibit more lively movements on the warm stage than the smaller ones.

Lymphoid tissue, according to Klein, occurs in the body in the following ways—(1) *Diffuse lymphoid tissue,* which is found extensively beneath the epithelium of mucous membranes, notably of the trachea, soft palate, tonsils, root of tongue, pharynx, small and large intestines. (2) *Cords, cylinders,* or *patches* in the pleura and spleen. (3) *Lymph follicles,* being oval or spherical masses, in the tonsils, root of tongue, upper part of pharynx, stomach, intestines (solitary glands), nasal and tracheal mucous membranes. In the Malpighian corpuscles of the spleen.

Compound Lymphatic Glands.—These are the common lymph glands, which are small rounded bodies placed in the course of the lymphatic and lacteal vessels, and through which the lymph and chyle pass on their way to the thoracic duct. They are collected in groups, such as the mesenteric, portal, bronchial, splenic, cervical, lumbar and inguinal

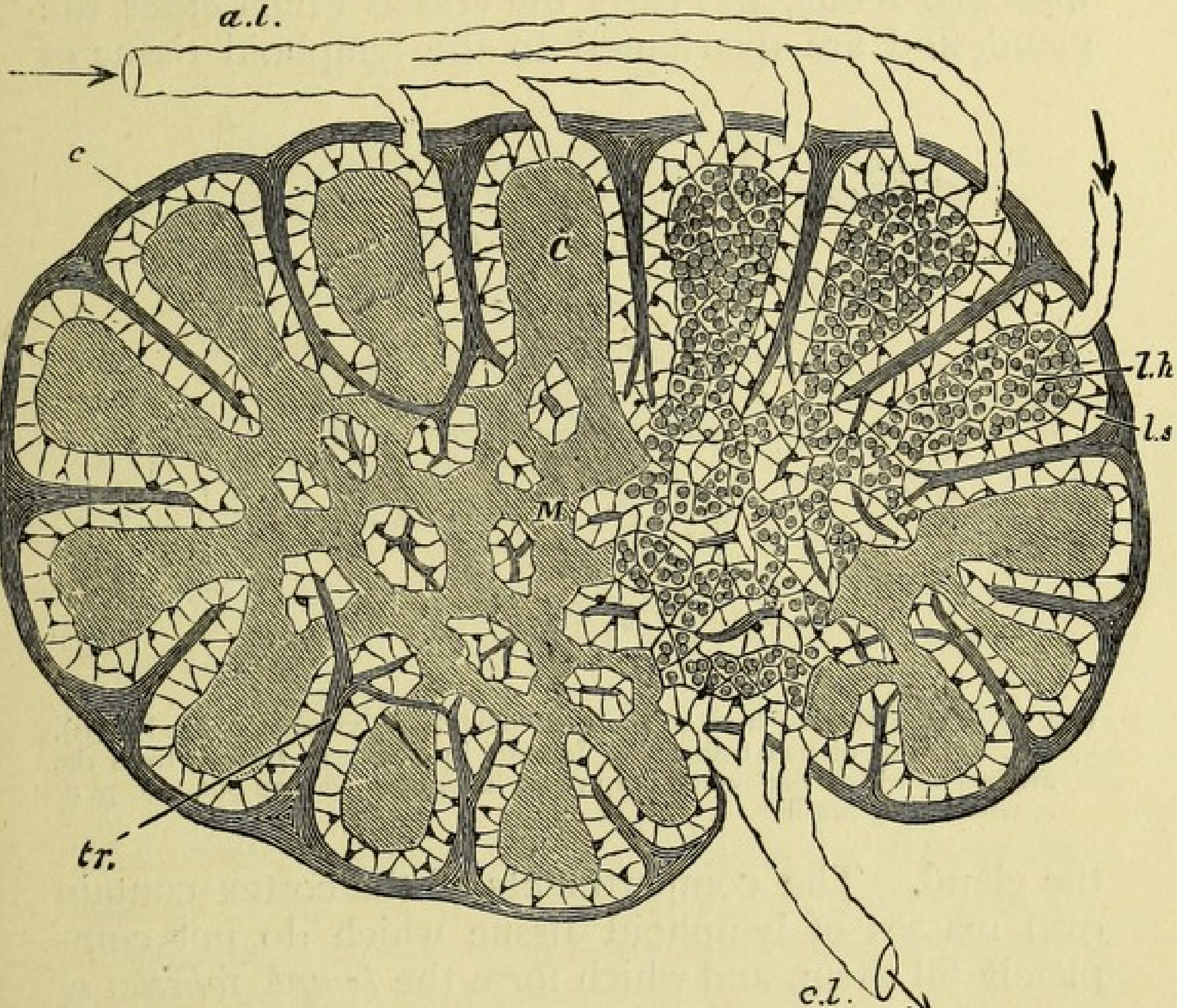

FIG. 56.—Diagrammatic section of lymphatic gland (Sharpey). *al*, afferent, *el*, efferent lymphatics; *C*, cortical substance; *M*, reticulating cords of medullary substance; *l s*, lymph sinus; *c*, fibrous coat sending trabeculæ *t r* into the substance of the gland; *l h*, lymphoid tissue.

glands. The afferent lymphatics enter the gland on its outer or convex surface, and emerge as the efferent lymph vessels at the hilum. Each gland is surrounded by a *fibrous capsule* which passes into the interior as the *trabeculæ* or septa.

The trabeculæ pass one-third or one-fourth of the way into the gland (the cortex), dividing it into oval compartments (fig. 56, *tr*), whilst in the central portion they join together and form small compartments of an irregular shape (medullary portion). The capsule and trabeculæ are formed of fibrous tissue and non-striped muscular tissue, and carry the vessels which enter the gland, and are distributed to the lymphoid tissue of

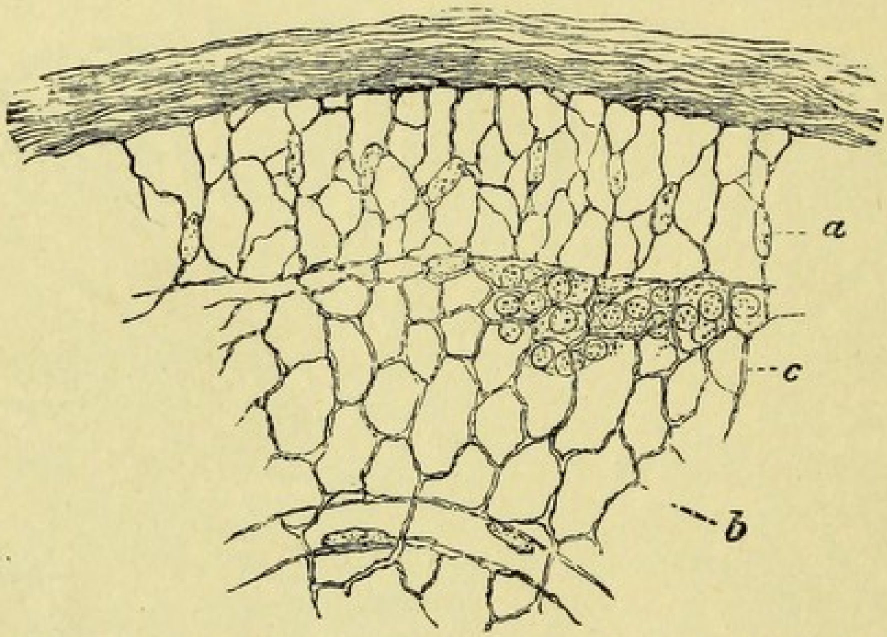

FIG. 57.—Thin section from the cortical part of a lymphatic gland (His). *a b*, network of fine trabeculæ, formed by retiform tissue, from the meshes of which the lymph-corpuscles have been washed out, except at *c*, where they are left.

the gland. The compartments of the cortex contain oval masses of lymphoid tissue which do not completely fill them, and which form the *lymph follicles of the cortex* ; the medullary portion contains irregularly shaped or elongated masses called the *medullary cylinders* (fig. 56, *C M*). The space left free between the lymph follicles and the cortical trabeculæ, and between the medullary cylinders and the trabeculæ, forms the *lymph sinus* (*ls*). The lymph path or sinus is occupied by coarse retiform tissue. The afferent lymphatic vessels, having entered at the cortex at the external surface, open into the lymph sinuses of the cortex, then the lymph passes into the lymph sinuses of the medulla, and leaves the gland by the efferent lymphatics at the hilum. The passage of the lymph through the sinuses is delayed by the reticulum, and any foreign bodies or inflammatory products may be arrested in the passage.

CHAPTER X.

RESPIRATION.

TRACHEA AND BRONCHI.

THE walls of the trachea and two bronchi consist of several constituents—

1. Connective tissue.
2. Cartilages.
3. Muscular.
4. Submucous.
5. Mucous membrane.

1. The **Connective Tissue** coat forms an external sheath for the trachea, surrounding and joining together the cartilages (fig. 58, *f*).

2. The **Cartilaginous Rings** are incomplete behind, being C-shaped, are 16–20 in number, consist of hyaline cartilage, and serve to maintain a certain amount of rigidity in the walls.

3. The **Muscular Layer** is present behind, connecting the tips of the cartilages together, and is also present behind in the intervals between the rings. Its fibres belong to the unstriated variety, and serve by their contraction to diminish the diameter of the tube.

4. The **Submucous Coat** (fig. 58, *e*) consists of loose connective tissue containing mucous glands, blood-vessels, and adipose tissue, and serves to con-

nect the mucous membrane with the cartilages and their sheath.

5. The **Mucous Membrane** consists of from within outwards (fig. 58)—(*a*) a single layer of columnar ciliated epithelium cells, with a few 'goblet

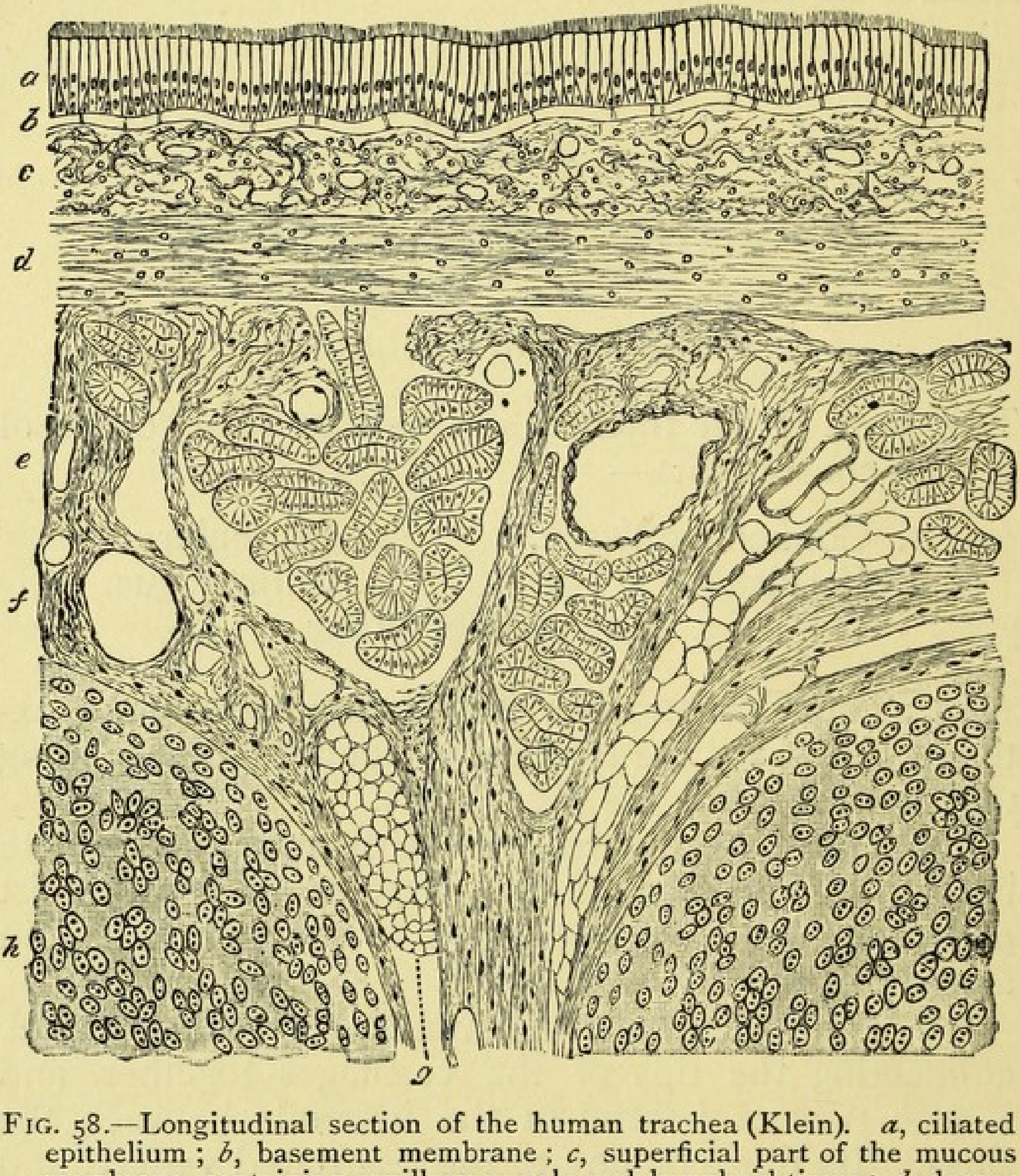

FIG. 58.—Longitudinal section of the human trachea (Klein). *a*, ciliated epithelium; *b*, basement membrane; *c*, superficial part of the mucous membrane, containing capillary vessels and lymphoid tissue; *d*, deeper layer of mucous membrane, consisting mainly of elastic fibres; *e*, sub-mucous tissue containing the larger blood-vessels, mucous glands and fat; *f*, fibrous tissue investing cartilages; *g*, fat-cells; *h*, cartilage.

cells'; (*b*) a basement membrane; (*c*) a layer of lymphoid tissue, with a network of capillary blood-vessels; (*d*) a layer of longitudinal elastic fibres, collected into bundles, which are readily seen as longitudinal striæ on slitting up the trachea.

The bronchi external to the lungs exactly resemble the trachea in structure, the right having 6 to 8, the left 9 to 12 incomplete cartilaginous rings.

LUNGS (weight—right, 24 oz., left, 21 oz.) The lungs are surrounded by the pleuræ, the smooth surfaces of the latter diminishing friction during the movements of respiration. In shape they are conical, the apex projecting into the root of the neck, the base resting upon the arch of the diaphragm; the inner surface being flattened where the bronchi and vessels enter.

The lungs consist of—

1. Lobes.
2. Lobules.
3. Bronchi.
4. Terminal bronchioles, alveolar passages and infundibula.
5. Air-sacs.
6. Blood-vessels and nerves.

1. The **Lobes** are the primary divisions, the right having three, the left two.

2. **Lobules.**—The lobes are divided into *lobules* of various sizes, their outline being most readily seen on the cut surface of fœtal lungs; they are separated by fine connective tissue. In structure they resemble a lung in miniature, having a terminal bronchiole, and a branch of the pulmonary artery and vein.

3. The **Bronchi**, on entering the lung, divide and redivide, each of the smaller divisions entering a lobule. In structure they resemble the trachea, with some modifications. The *cartilages* in the larger tubes form more or less complete rings, but as the tubes get smaller the cartilages form incomplete rings, consisting of small plates in the walls arranged in a

circular manner, and finally are wanting altogether in tubes of 1 mm. in diameter. The *muscular fibres* entirely surround the tubes, and may be traced into the finest ramifications. The *elastic fibres* extend to tubes of the smallest size, and become continuous with the elastic fibres forming the walls of the infundibula. The ciliated epithelium ceases before their entrance into the infundibula.

4. **Terminal bronchioles and infundibula.** After repeated sub-divisions, the bronchial tube, when reduced to 1 mm., is called a *terminal*, *lobular*, or *respiratory bronchiole*. Each terminal bronchiole ends in one or more enlarged passages called the *alveolar passages* or *ducts*, from which are given off blind dilatations, the *infundibula* or *end-sacs*. The walls of the terminal bronchioles are in part, and the walls of the alveolar passages and infundibula are completely, beset with a number of *air-cells* or *alveoli*, which open into them by wide apertures (fig. 59).

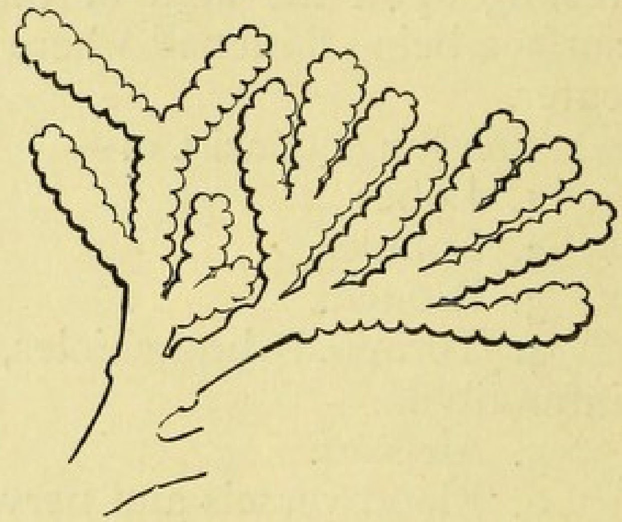

FIG. 59.—Diagrammatic representation of a terminal bronchiole, alveolar passages, and infundibula (Schäfer).

In the terminal bronchioles the cartilages have disappeared, and the cylindrical ciliated epithelium is being replaced by a layer of small polyhedral granular cells, so that their walls consist of (*a*) a layer of granular cells ; (*b*) a muscular coat of non-striated fibres ; (*c*) a thin layer of elastic fibres. (*a*) The granular cells are gradually replaced by flat, transparent, nucleated cells, as the alveolar passages open into the infundibula ; these flattened cells also line the air vesicles; (*b*) the muscular coat is continued into the alveolar passages and infundibula, but does not surround the air-cells; (*c*) the elastic fibres

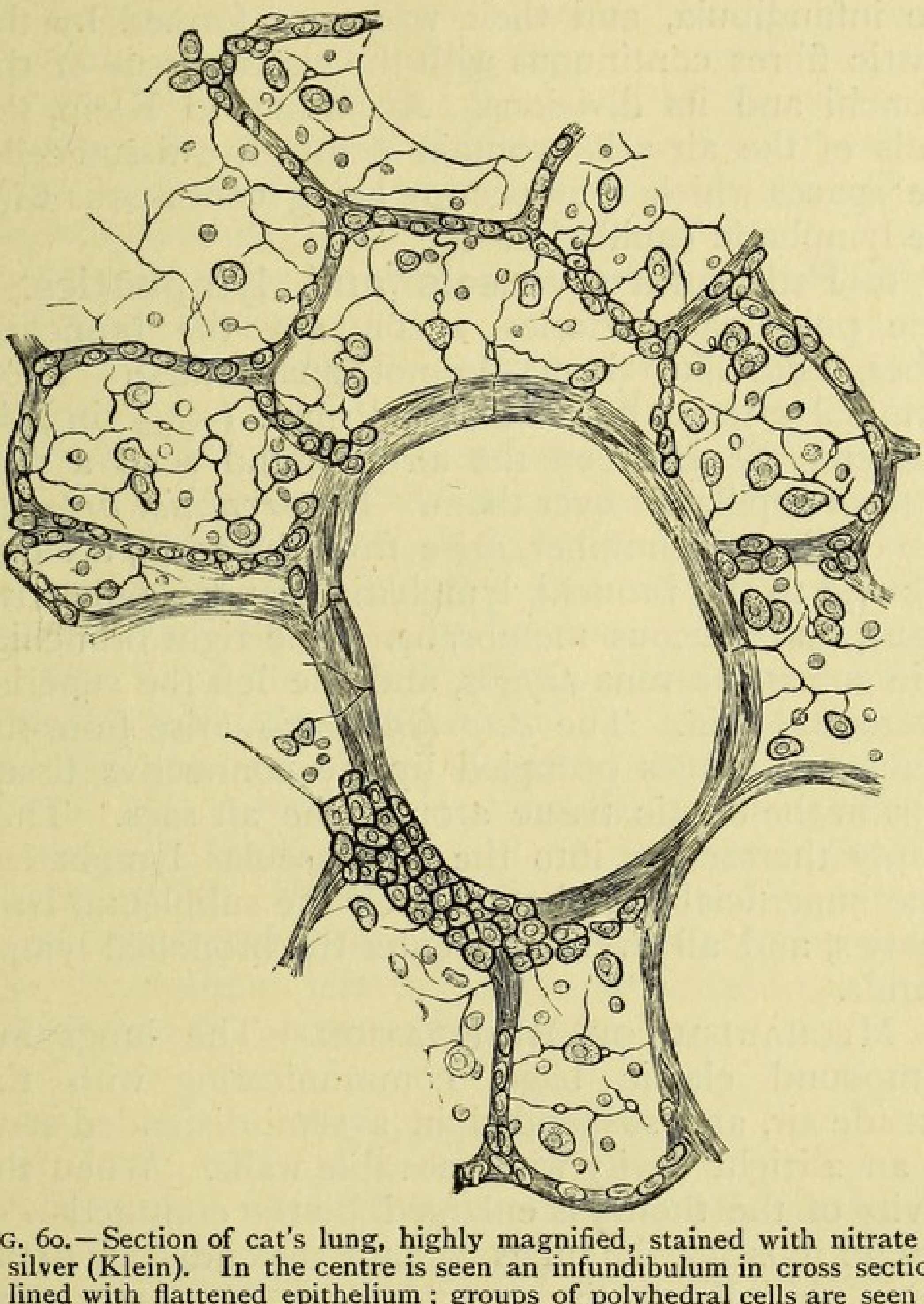

Fig. 60.—Section of cat's lung, highly magnified, stained with nitrate o. silver (Klein). In the centre is seen an infundibulum in cross section, lined with flattened epithelium; groups of polyhedral cells are seen on one side; the alveoli are lined by flattened cells.

forming the outer coat of the terminal bronchioles are continued on to the air cells, and form their walls (fig. 60).

5. **Air-cells** (fig. 60) are about ·25 mm. ($\frac{1}{100}$ in.) in diameter; they are lined internally by flattened, transparent nucleated cells, continuous with those of the infundibula, and their walls are formed by the elastic fibres continuous with the elastic tissue of the bronchi and its divisions. According to Klein, the walls of the air-cells contain connective-tissue cells, the spaces which they occupy being continuous with the lymphatic capillaries.

6. **Pulmonary vessels and lymphatics.**—The pulmonary arteries accompany the bronchial tubes, and, like them, do not anastomose. Their terminal arterial branches, ·025 mm. ($\frac{1}{1000}$ in.) in diameter, lie between the air-sacs, and send a network of capillaries over them. The *bronchial arteries*, two or three in number, arise from the aorta, are distributed to the bronchi, lymphatic glands, connective tissue, and mucous membrane. The right bronchial vein enters the vena-azygos, and the left the superior intercostal vein. The *deep lymphatics* arise from the lacunæ or spaces occupied by the connective tissue cells in the elastic tissue around the air-sacs. They empty themselves into the perivascular lymphatics. The superficial lymphatics enter the subpleural lymphatics, and all eventually enter the bronchial lymph glands.

MECHANISM OF RESPIRATION.—The lungs are compound elastic bags, communicating with the outside air, and suspended in a semi-distended state in an airtight cavity with movable walls. When the cavity of the thorax is enlarged by the contraction of certain muscles, the lungs become distended by drawing in air. When the muscles relax, the lungs tend to collapse, expelling most of their contained air—a result due in part to the contraction of the elastic tissue they contain, and also to the recoil of the elastic rib cartilages.

Inspiration.—The chest enlarges in three directions, viz., downwards, forwards, and laterally. The enlargement *downwards* is effected by the contraction of the diaphragm. At rest the diaphragm presents a convex surface to the thorax; in contracting this surface becomes flatter, the floor of the chest is lowered, the cavity of the thorax enlarged, and air enters to distend the lungs. The contraction of the diaphragm tends to press the abdominal viscera downwards and causes the walls of the abdomen to project during inspiration.

The *antero-lateral* enlargement is effected by raising the ribs. A vertebro-sternal rib has two movable joints, the posterior where the head articulates with the sides of the bodies of the vertebræ, and the anterior at the junction of the costal cartilage with the sternum. The anterior end occupies a lower position than the posterior, so that the rib is in more or less of an oblique position. When the anterior ends are raised the sternum will be pushed forward, and the antero-posterior diameter of the chest enlarged. In normal inspiration the antero-posterior diameter is increased 5 mill., in a deep inspiration about 30 mill. When the ribs are raised by the external intercostal muscles, the angles which they make with the sternum become more obtuse, and the chest enlarged in the transverse diameter.

INSPIRATION.

Muscles in action in easy inspiration:

1. *Diaphragm*, enlarges the chest downwards.
2. *Scaleni*, fix the upper two ribs.
3. *External intercostals* }
4. *Levatores costarum* } raise the ribs, and enlarge the chest antero-laterally.

Muscles which may be brought into action in laboured inspiration:

1. *Serratus posticus superior*, raise 2nd, 3rd, 4th, and 5th ribs.
2. *Sterno-mastoid*, raise the clavicle.

3. *Serratus magnus* 4. *Pectoralis major & minor* 5. *Latissimus dorsi*	raise the ribs, the scapula and arm being fixed.
6. *Rhomboidei* 7. *Trapezius*	fix the scapula.
8. *Serratus posticus inferior* 9. *Quadratus lumborum*	fix the last 4 ribs, and so aid the diaphragm.

With the respiratory movements there are associated movements of the face, pharynx, and glottis, the *dilatores naris*, *levator palati*, the *crico-arytenoideus posticus*, and *arytenoideus*, with their fellows, being called into action. The anterior nares may dilate, the palate be raised, and the glottis open, in tranquil inspiration, but these actions are exaggerated in laboured inspiration.

Expiration.

Easy Expiration.

In ordinary breathing expiration is effected by the elastic recoil of the lungs and costal cartilages, &c. During inspiration the elastic tissue of the lungs is put on the stretch, and the costal cartilages and ribs are abnormally bent; both tend to return to their unstretched condition. The elasticity of the abdominal muscles will also help.

Forced Expiration.

1. The *abdominal muscles*, by compressing the abdominal contents.

2. *Internal intercostals* (the part between the bony ribs) depress the ribs.

3. *Triangularis sterni*, depresses the costal cartilages.

4. *Serratus posticus inferior* } depress the lower four
5. *Quadratus lumborum* } ribs.

Summary.—Respiration is carried on under ordinary circumstances by the diaphragm and external intercostals enlarging the chest and sucking air into the lungs, followed almost immediately by the recoil of the elastic lungs and ribs forcing out the air so inspired. But when there is a more than ordinary venous condition of blood in the system greater efforts must be made to supply the lungs with oxygen, and muscles not ordinarily employed in the effort must be brought into play. The arms and scapulæ are fixed by seizing hold of some object, and by bringing into action the trapezius, levator anguli scapulæ and rhomboidei, so as to make firm attachments for serratus magnus, pectorales, and latissimus in their efforts to raise the ribs. Laboured expiration in like manner brings extra muscles into play. In laboured respiration the nostrils are expanded by the dilatores naris during inspiration, and resume their original size during expiration. The glottis is widely open during inspiration, while it is narrowed during expiration. These movements of the glottis occur during ordinary breathing, but are exaggerated during difficult breathing.

Rhythm and Number of Respirations.—Each respiratory act consists of three periods—(1) inspiration, (2) expiration, (3) pause. Inspiration is usually shorter than expiration, the open glottis readily admitting the air. Expiration is more prolonged, the glottis being smaller, the vocal chords being approximated and leaving only a narrow chink.

The number of respirations amounts to 14 to 16 per minute, or 1 to every 4 or 5 beats of the pulse in the adult; in infants about 40 per minute, in children of 5 years about 25, at puberty about 20 per minute. The number is diminished during sleep and increased by exercise.

Vital Capacity.—The vital capacity of the chest is the amount of air which can be expired from the chest after taking the deepest possible inspiration, and is equal to about 225 to 230 cubic inches.

The **Tidal Air** is the air which is constantly passing in and out of the chest during calm breathing, and amounts to 25 to 30 cubic inches.

The **Complemental Air** is the air which can be drawn into the chest after taking an ordinary inspiration; it amounts to about 100 cubic inches.

The **Reserve Air** is the air which can be expelled at a forcible expiration over and above the tidal air; it equals about 100 cubic inches.

The **Residual Air** is the air which still remains after every effort has been made to empty the lungs; it is equal to about 100 cubic inches.

Total vital capacity {	Complemental Air	= 100	cu. in.
	Tidal ,,	= 25–35	,,
	Reserve ,,	= 100	,,
	Residual ,,	= 100	,,

The lungs normally are never quite empty, even after the most forcible expiration, but still contain about 100 cubic inches. In some diseases, as bronchitis, especially in children whose chest-walls are weak, certain portions of lung may become collapsed and emptied of air by occlusion of a small bronchus, the air in the lung becoming absorbed. In effusion of fluid into the pleuræ, a portion of a lung may become compressed and airless. In other diseases, as in emphysema, the lungs contain a greater amount of residual air than normally, the chest becoming more or less barrel-shaped.

Changes of the Air in Respiration.

1. Temperature. The expired is warmer than the inspired air; the temperature depending to some extent upon the temperature of the inspired air, and the rate and depth of the breathing.

2. The expired air is saturated with aqueous vapour.

3. The expired air contains 4 to 5 per cent. less oxygen, and about 4 per cent. more carbonic acid gas.

	O	N	CO_2
Inspired air . .	21	79	·04
Expired air . .	16	79·5	4·3

A certain amount of oxygen does not reappear in the expired air, in the form of carbonic acid. During twenty-four hours an adult man gives out about 800 grammes (12,300 grains) of CO_2, containing 218 grammes (3,300 grains) of C, and consumes about 700 grammes (11,000 grains) of O.

4. In addition to carbonic acid, the expired air contains ammonia, and other unknown substances of a poisonous or deleterious nature. An atmosphere containing ·08 per cent. of CO_2, with the accompanying impurities, is unwholesome, while 1 per cent. of CO_2, with proportional amount of impurities, is very injurious.

Changes in the Blood in the Lungs.

1. It is cooled.
2. It loses watery vapour.
3. It gains oxygen (8 to 12 per cent. per volume), the amount of oxygen in the blood rising from about 12 to 20 per cent. per volume.
4. It loses carbonic acid (7 per cent. per volume), the amount of CO_2 in the blood falling from 46 to 39 per cent. (*see* p. 76).

Changes in the Blood in the Capillaries of the Body.

As the blood passes through the lungs the reduced hæmoglobin of the venous blood becomes almost wholly, by the absorption of O, converted into oxy-hæmoglobin. As the blood is distributed to the body the hæmoglobin, saturated with O, gives it up to the tissues, and the blood receives the CO_2, the tension of which in the tissues is higher than its tension in the blood.

Circumstances affecting the Excretion of Carbonic Acid.

1. Muscular exercise.
2. Food.
3. Age.
4. Disease.

1. Muscular exercise increases the amount of carbonic acid exhaled. E. Smith found that there was expired—

	Per minute
During sleep . . .	4·99 grains
Lying down . . .	5·91 „
Walking 2 miles an hour	18·10 „
Walking 3 miles an hour	25·83 „
Exercise on treadmill .	44·97 „

2. The amount exhaled in the expired air is increased by food, especially starchy foods.

3. The amount exhaled increases up to the 30th year, and diminishes after 45.

4. Many diseases, as the fevers, increase the amount of CO_2 in the expired air.

Abnormal Respiration. — If the blood in the body contains more than an ordinary amount of oxygen, no efforts to breathe will take place; this condition is called **Apnœa.** The ordinary natural condition of respiration is termed **Eupnœa.** As soon as the blood in the body becomes more venous than ordinarily, in consequence of the amount of oxygen sinking below normal, the respiratory movements become quicker, and both inspiratory and expiratory efforts are increased by bringing extra muscles into play. This condition of difficult breathing is termed **Dyspnœa.** As the blood becomes more and more deficient in oxygen, the respiratory efforts become more laboured, the expiratory movements becoming more marked than the inspiratory. The expiratory efforts become convulsive in character, and the whole muscles of the body presently take part in the convulsions. In the last stage the convulsions cease, coma sets in, the pupils dilate, the conjunctivæ are insensible, while at intervals respiratory efforts, chiefly inspiratory, are made. The term **Asphyxia** is applied to the later stages following dyspnœa, when insensibility has set in. Thus in oxygen-starvation three stages may be witnessed : (1) a stage of dyspnœa, characterised by increased respiratory movements, both inspiratory and expiratory ; (2) a convulsive stage, in which expiratory efforts are most marked ; (3) a stage of coma, marked by insensibility, and slow, deep, inspiratory efforts.

When the trachea of a dog is suddenly occluded the first stage lasts about one minute : the second stage also lasts a minute ; in the third stage some two or three minutes elapse before death ends the scene.

The Circulation in Asphyxia.—During the inspiratory and expiratory efforts of the first and second stages the blood-pressure rises, but during the third stage it sinks till death ensues. The rise of blood-pressure is brought about by constriction of the smaller arteries, the result of their carrying venous blood: the left side of the heart becomes full ; the increased respiratory movements assist the return of blood to the right side of the heart, so that the cavities on both sides of the heart become distended. The distended heart at first beats more quickly, then more slowly and forcibly, and finally, becoming exhausted from being continually supplied with venous blood, ceases altogether. The heart continues to beat for some time after the respiratory movements have ceased. At a post-mortem examination it will be found that there is a distended right side, but an empty left, rigor mortis having caused contraction of the left ventricle.

Asphyxia due to Oxygen-starvation.—When an animal is made to inhale nitrogen only, the exit of carbonic acid is not interfered with, yet all the effects of dyspnœa and asphyxia ensue, a result due to the absence of oxygen in the blood. If an animal breathe an atmosphere rich in carbonic acid, and with plenty of oxygen, the breathing becomes deeper at first; this afterwards passes off, and the animal becomes unconscious, without any convulsive movements, the carbonic acid acting as a narcotic poison.

The Nervous Mechanism of Respiration.—Breathing is a reflex act, capable of being modified by the will. The nerve-centre is situated in the medulla, the *afferent* nerves are the vagi; the *efferent* nerves are the phrenics, intercostals, &c. Respiration continues in the absence of consciousness and after the removal of the brain above the medulla; but destruction of a certain small portion of the medulla below the vaso-motor centre causes the movements at once to cease. This spot is called the *nœud vital.* The centre is influenced by impulses from without or within—a dash of cold water in the face, a cold bath, an emotion, venous blood in the pulmonary vessels, all call it into action. The centre is probably automatic as well as reflex, section of the vagi thereby interrupting the channel by which the afferent impulses reach it from the lungs, while interfering with the respiratory act does not stop its action. Automatic impulses descend from the centre along the efferent nerves. Probably the venous blood circulating through the centre itself supplies the stimulus.

Section of Vagi.—If one vagus is divided respiration is slower, if both are divided it becomes very slow, while each respiration is fuller and deeper, so that the amount of carbonic acid given off is not much altered. During life the terminal fibres of the vagi are stimulated by the venous blood in the pulmonary capillaries, the stimulus travelling upwards to the medulla. The more venous the blood, the more intense the stimulus transmitted upwards, and the greater the number of muscles brought into play. If the central end of a divided vagus be stimulated by the interrupted current, the respirations are quickened; if the stimulus is increased, the diaphragm is brought into a tetanic condition. Stimulation of the central end of the superior laryngeal causes a slowing of the respiratory movements to take place, the diaphragm becoming relaxed if the stimulus is sufficiently intense.

Coughing consists in a deep inspiration, followed by a closure of the glottis, and finally a sudden forcible expiration, which bursts open the glottis and forces out any mucus or foreign matter present in the air-passages. The *afferent* impulses travel along the superior laryngeal nerve from the larynx, or the vagi from the bronchi, lungs or pleura, or the auricular branch of the vagus distributed to the outer ear.

Sneezing closely resembles coughing, except that the expiratory blast is driven through the nose, the soft palate and anterior pillars of the fauces shutting off the mouth from the pharynx; the afferent impulses travelling along the fifth.

Hiccough is caused by the spasmodic action of the diaphragm, causing a sudden inspiration and closure of the glottis. The afferent impulses travel along the vagi from the stomach.

Effects of Respiration on the Circulation.—If a tracing be taken by means of a kymograph connected with the carotid of a dog, it will be seen that, in addition to the small oscillations produced by the intermittent action of the heart, there are larger waves which correspond with the respiratory movements. The summit and base of the waves do not exactly correspond with either inspiration or expiration. At the

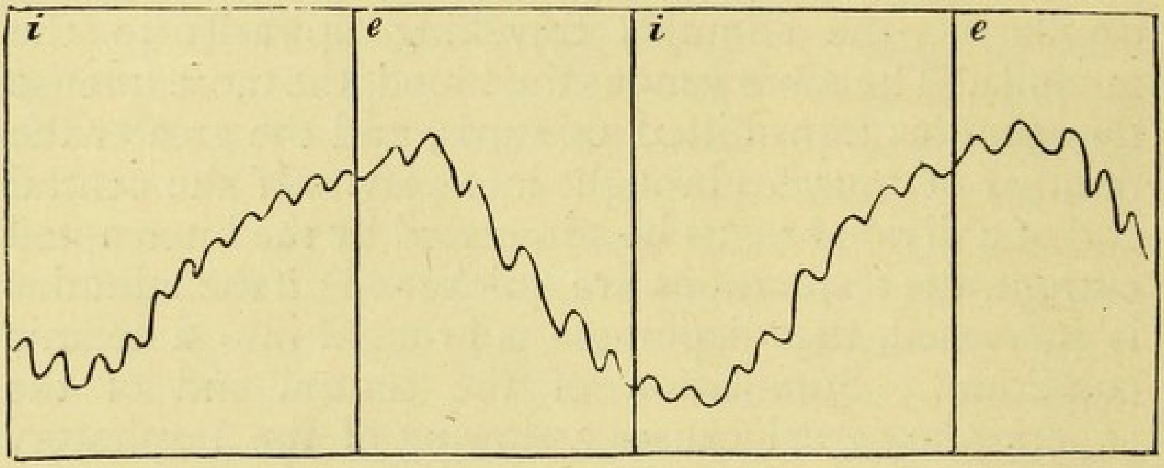

FIG. 61.—Blood-pressure curve from the carotid of a dog. Inspiration begins at *i*, expiration at *e*.

beginning of inspiration arterial pressure, as shown by a tracing, is falling; it soon begins to rise, and reaches its maximum soon after the commencement of expiration (fig. 61).

Similar curves may often be noticed in sphygmographic tracings taken at the radial artery (man), especially if the inspirations are deep; there is a double curve, see fig. 62, the respiratory undulations as well as the cardiac beats being seen. As the respiratory curve ascends the blood pressure is rising and the number of cardiac beats is increased; when descending, the tension is diminishing, the tracing is more markedly dicrotic, and the number of contractions is less. At the commencement of inspiration the tension is falling, but towards the end of inspiration the tension rises, but does not reach its height till after expiration has begun. These effects seem to be the resultant of several causes. Inspiration tends to suck the blood of the large veins into the chest, so that towards the end of the act an increased volume of venous blood has reached and passed through the heart and lungs into the large arteries, causing increased tension in the arterial system. During expiration the blood in the veins, especially if the expiration be a forcible one, is ponded back and prevented from entering the chest; there will therefore be less blood passing through the heart, and the tension in the arteries will fall. On the other hand the effect of inspiration and expiration on the blood in the arterial system will be the opposite to the effects on

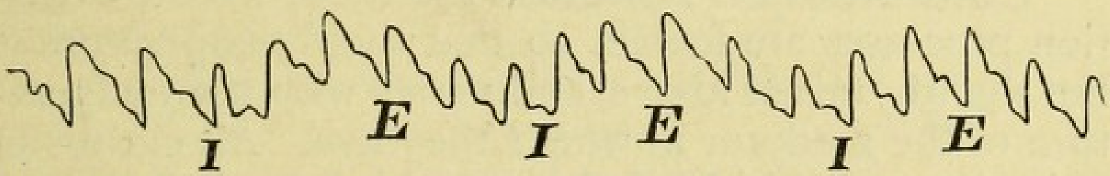

FIG. 62.—Sphygmographic tracing, showing the influence of respiration upon the pulse (Landois and Stirling). I, inspiration; E, expiration.

the veins; during inspiration the blood will be retarded from leaving the aorta, and during expiration will be assisted, but the effects will be comparatively small unless deep respirations are taken, as the arterial tension in the aorta and large arteries is so much greater than the tension in the veins. Another important factor in producing the respirations is the influence of the vaso-motor centre on the arterial system: the effect of inspiration is to stimulate the vaso-motor centre, the arteries in consequence contract and the blood-pressure rises.

CHAPTER XI.

ANIMAL HEAT.

Heat is generated throughout the body wherever oxidation processes are going on. Whenever arterial blood comes in contact with active protoplasm, in the glands, muscles, or tissues, heat is produced. The hæmoglobin gives up its oxygen to some hydrocarbon-containing material present in the tissues, heat is generated, and H_2O and CO_2 are formed.

Cold-blooded Animals are those whose oxidation processes are feeble, so that their temperature is but slightly raised above, and varies with the temperature of the medium in which they live. All classes of animals are cold-blooded except birds and mammals. The temperature of the frog is only slightly above that of the air, though it is 1° or 2° C. higher during the breeding season. Some fishes and snakes have a temperature of 10° C. above the medium in which they live. In the cold-blooded animals the amount of heat generated within their tissues is slight, and their temperature varies with the season, and the circumstances under which they are placed.

Warm-blooded Animals are those in which the oxidation processes are vigorous, so that they maintain a temperature considerably above that of the surrounding medium, and it is so regulated that it remains constant, notwithstanding a variation of temperature in surrounding objects. In man, the average temperature is 37° C. (98·6° F.) (axilla); in some birds, as the swallow, it is 44° C. (111° F.), the more active birds having a higher temperature than mammals. This temperature remains nearly constant, notwithstanding the changes of temperature in different seasons and climates. There are slight diurnal variations, the temperature being lowest from 2 a.m. to 6 a.m. and highest from 5 p.m. to 8 p.m. The temperature if taken in the rectum is higher by $\frac{1}{2}$ to 1° F. than if taken in the axilla. Slight elevations of temperature take place when the external air is considerably raised, as in a Turkish bath (100·6° F. in a bath of 120° F.). In disease there is often a notable rise of temperature; in scarlatina or typhus it may rise to 41·2° C. (106° F.), in acute rheumatism 43·3° C. (110° F.), and in one case of fracture of the spine to 50° C. (122° F.). In other diseases, as in uræmia and cholera, it sinks below normal.

The temperature of 98·6° F. is the resultant of two sets of processes :—

I. Those by which heat is gained.
II. Those by which it is lost.

I. **Heat is gained to the Body**—

1. Wherever arterial blood comes in contact with active protoplasm, chemical changes taking place.
2. By friction of the muscles.
3. By ingestion of hot liquids and foods.

II. **Heat is lost to the Body**—

1. By means of the skin—evaporation of the perspiration, radiation, and conduction. (77·5 per cent.)
2. By the lungs—evaporation of the water of respiration, and warming expired air. (20 per cent.)
3. By escape of urine and fæces. (2·5 per cent.)

Amount of heat generated in the Body.—The force-value of an ordinary diet (say 100 grms. of proteids, 100 grms. of fat, 240 grms. of starch) is equivalent to about 1,000,000 kilogramme-metres.

Of this 150,000 kilo.-metres, or about one-sixth, is expended in an average day's work, the remaining five-sixths, or 850,000 kilo.-metres, leave the body in the form of heat. If this be converted into terms of heat instead of mechanical energy, it may be said that roughly the amount of heat generated in the body of an adult man during 24 hours would raise 1,900,000 grammes of water one degree (centigrade).

Generation of heat in muscle, glands, &c.—Blood returning from active muscles (p. 52) is warmer than the blood supplied to them, a result of the active chemical changes going on in contracting muscle. In a lesser degree, blood returning from quiescent muscle is warmer than arterial blood generally. It is probable that the muscular tissue, more than any other tissue in the body, is a source of heat. Next to the muscles come the liver and various glands as sources of heat; the blood of the hepatic vein is the warmest blood of the body. The blood of the hepatic vein in a dog has been observed to be 3° C. above that of the right side of the heart. The brain in an active state is also a source of heat to the body.

Distribution of Heat.—The circulation of the blood ensures an equable temperature throughout the body by distributing the heat. But, in order to maintain an average temperature of 98·6° under different circumstances as regards external heat, the amount of blood supplied to different parts must be regulated. The amount of heat lost by the skin will depend upon the amount of blood circulating through the vessels near the surface of the body. If the cutaneous arteries are dilated, an increased amount of heat will be lost by evaporation of the perspiration poured out, as well as by radiation and conduction, and less blood is supplied to the internal organs where heat is produced. Thus, if the body be exposed to cold, the vessels of the skin are contracted and less perspiration poured out, and more blood is supplied to the liver and internal organs, and more heat generated, as well as less lost. But if the body be exposed to heat, as in a Turkish bath, the cutaneous vessels are dilated, perspiration is poured out and evaporated, more heat is lost and less generated in the internal organs.

The exact conditions under which the increased amount of heat is produced in fevers or acute rheumatism is unknown.

Regulation of Heat.—One of the functions of the vaso-motor system is to regulate the size of the arteries, and therefore the amount of blood supplied to a part. Increased supply of blood to a part will increase the tissue-change, and thereby the temperature, or, if it be near the surface, its temperature will be increased from a greater supply of blood, warmer than itself. Section of the sympathetic in the neck is followed by redness and heat of the corresponding ear and side of the face, a difference of 4° to 6° C. being noticed.

Injuries to the central nervous system, as in effusion of blood in the brain, or some injury to the spinal cord, are often followed at first by a lowering, probably from shock, and then in a few hours an increased temperature, ranging up to 108° F. or more. In hemiplegia the temperature of the paralysed side is generally one or two degrees higher than the sound side, but in old cases of paralysis the paralysed limbs are often cooler, apparently from defective circulation. The vaso-motor centre being situated in the medulla, any interference with its action will be likely to alter the temperature of the body by interference with the blood-supply.

CHAPTER XII.

FOOD.

THE various tissues of the body, like the parts of a machine, are subject to wear and tear. There is also a constant liberation of energy in producing muscular work and in the evolution of heat going on in the body, the normal daily expenditure in the form of mechanical work being equal to about 150,000 and in the form of heat 850,000 kilogramme-metres. The wear and tear of the various tissues of an active adult must be considerable. The brain-cells, the glandular epithelium, the blood corpuscles, from time to time require renewal and to be supplied with materials for their work. The body constantly requires new material for its growth and nutrition. The waste products of the disintegration of the tissues and of the combustion going on in the system are thrown out of the body at the lungs, the skin, and the kidneys. In round numbers these amount in an adult man, in twenty-four hours, to—

	Grammes
Nitrogen	19–20
Carbon	280
Salts	24
Water	2,000

To make good this loss food is required.

Classification of Food.—Foods may be divided into—

1. Nitrogenous.
2. Hydro-carbons or fats.
3. Carbo-hydrates or starches.
4. Inorganic or mineral.

Nitrogenous Food. — Nitrogenous material enters largely into the composition of the body, the muscles and the blood taken together forming 50 per cent. by weight of the whole body: proteids must, therefore, largely enter into the composition of the food, to make good the loss which is continually taking place. The nitrogenous principles present in the food are the following:—

Animal kingdom.		Vegetable kingdom.
Albumen	Syntonin	Gluten
Myosin	Globulin	Legumin
Casein	Gelatin	Albumen
Vitelline	Chondrin	

The proteids undergo digestion in the stomach and intestines and are converted into the peptones. The peptones enter the portal vein, but disappear before entering the general circulation; the steps by which they form protoplasm or are broken up or oxidised are unknown.

Meat.—The flesh or muscle of animals contains (1) several albuminous bodies, as myosin and serum-albumen, (2) gelatin, (3) fats, (4) extractives and minor constituents, as kreatin, kreatinin, xanthin, &c., (5) salts, notably potassium and phosphates. Meat is rendered more digestible and palatable by cooking. It is best roasted, as then it retains all its constituents and is in consequence more nutritious than when prepared in any other way; the surface of the joint is coagulated so as to prevent the escape of the juices from the central part. Beef tea and mutton broth should be prepared by *infusing* pounded meat, or meat cut into very small pieces, in water in a warm place, and then slowly simmering over a fire or in the oven. The beef tea then contains the albumen, gelatin, extractives, and salts of the meat, the myosin and fibrous tissues remaining behind. If prepared by boiling, the albumen is coagulated and remains in the meat. The most nutritious form is the 'peptonised' beef tea, or artificially digested meat, as more of the proteids are dissolved than in ordinary beef tea.

Eggs.—Eggs contain all that is required for the construction of the body, inasmuch as the young animal is developed from it, the O required being absorbed during the process. An average hen's egg weighs about two ounces, consisting of—

	Per cent.
White	60
Yolk	30
Shell	10

The solid contents weigh about 200 grains.

The white is composed of albumen in a soluble state, enclosed within very thin-walled cells. The yolk forms a sort of yellow emulsion containing fat emulsified by albuminous matter (vitelline). Lightly boiled eggs are more easily attacked by the gastric juice than either raw or when hard-boiled.

Cheese.—Cheese consists of the casein of milk with a variable amount of fat. Casein exists in milk in a solution, and is coagulated by the addition of the curdling ferments present in the gastric or pancreatic juices. Casein has a high nutritive value, and when freshly coagulated is easily digestible. It is less so in the form of cheese, as it is not easily penetrated by the gastric juice.

Vegetable Proteids.—Gluten, albumen, and legumin exist in variable quantities in foods derived from the vegetable kingdom. Wheat flour contains about 11 per cent., and bread 8 per cent. of gluten; oatmeal 12½ and rice only 5 per cent. Potatoes contain 1·5 per cent. of albumen; dried peas about 22 per cent. of legumin. Gluten can be obtained from wheaten flour by making into a dough and thoroughly washing away the starch. It is highly nutritious and of great value as a food. Peas and beans, though highly nutritious, are less digestible than foods prepared from wheaten flour.

Destiny of Nitrogenous Food.—(1) Development and renovation of the tissues; (2) to assist in the formation of the secretions; (3) force-production.

(1) During infancy the rapid growth of the body requires abundant nitrogenous material for conversion into the protoplasm of the tissues. During the first year of life the infant trebles its weight (7–21 lbs.), and, though this enormous increase of weight is brought about in part by the consolidation of the bones and the storage of fat, yet the viscera, muscles, and nervous system have also gained in substance at the expense of the albumen and casein of its mother's milk. Throughout the whole life there is a continual wear and tear of the tissues; each individual cell has a period of activity and a subsequent death; albuminous material is required to replace the cells which have perished. Thus the epithelial cells on the surface of the skin are constantly being worn away, and require renewal from the deeper cells. The red corpuscles, the secreting epithelium of the various glands, after remaining in an active state for a certain period, perish, and fresh ones are needed to replace them.

(2) The secretions of the body, as the gastric and pancreatic juices, are constantly using up albuminous material to form their active principles.

(3) Liebig maintained that nitrogenous food was utilised to build up the proteid tissues, as muscle and other forms of protoplasm, and that urea, uric acid, and their allies, arose solely from the breaking up of these tissues, while non-nitrogenous food was used exclusively for the maintenance of heat or was stored as fat; the mechanical energy of the body being derived from the oxidation of the muscles, or formed

nitrogenous material. If this were true the amount of muscular exercise would be proportional to the amount of urea appearing in the urine. But it has been proved by direct experiment, by estimating the amount of urea in the urine after active muscular exercise, that the amount of urea is but slightly increased. The experiments of Fick and Wislicenus upon themselves while ascending the Faulhorn on a non-nitrogenous diet, the observations of Parkes on soldiers, and those of Pavy and Flint on the pedestrian, Weston, clearly bring out the facts, (1) that active exercise only slightly increases the urea in the urine, the extra urea representing the wear and tear of the muscle, (2) that the active energy is derived from the combustion of the hydro-carbons or carbo-hydrates, (3) that in a well-nourished body the amount of urea in the urine is proportional to the amount of nitrogenous food ingested.

It would appear from these facts that the wear and tear of the body is not great; that the formed elements of the body, the cells, the muscular fibres, blood corpuscles, &c., do not quickly change or often need renewal, but that the larger proportion of nitrogenous food taken is split up in the body (either in the intestines, liver, or tissues) into urea, and some fatty bodies containing carbon, hydrogen, and oxygen. Indeed, it seems tolerably clear that in the formation of adipocere, in the fatty degeneration of muscle and cells, fat is formed as one of the products of the decomposition of albuminous bodies. If the composition of albumen and urea be compared

$$\text{Albumen}\left\{\begin{array}{ll} C = 53{\cdot}5 & \text{p. c.} \\ H = 7{\cdot}0 & \text{,,} \\ N = 15{\cdot}5 & \text{,,} \\ O = 22{\cdot}0 & \text{,,} \\ S = 1{\cdot}6 & \text{,,} \\ P = 0{\cdot}4 & \text{,,} \end{array}\right. \qquad \text{Urea}\left\{\begin{array}{ll} C = 20{\cdot}00 & \text{p. c.} \\ H = 6{\cdot}6 & \text{,,} \\ N = 46{\cdot}6 & \text{,,} \\ O = 26{\cdot}6 & \text{,,} \end{array}\right.$$

it will be seen that albumen is far richer in C H O than urea, and that if the former is split up, its N separating in the form of urea, there will be a residuary part consisting of C H O as well as of S and P.

Nitrogenous foods have not the same dietetic value. Gelatin is of distinctly less value than albumen. It has been shown by experiment that life cannot be maintained on gelatin alone, or, indeed, on gelatin in combination with fats and starches. It would thus appear that it is not capable of being converted into protoplasm, but is at once split up into urea and fat.

Dynamic Value of Nitrogenous Foods.—Albumen, when completely oxidised, is converted into NH_3, CO_2, and H_2O. It is not completely oxidised in the body, being converted into urea, uric acid, CO_2, &c.; some (about one-seventh) therefore of its energy is unexpended.

One gramme of beef muscle, when completely oxidised, will give out sufficient heat to raise	5,103 grammes of water 1° C., or 2,161 kilogrammes, 1 metre;
One gramme of beef muscle, as oxidised in the body, gives out	4,368 gramme-degrees, or 1,850 kilogramme-metres.

HYDROCARBONS, or FATS, are neutral bodies derived from both animal and vegetable foods. They consist of *olein*, *palmitin*, and *stearin*. Olein and palmitin are met with both in animal and vegetable products; olein is fluid at ordinary temperatures; palmitin has a semi-fluid consistence. Stearin is a solid fat, is found only in animal products, and exists largely in suet. They all have glycerine for a base in combination with the corresponding fatty acids, oleic, palmitic, and stearic. The fats are remarkable for the small quantity of O they contain; thus in palmitic acid

C_{16}, H_{32}, O_2 the amount of O is about 12 per cent. of its weight, leaving from 80 to 90 per cent. available for force-production.

Digestion of Fats.—The gastric juice dissolves the connective tissue binding together the fat vesicles and sets free the fat. The fatty matters are emulsified in the small intestine by the action of the pancreatic juice, and in a lesser degree by the other secretions, and for the most part enter the lacteals, though a certain proportion, which has possibly become saponified, enters the portal vein.

Destiny of Fats.—The fats are utilised in the body for force-production, either immediately, or are stored as adipose tissue to be used when required. They therefore serve for the maintenance of heat and performance of muscular work. The capacity of a material for force-production depends upon the amount of unoxidised C and H it contains, and of all alimentary substances fats take the highest place. Experimentally, Frankland has shown that the actual heat developed by the various alimentary substances when burnt in O is as follows :—

1 gramme	beef fat .	9,069 gramme-degrees.
,,	butter .	7,264 ,, ,,
,,	beef muscle	5,103 ,, ,,
,,	arrowroot .	3,912 ,, ,,

That is to say, 1 gramme of fat, when burnt, will give off heat sufficient to raise 9,069 grammes of water 1° C, whereas the same amount of arrowroot would, when burnt, only raise 3,912 grammes of water 1° C.

It is found that the inhabitants of arctic regions readily devour all kinds of fat, while in the tropics the foods of the inhabitants consist largely of farinaceous and saccharine matters. The force generated by the oxidation of the hydrocarbons is available for muscular work. A large amount of muscular work can be performed on a fatty or starchy diet. During muscular exercise the amount of CO_2 given off by the lungs varies according to the work done: thus, 5 grains per minute during sleep, and 25 grains per minute walking at the rate of three miles an hour.

The amount of mechanical work obtainable from the oxidation of—

1 gramme	beef fat	= 3,841	kilogramme-metres
,,	butter	= 3,077	,, ,,
,,	beef muscle	= 2,161	,, ,,
,,	arrowroot	= 1,657	,, ,,

that is, the force derivable from the oxidation of 1 gramme of fat is sufficient to raise 3,841 kilogrammes one metre. (1 kilogramme-metre = 7·232 foot-pounds.)

The products of the combustion of fat are H_2O and CO_2. Animal life cannot long be maintained on a non-nitrogenous diet. Dogs fed on fat, or fat and starches, emaciate and die. Nitrogenous food is required to renew the tissues, which become wasted and worn during the processes of life.

CARBO-HYDRATES or AMYLOIDS comprise starch, cane sugar, grape sugar, milk sugar, glycogen. Chemically these bodies differ from the fats in containing a smaller quantity of uncombined carbon and hydrogen, the O existing in sufficient quantity to form water with all the H present, as in starch ($C_6H_{10}O_5$), grape sugar ($C_6H_{12}O_6$).

Starch is met with in vegetable products. It is prepared for absorption by being converted into grape sugar in the mouth and small intestine. Cane sugar and glycogen are converted into grape sugar in the stomach and intestines. Milk sugar ($C_{12}H_{22}O_{11}+H_2O$) and grape sugar ($C_6H_{12}O_6+H_2O$) are readily absorbed by the portal vein and submitted to the action of the liver. Here some change takes place. Sugar injected into the jugular vein rapidly appears in the urine; injected into the portal, it does not, unless in large quantity. The grape sugar is converted in the liver into glycogen ($C_6H_{12}O_6 - H_2O = C_6H_{10}O_5$) and probably also into fat.

It is uncertain whether the glycogen is reconverted into sugar and oxidised in the system, or whether it enters the system as glycogen or some similar body. In any case it is oxidised, being converted into CO_2 and H_2O, and giving rise to heat, and supplying force for the performance of work.

INORGANIC MATERIALS.

Various salts exist in the body in combination with the organic materials that form the tissues. The chief salts consist of calcium, sodium, potassium, magnesium, and iron, in combination with chlorine, and phosphoric, carbonic, and sulphuric acids.

The various salts form an essential part of the food, inasmuch as they exist in every tissue of the body. They exist in most forms of food consumed, both animal and vegetable, in milk, in drinking-water. Water is an important element in the food; it forms nearly 60 per cent. of the body weight, and is constantly being lost to the body through the lungs, kidneys, and skin.

DIETETICS.

Experience proves that a mixed diet is the best to maintain the body in health. Dogs will not live on hydrocarbons or carbo-hydrates alone. Too much nitrogenous food leads to an excessive amount of urea and uric acid, and throws increased work on the excretory organs.

Milk, the food of early life, may be taken as a typical illustration of a natural combination of the various foods. Milk contains—

	Cow	Woman
Nitrogenous matters (casein and albumen)	4·1	3·35
Butter	3·9	3·34
Milk sugar	5·2	3·77
Salts	0·8	
Water	86·0	89·54
	100	100

Cow = 14 per cent. solids.
Woman = 10 to 11 per cent.

Diet for Moderate Work.—The normal diet for a man in health can only be arrived at by experience. Taking the average of a large number of healthy persons, it has been found that the following diet will suffice :—

	ozs. avoir.	grammes
Albuminous matter	4·5	130
Fatty matter	3·0	84
Carbo-hydrates	14·2	404
Salts	1·0	30

Thus about 23 ozs. of dry solid food are contained in this standard diet, about $\frac{1}{5}$ of which is nitrogenous. If we reckon that 50 per cent. of ordinary food is water, these 23 ozs. will correspond to 46 ozs. of ordinary solid food. In addition about 50–80 ozs. of water are taken. The force-producing value of this standard diet is nearly 4,000 foot-tons.

The standard diet will necessarily be altered under different conditions.

It is said that an Esquimaux eats about 20 lbs. of flesh and oil daily, and men working heavily necessarily require more than when at rest.

Diet for Idleness:—

	ozs.	grammes
Albuminous matter	2·5	77
Fats	1·0	28
Carbo-hydrates	12·0	340
Salts	0·5	14

This diet will keep a man alive, but is not sufficient if he performs any work.

Hard Work Diet.—The average dietary of a labourer performing hard work has been calculated at—

	ozs.	grammes
Nitrogenous matter	5·0	142
Fat	3·0	84
Carbo-hydrates	22·2	630
Mineral	1·0	30

Dynamic value, 5,232 foot-tons.

Taking the model diet for ordinary men :—

	ozs.	N. grains	C. grains
Nitrogenous matter . . .	4·5	316	1,068
Fat	3·0	—	1,024
Carbo-hydrates	14·25	—	2,768
		316	4,860

It appears, therefore, that a man on ordinary diet and doing an ordinary amount of work requires 300 grains of N and 4,800 grains of C. (N 20 grammes and C 320 grammes.)

The ratio of the quantities is 1 : 15. In albumen the ratio is 1 : 3·5. Hence, if albumen alone were used, and the 300 grains of N were supplied, there would be a deficiency of C, and if the 4,800 grains of C were supplied there would be more N than required. In bread the ratio is as 1 : 30 ; so that if bread alone were used there would be a superfluity or deficiency of either N or C. Two pounds of bread and three-quarters of a pound of meat will fulfil the above conditions, though they will do so better if 1–2 ozs. of butter be added.

Table showing amount of different constituents in some foods.

In 100 parts.

Articles	Water	Albuminates	Fats	Carbohydrates	Salts
Beef and mutton	75	15	8·4	—	1·6
Bacon	15	8·8	73·3	—	2·9
Salt beef	49·1	29·6	·2	—	21·1
White fish	78	18·1	2·9	—	1
Flour	15	11	2	70·3	1·7
Bread	40	8	1·5	49·2	1·3
Rice	10	5	·8	83·2	·5
Oatmeal	15	12·6	5·6	63	3
Peas (dry)	15	22	2	53	2·4
Potatoes	74	1·5	·1	23·4	1
Eggs	73·5	13·5	11·6	—	1
Cheese	36·8	33·5	24·3	—	5·4
Milk	86·7	4	3·7	5	·6
Butter	6	·3	91	—	2·7
Sugar	3	—	—	96·5	·5

(After Parkes.)

Dietaries.—INFANCY.—The newly-born infant is generally put to the breast a few hours after birth, but a few days generally elapse before the flow of the breast-milk is thoroughly established, especially in the case of women who are mothers for the first time. The infant at first takes the breast every two hours during the day, and every four to six hours during the night for the first six weeks or two months. After this the infant takes more at a meal, and only takes the breast every four hours during the day, and sleeps most of the night. The infant is to be nursed entirely from the breast for the first six or seven months.

If artificially fed for the *first month*, it should take 10 ozs. of good cow's milk, diluted with an equal quantity of barleywater or freshly-made whey ; 2 ozs. being given every two or three hours during the day, and every four hours at night.

This amount should be gradually increased so that at *three months* of age 20 ozs. of milk diluted with 10 ozs. of barleywater or whey may be given every four or five hours.

This amount should be again increased so that when the infant is *six months* of age it is taking 30 ozs. of undiluted milk.

From *six months* to *twelve months*.—From 30 ozs. to 40 ozs. of milk should be taken, the milk being thickened at some of the meals with some starchy form of food, as rusks, biscuit powder, &c. As the salivary and pancreatic secretions are not thoroughly established before the age of six months, it is unwise to give children any starchy foods before that date.

From *one* to *two years*.—At a year old, thicker food, taken with a spoon instead of through a bottle, may be given.

First meal, 7.30 A.M.—8 to 10 ozs. of milk, with finely crumbled bread or porridge.

Second meal, 11 A.M.—6 to 8 ozs. of milk and water.

Third meal, 1.30 P.M.—Some gravy or beef-tea, with sopped bread-crumbs ; or a table-spoonful ot finely minced mutton chop and bread-crumbs. Light pudding.

Fourth meal, 6 P.M.—Same as the first.

DIET FOR CHILDREN :—

Breakfast.—Bread and butter, 5 ozs., or porridge ; milk, 10 ozs. or *ad lib.*, may be diluted with weak tea and sugar added.

Dinner.—Cooked meat, 3 ozs. ; vegetables, 2 ozs. ; light pudding, 4 ozs.

Tea.—Bread and butter, 5 ozs. ; milk, 10 ozs. or *ad lib.*

DIET FOR ADULTS :—(*Full Hospital Diet*)—

Breakfast.—Bread, 10 ozs. ; butter, ¾ oz. ; coffee or tea, with milk and sugar, 15 ozs.

Dinner.—Cooked meat, 6 ozs. ; potatoes, 8 ozs. ; light pudding, 8 ozs.

Tea.—Bread, 10 ozs. ; butter, ¾ oz. ; coffee or tea, 15 ozs.

Supper.—Milk or bread and milk, 10 ozs.

Receipts and Losses of a Strong Man in 24 hours.

(Pettenkofer and Voit.)

Grammes in 24 hours	Water	C	H	N	O	Mineral matter
Gains						
Meat . . 139·7	79·5	31·3	4·3	8·5	12·9	3·2
Albumin . 41·5	32·2	5·0	0·7	1·55	2·0	0·3
Bread . 450·0	208·6	109·6	15·6	5·77	100·5	9·9
Milk . . 500·0	435·4	35·2	5·6	3·15	17·0	3·6
Beer . . 1025·0	961·2	25 6	4·3	0·67	30·6	2·7
Fat . . 70·0	—	53·5	8·3	—	8·1	—
Butter . 30·0	2·1	22·0	3·1	0·03	2·8	—
Starch . 70·0	11·0	26·1	3·9	—	29·0	—
Sugar . 17·0	—	7·2	1·1	—	8·7	—
Salt . . 4·2	—	—	—	—	—	4·2
Water . 286·3	286·3	—	—	—	—	—
Inspired Oxygen 709·0	—	—	—	—	709·0	—
	2016·3=	—	224·0	—	1792·3	—
Sum of gains 3342·7	—	315·5	270·9	19·47	2712 9	23·9
Losses						
Urine . . 1343·1	1278·0	12·60	2·75	17·35	13·71	18·1
Fæces . 114·5	82·9	14·50	2·17	2·12	7·19	5·9
Expired products 1739·7	828·0	248·60	—	—	663·10	—
	2189·5=	—	243·22	—	1946·20	—
Sum of losses 3197·3	—	275·70	248·22	19·47	2630·20	24·0
Difference— Gains minus losses +145·3	—	+39·8	+22·7	—	+82·7	−0·11

An examination of the above table shows the gains and losses of an adult man in twenty-four hours, as estimated by direct experiment when the body-weight is remaining nearly stationary. These gains in the form of food, &c., roughly amounted to 20 grammes of N, 315 grammes of C, and 2,000 grammes of water, 709 grammes of O in respiration, and 24 grammes of salts, being equal to about $\frac{1}{20}$th the weight of the body. His losses by the urine, fæces, and expired products amounted to 20 grammes of N, 275 of C, 248 of H, mostly in form of water, 2,630 of O in the form of CO_2 or H_2O and 24 of salts; thus leaving him 145 grammes heavier than before.

Effects of an Insufficient or Improper Diet.—Infants or adults supplied with insufficient food become pale, emaciated and weak, and often die of some intercurrent disease, to which their weak state predisposes, as diarrhœa or dysentery. The effects of an improper diet are especially seen in infants when fed on thick starchy foods. They suffer from indigestion, flatulence, constipation or diarrhœa, are fretful and sleepless, become wasted, suffer from skin eruptions, and are frequently convulsed before death.

Effects of Food in Excess.—One of the principal effects of an excess of proteid food is to throw extra work on the excretory organs, as the liver and kidneys: this result is especially marked when little exercise is taken. Gout, lithæmia with disordered liver and kidneys, and indigestion are apt to follow. The effects of an excessive amount of fatty or starchy matters in the food is sometimes shown in the excessive formation of adipose tissue, and often in indigestion.

Effects of Starvation.—The most prominent symptoms are, first, pain in the epigastrium, relieved by pressure; this subsides in a day or two, and is succeeded by a feeling of weakness and of intense thirst. The countenance becomes pale, the body exhales a peculiar fœtor, and the bodily strength rapidly fails. The temperature is lower than normal. The mental powers exhibit similar weakness, first stupidity, then imbecility, which sometimes is succeeded by maniacal delirium. Life terminates by gradually increasing torpidity, or, occasionally, by a convulsive paroxysm.

With entire abstinence from food and drink, death occurs in from eight to ten days. The Welsh fasting girl lived eight days. This time may be prolonged if water can be obtained, or if surrounded by a warm, damp medium.

The loss during starvation falls most heavily on the fat, next the glandular organs, then the muscles, the heart and brain being affected least. The post-mortem examination shows extreme emaciation and complete absence of fat. All the organs, with perhaps the exception of the brain, are bloodless; the coats of the intestines thin and empty of contents; the gall-bladder full, the bile staining the surrounding parts. The body rapidly passes into decomposition.

The percentage of dry solid matter lost during thirteen days by the most important tissues of a cat was as follows :—

Adipose tissue . . .	97·0 per cent.
Spleen . . .	63·1 „
Liver	56·6 „
Muscles . . .	30·2 „
Blood . . .	17·6 „
Brain and cord . .	0·0 „

CHAPTER XIII.

DIGESTION.

Teeth.

Two sets of teeth make their appearance during the life of man :—

I. *The temporary or milk teeth* (20).
II. *The permanent set* (32).

I. **The Temporary Set** appear during the first two years of life. They consist of two incisors, one canine, and two molars in each half-jaw, making twenty in all.

They make their appearance through the gums in five groups, in the following order (though exceptions occur even in healthy children) :—

First group—Two lower central incisors	6th– 8th months.
Second group—Four upper incisors	8th–10th ,,
Third group—Two lateral lower incisors and first four molars .	12th–14th ,,
Fourth group—Four canines .	18th–20th ,,
Fifth group—Four back molars	20th–30th ,,

II. **The Permanent Set.**—The first six months of life are passed without any teeth ; by the end of the second year the milk teeth have all appeared, and these begin to be replaced by the permanent set at the sixth year, and are completely replaced by them at the twelfth or thirteenth year ; the teeth being completed by the eruption of the wisdom teeth at the age of about twenty-one. When complete there are thirty-two, there being two incisors, one canine, two bicuspids, and three molars, in the half of either jaw.

The molars of the temporary set are replaced by the permanent bicuspids ; the three permanent molars appear in the jaw behind the molars of the milk teeth.

The permanent teeth appear in the following order :—

6th year . .	First molars.
7th ,, . .	Two central incisors.
8th ,, . .	Two lateral incisors.
9th ,, . .	First bicuspids.
10th ,, . .	Second bicuspids.
11th–12th years .	Canines.
12th–13th ,, .	Second molars.
17th–21st ,, .	Wisdom teeth.

The **Incisors** (8) are arranged side by side in the front of the jaws. They have a single long conical fang, and a sharp chisel-shaped edge, for dividing the food.

The **Canines** (4) are placed singly, next to the lateral incisors. Their fangs are single, large, and conical, compressed laterally, and cause a prominent ridge in the alveolus of the jaw. The crown is more pointed than in the incisors.

The **Bicuspids** (8) are arranged four in each jaw. The fangs are bifid at their apices, more marked in the upper and second bicuspids, and are grooved laterally. The crown is compressed from before backwards, and is surmounted by two tubercles, or cusps, separated by a groove. half.

The **Molars** (12) are arranged three in each jaw, behind the bicuspids. They have from two to three fangs. In the two anterior molars of the upper jaw there are three in number, two external and one internal. The two anterior molars of the lower jaw have two fangs, one anterior and one posterior. In the third molar, or wisdom tooth, the fang is irregular and single. The crowns of the molar teeth are cuboidal in form, rounded on each lateral surface, and flattened in front and behind. The upper molars have four cusps at the angles of the grinding surface,

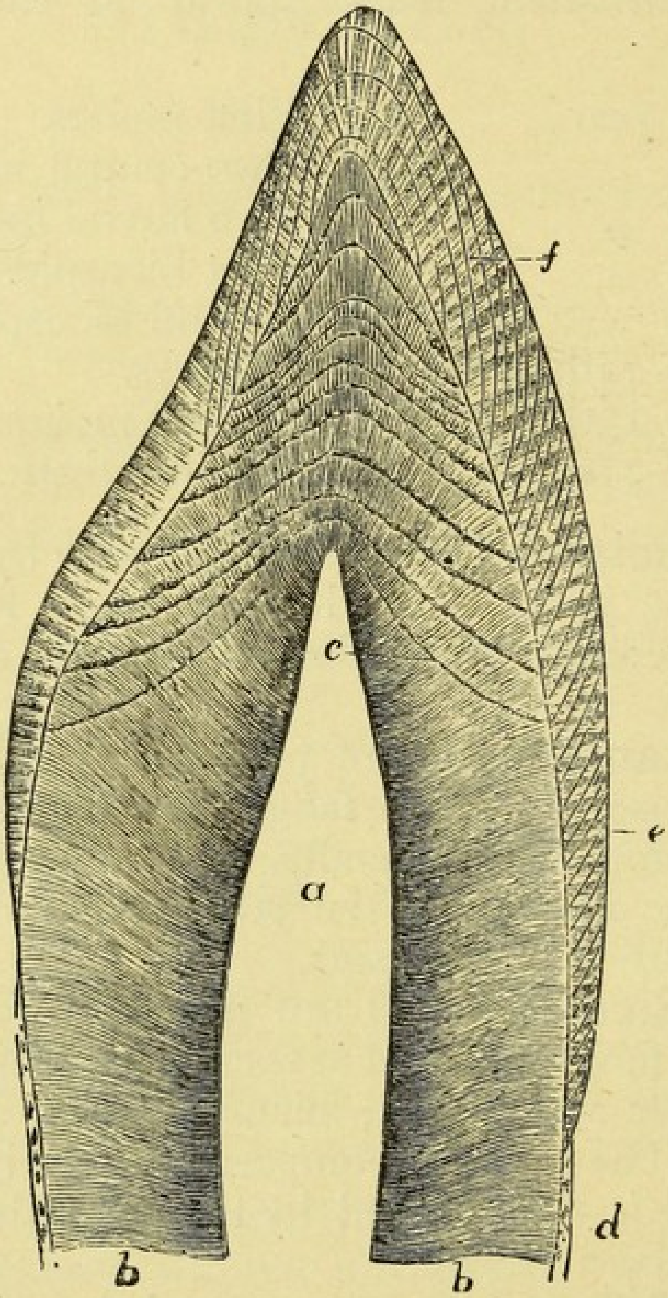

FIG. 63.—Vertical section of the upper part of an incisor tooth (Köllike). *a*, the pulp cavity ; *b*, dentine ; *c*, arched incremental fibres ; *d*, cement ; *e*, enamel with bands indicating the direction of the range of fibres ; *f*, coloured lines of the enamel.

separated by a crucial depression ; the lower molars have five cusps. The molars, from the great breadth of their crowns, are suitable for grinding and pounding the food.

Structure.—*Minute anatomy*: A tooth consists of a *crown*, which projects from the gum; a *root*, or *fangs*, which are fixed in a socket in the bone; and a short intermediate *neck*. Each is supplied with an artery and nerve, and has a central cavity filled with a soft vascular sensitive substance, the pulp. On vertical section a tooth shows—

1. Pulp.	3. Dentine.
2. Crusta petrosa.	4. Enamel.

1. The **Pulp** occupies the central cavity of the tooth, and consists of fine connective tissue, nucleated cells, blood-vessels, and nerves. The cells, or *odontoblasts*, form a stratum on the surface of the pulp, and send fine processes into the dentine tubules. The arteries are derived from the internal maxillary, and the nerves from the fifth pair.

2. The **Crusta petrosa,** or cement, covers the fang of the tooth, its place being taken below by the enamel which covers the crown. In structure it resembles bone, containing lacunæ and canaliculi, but they are larger and more irregular. above

3. The **Dentine** forms the principal mass of the teeth, it is protected by the crusta petrosa and enamel, and hollowed out in the centre to form the pulp-cavity. It is somewhat harder than bone, and differs from it in structure. It is penetrated by numerous fine tubes, giving it a striated appearance beneath the miscroscope, the tubes appearing dark and the matrix in which they lie transparent. The tubules open into the pulp-cavity, and radiate to the periphery, giving off small branches. They are $\frac{1}{4500}$ in. in breadth, and have a distinct wall, the dental sheath. As the dentine is sensitive, it is possible they may convey nerve-fibres as well as prolongations of the cells of the pulp-cavity. The matrix is homogeneous.

4. The **Enamel** is very hard and covers the crown.

It is made up of microscopic prisms arranged side by side; these prisms are six-sided and $\frac{1}{5000}$ in. in diameter, and are marked at intervals by transverse lines.

Chemical Composition.—The hard tissues of the teeth, like bone, consist of animal and mineral matter: the former yields gelatin on boiling, and exists in different amounts in the tissues—

Bone . .	33	per cent. animal matter.
Crusta petrosa	30	„ „ „
Dentine . .	28	„ „ „
Enamel . .	3·5	„ „ „

The mineral matter consists of calcic phosphate and carbonate, magnesic phosphate and calcic fluoride.

Development.—At the seventh week of intra-uterine life a groove appears on the surface of the jaws, which involves the soft embryonic tissues of the jaw as well as the Malpighian layer of the epithelium. It was called by Goodsir the *primitive dental groove.* This down-growth of epithelium forms the *common enamel-germ* (fig. 64, *f′*), and from it the enamel is developed. From the bottom of this groove, which has become flask-shaped in section, papillæ, ten in number, arise. These papillæ, as they grow upwards, push before them and become surrounded by the enamel-germ, and the portion of the primitive groove in which each is

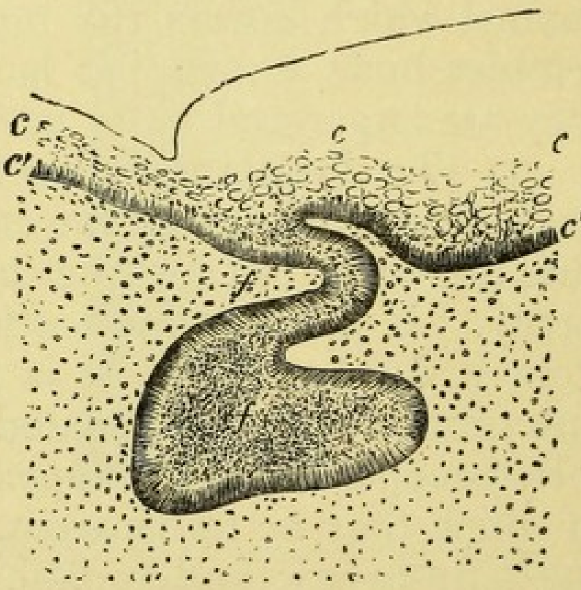

FIG. 64.—Section across the upper jaw of a fœtal sheep (Waldeyer). *c c′*, epithelium of mouth; *f*, neck; *f′*, body of special enamel germ.

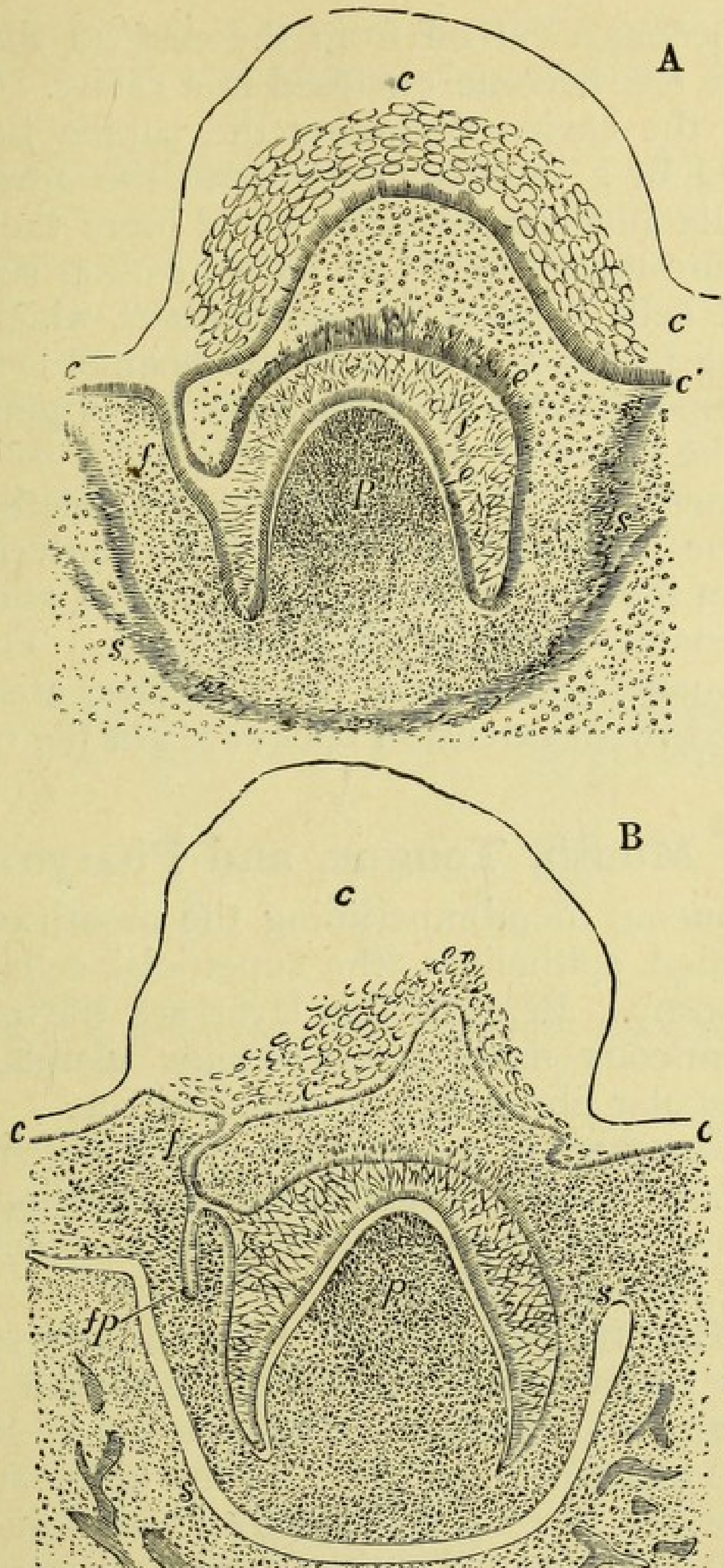

FIG. 65.—Sections at later stages than fig. 64, the papilla having become formed (Kölliker). *c*, epithelium of the gum ; *f*, neck of enamel germ ; *f'*, enamel organ ; *e*, its deeper columnar cells ; *p*, papilla ; *s*, dental sac ; B *fp*, enamel germ of permanent tooth.

situated becomes cut off from the rest, so that now the papilla has become enclosed in a cavity. In the meantime the cavity containing the papilla becomes surrounded by a vascular membrane, the *dental sac.* The papilla now acquires more and more the shape of the future tooth (fig. 65 *p*). On its outer surface a stratum of cells appears, the *odontoblasts*, which form the dentine ; outside this layer the enamel is formed from the enamel cells, the remains of the original cell-lining of the primitive groove.

The sacs in which the ten permanent teeth which replace the temporary are formed are derived from the neck of the enamel-germ (fig. 65 B, *fp*), and these form the enamel-germs of the future teeth. The posterior permanent teeth (the three molars) arise from sacs formed by an extension backwards of the original groove.

The Mouth, Tongue, and Pharynx.

The mucous membrane lining the mouth consists of a stratified epithelium, the superficial cells being flat and horny. Beneath this layer are the papillæ. The sub-mucous membrane contains glands, fatty tissue, muscular fibres, and lymphoid tissue.

The **Tongue** is a muscular organ which plays an important part in articulation, mastication, and deglutition ; it is covered with mucous membrane containing the organ of taste.

The **Mucous Membrane** surrounds the tongue, and forms various folds, as it is reflected to neighbouring parts. In the middle line, on the under surface, is the frænum linguæ, and on the upper surface, behind, are the three glosso-epiglottidean folds. In structure it resembles the skin, having a cutis with papillæ, covered by a stratified flattened epithelium. The under surface of the tongue is smooth, the upper surface, especially the anterior two-thirds, is rough, from the presence of numerous special *papillæ.* There are three kinds of papillæ—circumvallate, fungiform, filiform.

The **Circumvallate** papillæ are eight to ten in number, situated at the back of the tongue, arranged in the form of the letter **V**, with the apex backwards. They are rounded in form, and $\frac{1}{12}$ in. in width, their attached ends being somewhat narrower than their free ends, and are situated in a cup-shaped depression, which surrounds them like a trench (fig. 66). They are beset with numerous secondary papillæ, which are covered by the flattened stratified epithelium that

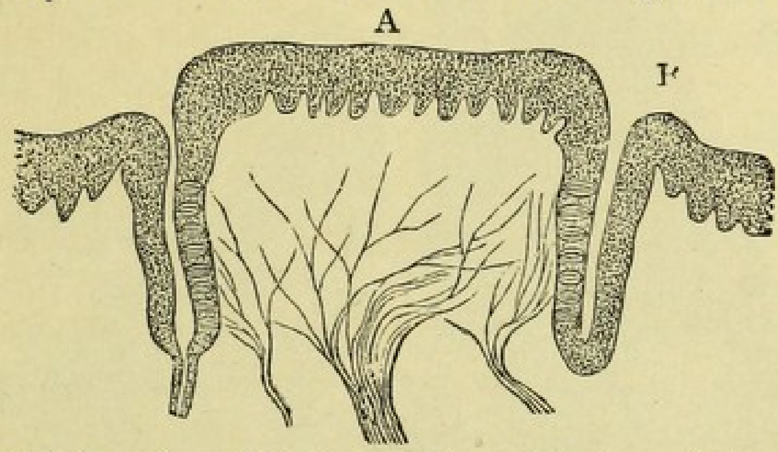

FIG. 66.—Vertical section of circumvallate papillæ × 25 (Engelmann). A, the papilla ; B, the surrounding wall. The figure shows the nerves of the papilla, connected with the taste-buds embedded in the epithelium at the sides.

lines the tongue. Embedded in the sides of the papillæ are numerous flask-shaped bodies composed of modified epithelium cells called *taste-buds*, with which the nerve-endings are connected. The papillæ are supplied with an arterial twig and nerve.

The **Taste-buds** reach the corium by their bases, while their apices appear as round openings among the epithelium on the surface. Each taste-bud consists of a layer of flattened epithelial cells on its surface, whilst the interior is composed of spindle-shaped cells with oval nuclei, which are elongated at either end, the deep extremity being connected with a plexus of nerves.

The **Fungiform** papillæ are smaller than the preceding, and are scattered over the dorsum, more particularly at the sides and apex. They are of a deep red colour, narrow at their attached ends and broad and rounded at their free extremities. They contain some of the taste-buds, and are supplied with nerves and capillaries.

The **Filiform** papillæ cover the anterior two-thirds of the dorsum of the tongue; they are long

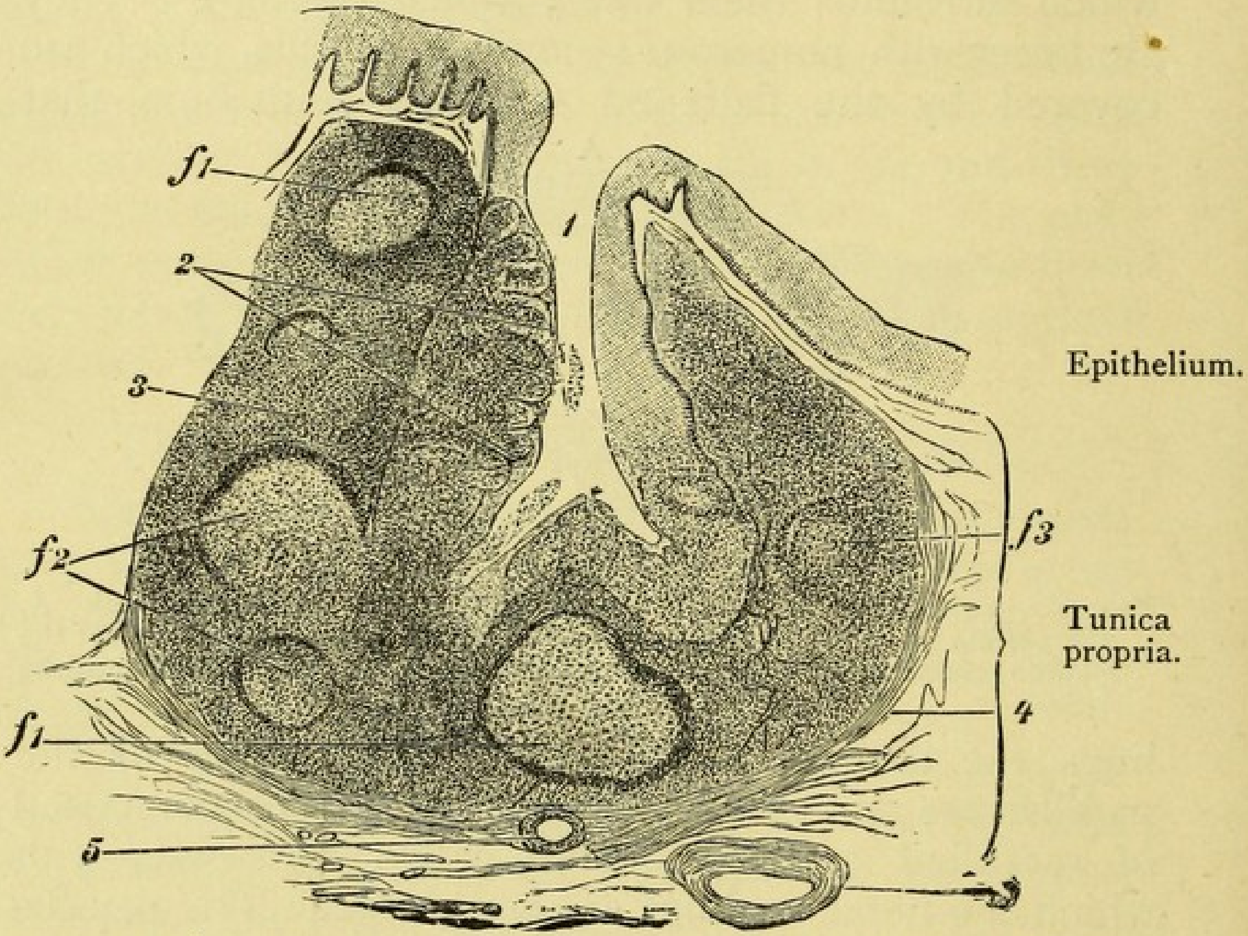

FIG. 67.—Vertical section of a human tonsil × 20 (Landois and Stirling). 1, crypt; 2, epithelium infiltrated with leucocytes below and on the left, but free on the right; 3, adenoid tissue with sections *f*1, *f*2, *f*3, of masses of it; 4, fibrous sheath; 5, section of gland duct; 6, blood-vessel.

and slender, and of a whitish tint. They are covered by a peculiar kind of epithelium, which is dense and imbricated, and possesses many hair-like processes.

Minute glands.—There are two kinds, serous and mucous. The *serous glands* are found at the back of the tongue in the neighbourhood of the circumvallate papillæ; they secrete a fluid resembling saliva. They are very small, and are of the same structure as the salivary glands. The *mucous glands* are present in the mucous membrane of the lips, soft palate and uvula, tonsils, back of tongue and pharynx. The alveoli of these glands are identical with the mucous alveoli in the sublingual gland (p. 164). Their ducts are lined with columnar epithelium.

The **Tonsils** are two rounded bodies situated between the anterior and posterior pillars of the pharynx. In structure they consist of lymphoid tissue and lymphoid follicles; some twelve or fifteen recesses, or crypts, open on the anterior surface (see fig. 67).

Muscles of the tongue.—The *extrinsic* are the genio-hyoglossus which protrudes the tongue; the hyo-glossus, stylo-glossus, and palato-glossus which retract; the hyo-glossus also depresses; the genio-glossus aids in hollowing the dorsum. The *intrinsic* are the superficial and deep lingual, which elevate the tip and turn the tongue to either side. The transverse fibres hollow the dorsum, assisted by the vertical fibres. The muscles of the tongue are supplied by the hypoglossal. Two muscles, the mylo-hyoid and stylo-hyoid, which assist indirectly in the movements of the tongue, receive their nerve-supply, the former from the fifth and the latter from the seventh.

Mastication.

The first stage in the digestion of food consists in its mastication in the mouth. It is crushed between the teeth and rolled about by the movements of the tongue, to mix it thoroughly with the saliva.

The **movements of the muscles** are voluntary, though from use they become habitual in character and will continue when the influence of the will is withdrawn and the attention directed elsewhere, provided there is a sensation of hunger and food within reach. The mouth is opened by the anterior belly of the digastric, mylo-hyoid, and genio-hyoid muscles. It is shut by the combined action of the masseter, temporal, and internal pterygoid muscles. The external pterygoids, acting together, thrust the jaw forward : it is retracted by the posterior fibres of the temporal. The grinding movement is performed by the alternate actions of the external pterygoids. The tongue on the inner, and the buccinator on the other side, press the food between the molars, and the action of the zygomatici helps to keep the buccinator and mucous membrane of the cheek from being included between the teeth.

The sensory branches of the fifth nerve convey to the brain the tactile sensations produced by food in the mouth. The motor part of the same nerve supplies the muscles. The nerve-centre for mastication is in the medulla.

Saliva.

The saliva is secreted by three glands—parotid, sub-maxillary, sub-lingual—and also by the smaller glands beneath the mucous membrane of the tongue and cheeks.

Structure of the Salivary Glands.—The salivary glands may be divided, according to Klein, into (1) *True salivary*, or *serous* glands, as the parotid and lachrymal in man, and the submaxillary in the rabbit and guinea-pig : (2) *Mucous glands*, as the submaxillary and sublingual in the cat and dog : (3) *Muco-salivary*, or *mixed glands*, as the submaxillary and sublingual in man (fig. 68).

They are compound racemose glands, and consist of numerous lobules, each supplied with a duct and blood-vessels, and bound together by connective tissue. The alveoli differ somewhat in structure according to the nature of their secretion, the one set yielding a thin watery secretion containing serum-albumen, and the other set yielding a ropy secretion containing mucus.

Serous alveoli.—The alveoli are formed by a basement membrane which is reticulated, and are lined by

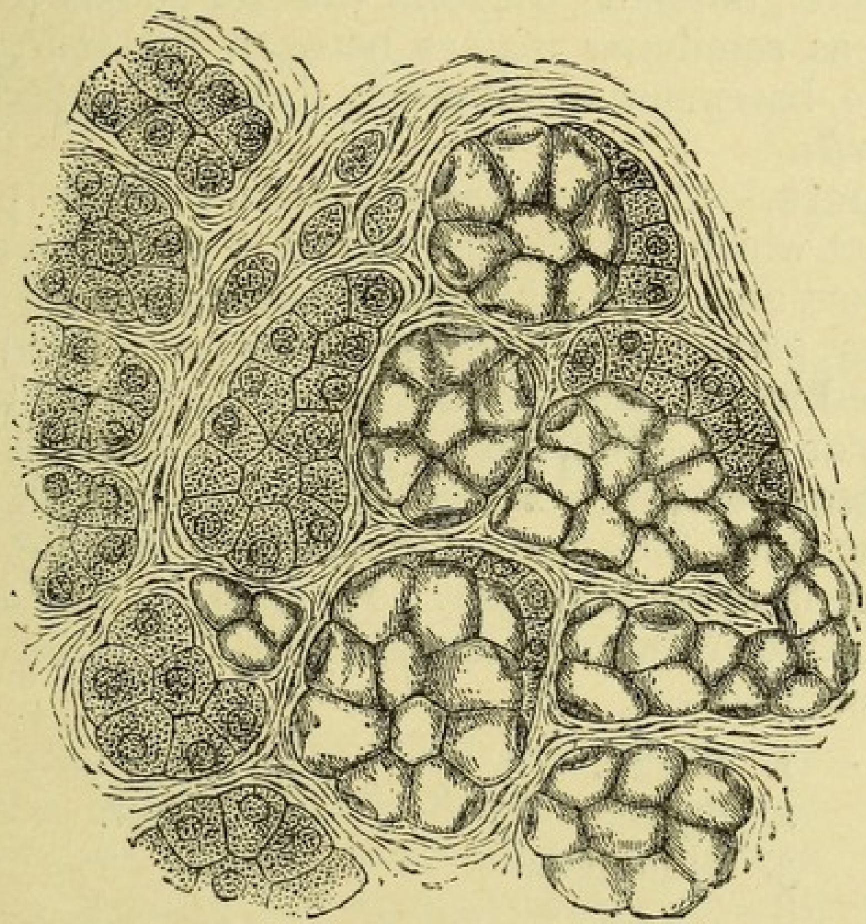

FIG. 68.—Section of part of the human submaxillary gland (Heidenhain). To the right of the figure is a group of mucous alveoli, to the left a group of serous alveoli.

a single layer of short columnar, or pyramidal, cells with round nuclei. In the inactive condition the cells contain numerous granules, which obscure the nuclei. The cells nearly fill the alveoli, no lumen being visible (fig. 69 A). After a period of activity the granules have nearly disappeared, only a few remaining near the lumen, the cells have become smaller and the lumen larger (fig. 69 c).

Mucous alveoli.—The cells in the mucous alveoli when the gland is inactive appear large, transparent, and spheroidal, and nearly fill the alveoli. A nucleus is present near the basement membrane. The transparent appearance of the cells is due to their being distended with mucin. After a period of activity the mucin has disappeared, the cells appear smaller and more granular. In some mucoid glands cells are visible as semilunar masses between the mucin cells and the basement membrane; these are called *marginal cells.*

Ducts. — In the serous glands the first part of the duct which conveys the secretion from the alveoli is narrow, and lined with clear flattened cells. In the mucous glands the smallest ducts are lined with flattened mucin cells. The larger ducts are lined by columnar epithelium, with a prominent nucleus.

Composition.—Mixed saliva is a viscid, frothy alkaline fluid, S.G. 1002–1007, and containing about $\frac{1}{2}$ per cent. of solid matter. From 30 to 60 fluid oz. are secreted in twenty-four hours.

It contains—

1. Mucin.
2. Ptyalin.
3. Albumen.
4. Salts.
5. Water.

Microscopically, epithelium cells, mucus and salivary corpuscles are seen.

Ptyalin or *diastase* is an albuminous body of the nature of a ferment.

The *salts* include potassium sulpho-cyanide; the latter salt is recognised by its giving a red colouration with ferric chloride, which is unaltered by HCl, and destroyed by mercuric chloride $HgCl_2$.

Saliva owes its energetic action on starch to the presence of ptyalin. This substance exists in saliva in very small quantities; it is apparently not used up or destroyed in the conversion of starch into maltose, but can convert an indefinite amount provided the dextrines and maltose formed are removed as fast as formed. It acts most vigorously at a temperature of 38° to 41° C.; its action ceases at a temperature of 60° to 70° C. It is most active in a slightly alkaline or neutral solution, the presence of free acid at once arresting its action. It much more quickly converts cooked starch than raw starch. It is doubtful if ptyalin can be obtained entirely free from proteids.

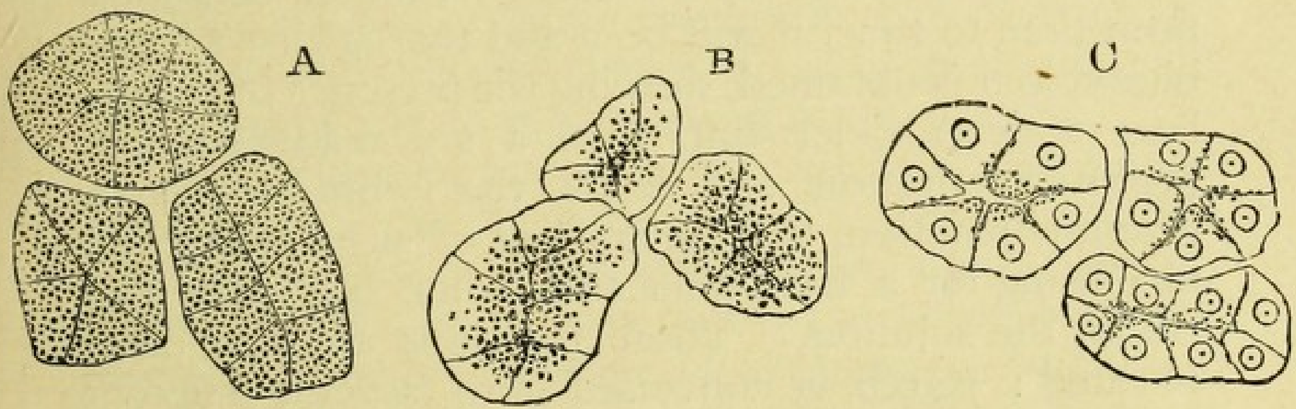

FIG. 69.—Alveoli of serous glands. A, at rest; B, after a short period of activity; C, after a prolonged period of activity (Langley).

On precipitating saliva freed from mucus with a large quantity of alcohol, allowing to stand and making an aqueous extract from the precipitate, a very active substance is obtained with but little proteid material.

Parotid saliva is clear and limpid, containing but little mucus and no salivary corpuscles. Submaxillary and sublingual saliva in man is more alkaline and viscid, containing more mucin than parotid saliva. It contains many salivary corpuscles.

Uses. — 1. Liquefies starch foods, and changes the starch into dextrin and maltose. 2. Moistens the food, and therefore assists in mastication and deglutition. 3. Administers to the sense of taste by dissolving the food.

Probably at least two-thirds of our food consists of starch. Starch in its uncooked state resists the action of the saliva, but when cooked it is digested with facility. If saliva be added in moderate quantity to a jelly or paste made from corn-flour or other form of starch at the temperature of the body, in a few moments the jelly becomes thin and watery; this change takes place prior to any chemical change. Shortly a distinct action will be obtained with Fehling's solution for sugar. Later on the reaction becomes abundant. If a solution of iodine be added from time to time, it will be noted that at first a pure blue colour is obtained, showing the presence of starch, later a deep violet tint, then a red colouration, a brown colouration, and finally the iodine ceases to give any reaction, but the amount of sugar will go on increasing for a time after the iodine has ceased to colour the solution. These reactions are very complicated; starch is converted into several different kinds of dextrin before the final change into sugar is reached.

The stages of the process may be represented thus:—

1. Starch gives a blue colour with iodine.

2. Soluble starch also gives a blue colour with iodine.

3. Erythro-dextrines, reddish or brown colour with iodine.

4. Achroo-dextrines, no colouration with iodine.

5. Maltose and a variable quantity of dextrose give reaction with Fehling's solution.

Starch is converted into maltose ($C_{12}H_{22}O_{11}$), a sugar which differs from grape sugar ($C_6H_{12}O_6$) in having less sweetening power, less readily reduces cupric oxide, but exercises more rotatory power on polarised light. The starch molecule is probably $10(C_{12}H_{20}O_{10})$. The final result is represented by—

$$\underset{\text{soluble starch}}{10(C_{12}H_{20}O_{10})} + \underset{\text{water}}{8H_2O} = \underset{\text{maltose}}{8(C_{12}H_{22}O_{11})} + \underset{\text{dextrin}}{2(C_{12}H_{20}O_{10})}$$

Innervation of the Salivary Glands.—The secretion of saliva is a reflex act, due to the excitation of food placed in the mouth, or to mental stimuli induced by the sight or thought of food.

The afferent or sensory nerves of the submaxillary gland are (*a*) the lingual of the fifth ; (*b*) the glosso-pharyngeal.

The efferent or motor are (*a*) the chorda tympani, which is the vaso-inhibitory or vaso-dilator ; and (*b*) the sympathetic or vaso-motor (fig. 95, p. 245).

The nerve-centre is in the medulla, but higher centres exist on the surface of the brain, where the sensation of taste is perceived by the mind. Stimulation of the lingual and glosso-pharyngeal causes a flow of saliva ; stimulation of the mucous membrane of the stomach also produces a flow. Stimulation of the chorda tympani renders the gland turgid with blood ; the arteries dilating, a copious supply of limpid saliva is secreted ; the stimulation producing two effects, dilatation of the arteries and a greater activity of the salivary epithelial cells. Stimulation of the sympathetic produces constriction of the arteries and the secretion of viscid saliva, rich in salivary corpuscles. Apparently excitation of the sympathetic produces a secretory activity in the cells, as well as contracting the arteries.

The motor nerves of the parotid are (*a*) vaso-inhibitory, the lesser superficial petrosal from the otic ganglion ; and (*b*) sympathetic from the cervical sympathetic.

Deglutition.

Deglutition is a complicated act by means of which food passes from the mouth into the œsophagus without any part of it being allowed to enter the nasal cavity or the larynx. It is usually divided into three acts :—

1. The passage of food to the back of the mouth.
2. Its passage across the orifice of the larynx.
3. Its seizure by the constrictors and its passage through the œsophagus to the stomach.

1. The bolus having been prepared, the tongue carries it back through the anterior pillars of the fauces, the movement being effected through the agency of the stylo-glossus and intrinsic muscles of the tongue.

2. The soft palate is raised by the action of its muscles, and, assisted by the contraction of the upper part of the superior constrictor, shuts off the cavity of the nose from the pharynx. The larynx is raised behind the hyoid bone by the action of the stylo-pharyngeus and thyro-hyoid, the vocal chords are approximated, and the epiglottis closely fitted over the rima glottidis by the action of the depressor. The passages both into the nares and larynx being closed, the descending bolus passes over the root of tongue, the epiglottis, and beneath a roof formed by the contraction and approximation of the palato-pharyngeal muscles, is seized by the constrictors, and propelled into the œsophagus.

The first stage in which the tongue passes the bolus to the isthmus faucium is a voluntary act. The second and third are purely reflex, and can take place independently of the will and during sleep, or in a state of coma. Patients who are unconscious will swallow if partly raised up and liquids out of a 'feeder' be allowed slowly to trickle over the back of the tongue. In profound coma swallowing becomes impossible. The respiration centre is lower in the medulla than the deglutition centre, and may continue in action when the former will not.

Deglutition is a reflex act. The *afferent nerves* are the glosso-pharyngeal and branches of the 5th. The *nerve centre* is in the medulla. The *efferent nerves* are the pharyngeal branch of vagus, hypo-glossal, glosso-pharyngeal, and facial.

The Œsophagus.

The œsophagus is the muscular tube extending from the pharynx to the stomach. It consists of three coats :—

1. External, or muscular.
2. Middle, or submucous.
3. Internal, or mucous.

1. The **External** consists of an outer layer of longitudinal and an inner layer of circular muscular fibres. The muscular fibres in the upper part are striated, but are gradually replaced by non-striated in the lower half.

2. The **Submucous** coat consists of connective tissue, and contains some mucous glands.

3. The **Mucous** coat is pale in colour, and when the œsophagus is contracted is thrown into longitudinal folds. In structure it resembles the skin, having a cutis, papillæ, rete mucosum, lined by stratified flattened cells.

The food is propelled along the œsophagus by the peristaltic action of its muscular walls. It is a reflex act ; the afferent and efferent nerves are supplied by the vagus. The centre is in the medulla. Food accumulates in the œsophagus of an animal in which the vagus is divided below the pharyngeal branches, the animal being able to swallow the food, but the œsophagus fails to pass it on into the stomach, from paralysis of its muscular walls.

Stomach.

The stomach is a somewhat conical or pyriform-shaped sac, the left extremity or *cardiac* end being the larger, the right or *pyloric* extremity being the smaller. It has two orifices, the cardiac, where the œsophagus enters, and the pyloric orifice, at the entrance into the duodenum. When moderately distended it measures 10 to 12 inches in length, and from 4 to 5 inches in breadth.

Structure.—Four coats :

1. Serous.	3. Submucous.
2. Muscular.	4. Mucous.

1. The **Serous** is divided from the peritoneum ; it invests the whole organ, except at the curvatures.

2. The **Muscular** contains fibres of the non-striated variety. *Longitudinal*, best marked along the curvatures and near the pylorus. *Circular*, forming a complete layer over the whole extent of stomach, becoming thick and strong at the pylorus, and forming the sphincter. *Oblique*, scattered over surface and continuous with circular of œsophagus.

3. The **Submucous** consists of a layer of connective tissue between the muscular and mucous.

4. The **Mucous** is a smooth pink membrane, which is loosely attached to the tissue beneath, and when the stomach is empty is thrown into rugæ. The mucous membrane contains a fine layer of muscular tissue, the *muscularis mucosæ*, internal to which are the tubular glands.

Epithelium of the surface consists of a layer of columnar cells, extending into the mouths or ducts of the gastric glands.

Gastric Glands.—On examining a section of stomach stained with logwood or aniline, rendered transparent with glycerine, the gastric glands are seen parallel to one another and closely crowded together with their blind extremities towards the muscularis mucosæ, and opening on the surface of the mucous membrane. Their length varies from $\frac{1}{20}$ to $\frac{1}{60}$ in., and diameter $\frac{1}{300}$ to $\frac{1}{500}$ in. in breadth. Two different kinds of glands are distinguished; some in larger numbers near the pyloric orifice are lined throughout with columnar epithelium, and are supposed to secrete mucus and are called *pyloric glands.* The *cardiac glands,* so named from the portion of the stomach where they occur most numerously, have columnar epithelium at their mouths only, the rest of the gland being lined by two different sets of cells; those at the circumference of the tubule resting on the basement membrane, being oval in shape, are called *ovoid* or *parietal,* and another set, occupying a more central position, are *cubical* or *columnar* in shape, and are termed

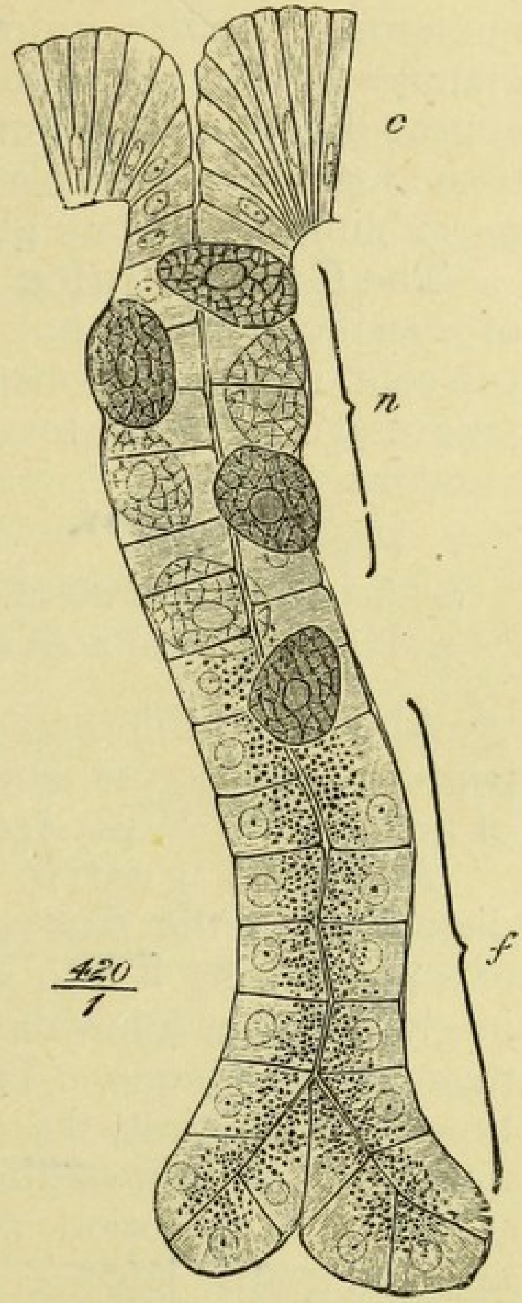

Fig. 70.—A cardiac gland from the bat's stomach (Langley). *c*, columnar epithelium of the surface; *n*, neck of the gland with central and parietal cells; *f*, base or fundus, occupied only by principal or central cells, which exhibit the granules accumulated near the lumen of the gland.

central cells. These cells are finely granular, and contain an oval nucleus. They are occupied by numerous granules during fasting, but which, like the granules in the cells of the salivary glands, mostly disappear during a period of activity. Delicate lymphoid tissue may be seen in places in the mucous membrane, resembling the solitary glands of the intestine.

The **Gastric Juice** is a thin colourless acid fluid of specific gravity 1,001 to 1,010, containing $\frac{1}{2}$ to 1 per cent. of solids in man. The daily amount varies, an average being 22 to 24 pints (13 to 14 litres). It contains—

1. Pepsin. ·4% f.s.
2. A curdling ferment.
3. Hydrochloric acid (free). ·3%
4. Mucin.
5. Salts and water. ·2%

About two-thirds of the solid matter consists of peptones and pepsin, and one-third of salts. Amount of free HCl = ·2 per cent.

Artificial gastric juice is best prepared by dissecting off the mucous membrane of the stomach of a pig, cutting it into small pieces and digesting it in glycerine for a few days, filtering and adding fresh mucous membrane. This may be repeated several times. Each time the glycerine will take up a fresh quantity. A little of the glycerine extract added to ·2 per cent. solution of HCl will form an active artificial gastric juice.

Action of Gastric Juice on Proteids.—The characteristic action of gastric juice is its action on albuminous compounds, converting them into the peptones. If shreds of fibrin be placed in artificial gastric juice the shreds first swell up and become transparent, then gradually dissolve, leaving only some slight flocculent remains. If thin slices of white of egg be similarly treated, the edges become translucent, and finally they completely disappear. The principal product formed will be peptone, though, if the action continues, leucin and tyrosin, and other similar bodies, will be formed.

Action on various foods.—Cooking renders *meat* more digestible by separating and breaking down the fibres. When exposed to the action of gastric juice the connective tissue is dissolved, and the fibres set free ; the transverse striæ become well-marked, the fibres show a tendency to transverse cleavage, and finally become broken up and disappear. The fatty matters are set free from their envelopes. Fish and eggs are digested in the stomach in about one hour and a half ; beef, mutton, and fowls in two and a half to three hours. The *gluten* of bread is dissolved and converted, like albumen, into peptone, the starch being set free. *Milk* is quickly coagulated by gastric juice, the casein being precipitated ; this is apparently brought about by the action of a curdling ferment. The coagulated casein is quickly redissolved and converted into peptone.

Gastric juice has no action upon elastic tissue, cellulose, starch, or mucus.

There are several different bodies included under the peptones, such as metapeptone, parapeptone, dyspeptone, but they closely resemble one another in properties. They differ from albumen in the following ways :—

1. They readily diffuse through animal membranes.

2. They are not coagulated by heat or nitric acid.

3. They are not precipitated by acetic acid and ferrocyanide of potassium.

4. They give a pink colour on the addition of caustic potass and a trace of cupric sulphate or Fehling's solution.

They resemble albumen in being precipitated—

1. By tannic acid. 2. By lead acetate.

The part that pepsin plays in digestion is that of a ferment resembling the action of ptyalin in the saliva. Pepsin is not destroyed in the act of digestion; its digestive power appears to be infinite. Yet, if more and more fibrin be added to artificial gastric juice, it will at last remain undissolved, the arrest of digestion being due to an accumulation of the peptones and want of acid. For, if the liquid be diluted and more acid added, digestion will recommence. The activity of the pepsin is greatest at a temperature of 30°–50° C. (90°–112°F.). It is completely destroyed by boiling.

Gastric juice contains a distinct ferment which has the property of curdling milk (W. Roberts).

Chyme.—The grumous acid fluid, resulting from the digestion of the food in the stomach, is termed chyme. It contains (1) peptones resulting from the conversion of various proteid substances—albumen, fibrin, casein, gelatin, &c.; (2) various partly-digested proteids, as muscular fibre, connective tissue; (3) certain substances which are not digested in the stomach, as fat, cellulose, elastic tissue, starch, &c.; (4) various salts and sugar in solution.

Digestion of the Stomach.—If a quantity of milk be introduced into the stomach of a rabbit and the animal killed an hour after and laid in a warm place for twenty-four hours, the walls of the stomach will probably be found digested. If a portion of the stomach of a dog be ligatured, the wounded stomach sewn up, and the dog allowed to live a few hours, the portion included in the ligature will be digested. The stomach itself is not digested during life, in consequence of the circulation through its walls of alkaline blood.

Secretion of Gastric Juice.—The stomach has two secretions, one thick, tenacious, and alkaline —the gastric mucus ; the other, thin, acid, and watery —the gastric juice proper. The former is secreted during fasting, while the latter is only secreted when food or fluid enters the stomach. Saliva or alkalis, pepper, alcohol, excite the secretion of gastric juice. Their action is reflex : the vagus is probably the afferent nerve, which, acting on the medulla, inhibits the sympathetic and dilates the blood-vessels supplying the glands ; the efferent impulses descending along the splanchnics.

Movements of the Stomach.—Food during digestion in the stomach is kept in motion by the peristaltic action of its walls. By the contraction of its muscular fibres currents are set up in its contents, the food travelling along the large curvature and returning by the lesser, while as digestion proceeds certain portions are passed through the pylorus into the duodenum.

Vomiting is a reflex act by which the contents of the stomach are expelled through the œsophagus and mouth. Very different circumstances may give rise to vomiting :—

1. Irritation of the terminal fibres of the vagus from the presence in the stomach of certain substances, as ipecacuanha, or a catarrhal state of the mucous membrane.

2. Irritation of the terminal fibres of different branches of the vagus or sympathetic, as in tickling the fauces, an inflamed peritoneum, an enlargement of the uterus, as in the vomiting of pregnancy.

3. Direct irritation of the nervous centres, as in tumour of the brain, or circulation through the nerve-centres of certain substances, as apomorphia.

4. Vomiting may also be induced by disgusting smells, sights, or tastes. The *afferent* nerves depend upon the cause ; they may be the vagus, sympathetic,

first, second, &c. The *nerve centre* is probably in the medulla. The *efferent nerves* are the phrenics and nerves to the abdominal muscles.

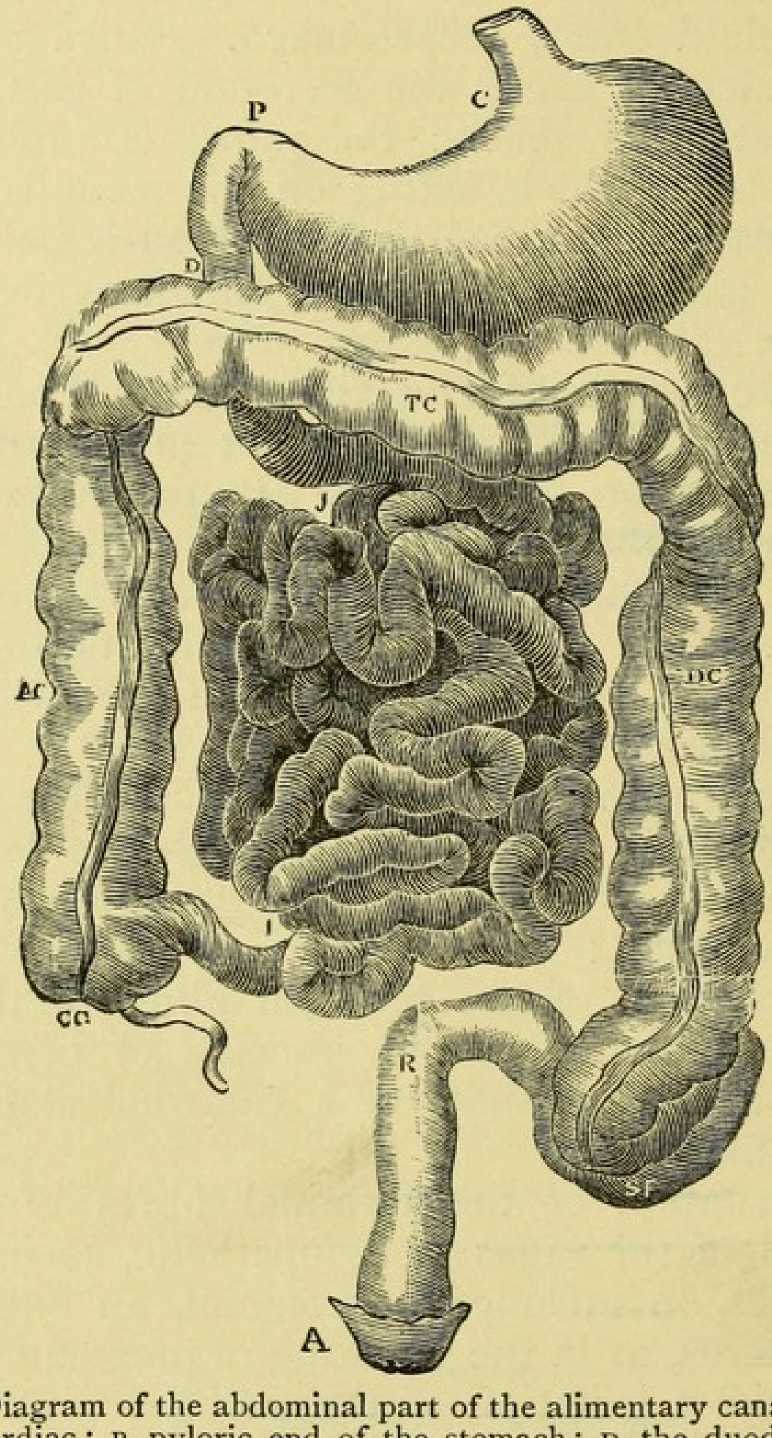

FIG. 71.—Diagram of the abdominal part of the alimentary canal (Brinton). C, the cardiac; P, pyloric end of the stomach; D, the duodenum; J, I, convolutions of the small intestine; CC, cæcum; AC, ascending colon; TC, transverse, and DC, descending colon; SF, sigmoid flexure; R, rectum; A, anus.

Mechanism of Vomiting.—Peristaltic waves run from the pylorus to the cardiac end of the stomach, the cardiac aperture being firmly closed. Then, a deep breath having been taken, the diaphragm fixed, and glottis closed, the cardiac sphincter is suddenly opened by fibres continuous with the longitudinal fibres of the œsophagus, the abdominal muscles contract, and, the stomach being fixed by the diaphragm, its contents are expelled.

Structure of Small Intestine.—The small intestine commences at the pylorus and empties itself into the cæcum, and is about 20 ft. in length. It is divided into three portions, the *duodenum*, occupying the first 10 or 12 in., the upper $\frac{2}{5}$ths of the remainder being *jejunum*, and the lower $\frac{3}{5}$ths *ileum*.

It has four coats, serous, muscular, submucous, mucous. The **Serous** entirely surrounds the gut, except where the vessels enter. The **Muscular** consists of two layers, external *longitudinal* and internal *circular*. The **Submucous** is a loose connective tissue layer between the mucous and muscular. The **Mucous** lines the intestine, and in the upper part of the jejunum is thrown into numerous transverse folds called the *valvulæ conniventes*, which are permanent and extend about $\frac{2}{3}$rds of the way round the intestine. They increase the absorbing surface and help to delay the contents of the intestine. The mucous coat is separated from the areolar by a thin layer of muscular fibres, the *muscularis mucosæ*, and, like the stomach, is lined by *columnar epithelium*. It is provided with—

1. Villi.
2. Brunner's glands.
3. Crypts of Lieberkuhn.
4. Solitary glands.
5. Peyer's glands.
6. Lymphoid tissue and vessels.

1. The **Villi** are small processes of mucous membrane which extend from the pylorus to the ileo-cæcal

valve, and give the inner surface of the intestine a velvety appearance. They are about $\frac{1}{40}$ to $\frac{1}{50}$ inch in length, and are closely set together. They consist of an external layer of columnar epithelium, a basement membrane, a plexus of capillary vessels, a lacteal vessel, a few muscular fibre cells prolonged from the muscularis mucosæ and *lymphoid* tissue (fig. 72).

2. **Brunner's Glands** are small compound glands existing in the duodenum. They consist of

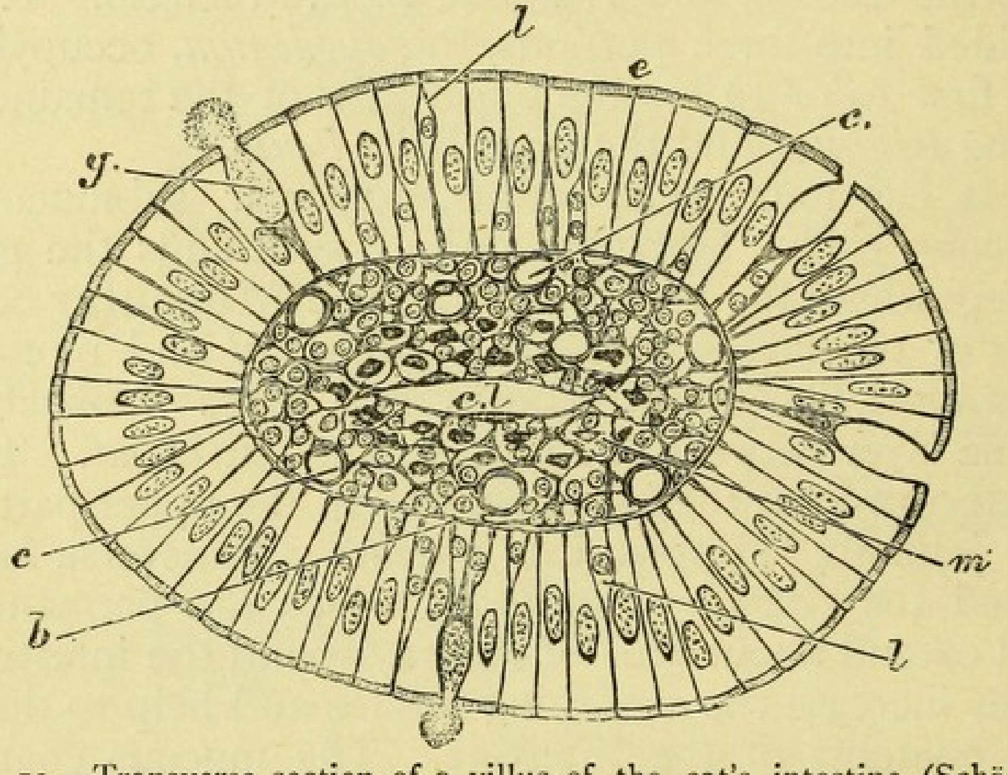

FIG. 72.—Transverse section of a villus of the cat's intestine (Schäfer) *e*, columnar epithelium; *g*, goblet cell; *l*, lymph corpuscles between epithelium; *b*, basement membrane; *c*, blood capillaries; *m*, section of muscular fibre; *cl*, central lacteal.

clusters of acini in connection with a minute duct, which opens on the surface.

3. The **Crypts of Lieberkuhn** are minute blind tubes which exist in every part of the intestine opening between the villi. They are lined by columnar epithelium, and are $\frac{1}{120}$ in. to $\frac{1}{300}$ in. in length (fig. 73 *b*).

4. The **Solitary Glands** are small white bodies about the size of millet seeds scattered through the

intestine. They consist of lymphoid tissue surrounded by a plexus of capillaries.

5. **Peyer's Glands** are a group of glands resembling the solitary glands in structure (fig. 73). They are situated for the most part in the lower

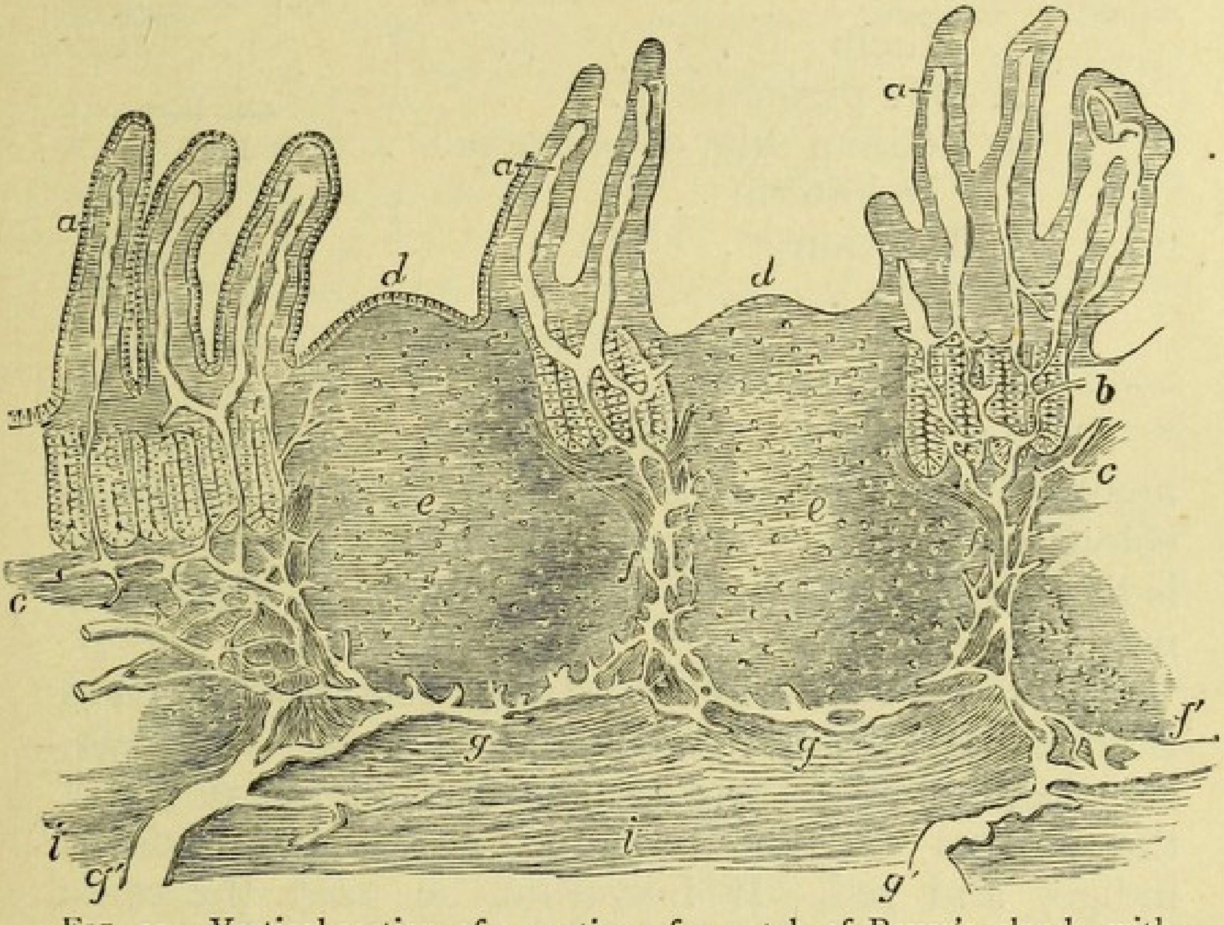

FIG. 73.—Vertical section of a portion of a patch of Peyer's glands, with lacteal vessels injected (Frey). *a*, villi; *b*, tubular glands; *c*, muscular layer of the mucous membrane; *d*, cupola or projecting part of a lymphoid gland; *e*, their central part; *f*, *g*, *g'*, lacteal vessels.

portion of the ileum. The groups are oblong and placed lengthways in the intestine opposite to the attachment of the mesentery.

6. **Lymphoid** tissue is found in various places in the submucous tissue, in addition to that of the solitary and Peyer's glands.

Secretions poured into the Intestine.

Bile is an alkaline, golden yellow fluid of a bitter taste and specific gravity 1018, and containing about

14 per cent. solid matter. If it remain long in the gall-bladder it becomes viscid, from the presence of mucus. From 30 to 40 oz., or 1000–1500 grammes, are secreted in 24 hours.

Composition :—

	Per cent.
1. Mucin . . . . } 2. Bile-pigments . . . }	2–3
3. Sodium salts of bile-acids .	9–10
4. Cholesterin . . . } 5. Lecithin . . . . }	·2–·3
6. Salts	·5–1
7. Water	85–86

BILE-PIGMENTS.—The yellow colour of the bile ot man and the carnivora is due to *Bilirubin* ; the green colour of herbivora and that of man after oxidation is due to *Biliverdin.* A small quantity of *Biliprasin* may be present.

Gmelin's Test.—When strong yellow nitric acid is added to bilirubin or human bile on a white plate, a succession of colours is produced in the order of the colours of the spectrum—green, blue, violet, indigo, and red. If biliverdin be used the same result occurs, the first colour being blue. In applying the test to urine, care must be taken to notice the colours succeed one another in their right order, as the presence of indican may cause green, blue, and yellow colours.

Bilirubin may be prepared from dog's bile by acidulating with acetic acid and shaking with chloroform ; the chloroform dissolves the bilirubin, and on evaporation leaves the pigment of a red colour.

Biliverdin may be obtained by allowing an alkaline solution of bile to become green by exposure to the air. The bilirubin is oxidised and biliverdin formed ; it may be separated by precipitating by HCl, dissolving in alcohol and evaporating. Bilirubin is believed to be derived from hæmoglobin during its passage through the liver. It seems to be identical with the hæmatoidin found in old blood-clots.

The **Bile Acids** are taurocholic and glycocholic acids. These acids are composed of cholic acid in combination with taurin and glycocine.

Pettenkofer's Test.—A small quantity of dilute bile is mixed with a few drops of sugar (cane sugar) and strong H_2SO_4 added; the solution becomes first cherry red, then of a purple colour. Some other organic substances give a similar colour, but may be distinguished by the spectroscope. Hay's test

Preparation.—Bile is rubbed up with animal charcoal and dried at steam heat; it is thus rendered colourless. The bile-acids are then dissolved out by absolute alcohol and precipitated by ether, as silky needles, which readily take up moisture and form a syrupy fluid.

Cholesterin can be obtained best from gall-stones by boiling with alcohol and filtering while warm; white rhombic crystals of cholesterin form (fig. 6.)

Uses of Bile.

1. Slight action in converting starch into sugar.
2. Assists in emulsifying and saponifying fats.
3. Assists in the absorption of fats.
4. Increases peristaltic action.
5. Prevents putrefactive changes in intestines.

The action that bile exerts in converting starch into sugar and in emulsifying fat is slight. Mucous membrane, wetted with bile, allows minute globules of fat to pass readily through it, and in this way it aids the absorption of fat. It increases the peristaltic action of the intestine, thus aiding in the propulsion forwards of the contents of the intestine.

It stimulates the contraction of muscular fibres of the villi, emptying the lacteal, and forcing onwards its contents. It checks putrefactive changes. In jaundice, where the bile is prevented from flowing into the intestine, there is a tendency to constipation and flatulence.

Bile is being constantly secreted, and accumulates till required in the gall-bladder. When the acid contents of the stomach enter the duodenum a reflex action is set up, leading to the contraction of the gall-bladder, and pouring out of bile into the intestine.

Pancreas.

The pancreas is an elongated lobulated gland, which lies across the abdomen, behind the stomach,

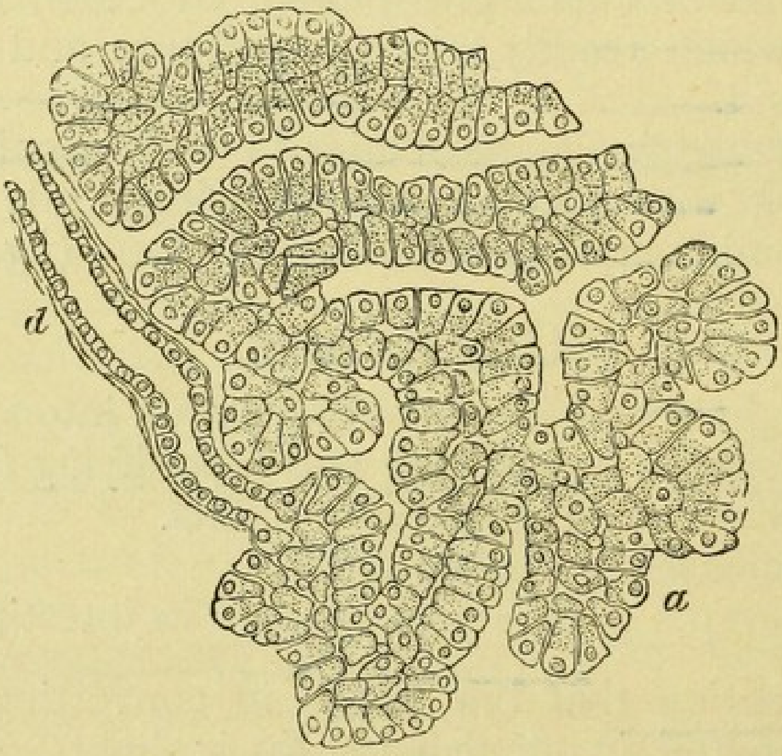

FIG. 74.—Section of the pancreas of the dog (Klein). *d*, termination of duct in the tubular alveoli, *a*.

and in front of the first lumbar vertebra. It is 6 to 8 inches long, $1\frac{1}{2}$ inches average thickness, and weighs from $2\frac{1}{2}$ to $3\frac{1}{2}$ ounces.

The cells lining the alveoli are columnar or pyramidal in shape, with a spherical nucleus. Their protoplasm is finely granular near the lumen, and transparent near the basement membrane (fig. 74). After a period of activity, nearly the whole cell becomes clear.

Structure.—The pancreas belongs to the class of compound racemose glands, and closely resembles the salivary glands, though of somewhat looser texture, the lobules being separated by more connective tissue.

Pancreatic Juice is a clear, viscid alkaline fluid resembling saliva, but of greater specific gravity, and containing from 2 to 5 per cent. of solid matter. About 12 to 16 ounces are secreted in 24 hours.

It contains—

1. Four ferments :
   (*a*) Trypsin, changes proteids into peptones.
   (*b*) Pancreatic diastase, changes starch into dextrin and maltose.
   (*c*) Curdling ferment, precipitates the casein of milk.
   (*d*) Emulsive ferment, emulsifies and saponifies fats.

2. Albumen. 3. Mucin. 4. Salts and water.

Action.

1. It changes proteids into peptones in alkaline or neutral solutions, afterwards decomposing them into leucine and tyrosine.
2. It converts starch into dextrin and sugar.
3. It emulsifies and saponifies fats.

On Proteids.—Pancreatic juice artificially prepared from pancreas acts in a somewhat similar manner on proteids as gastric juice, more leucine and tyrosine, however, are formed. It acts energetically on some proteids, as the casein of milk, provided the solution is alkaline, but is less active than artificial gastric juice on white of egg. Its solutions require to be alkaline, equivalent to one per cent. of sodium carbonate. Its activity depends upon a ferment called trypsin.

Pancreatic digestion of proteids differs from gastric, in that (1) it requires an alkaline instead of acid medium ; (2) the proteids are dissolved without the preliminary swelling ; (3) leucin, tyrosin, and similar bodies are formed.

On Starch.—Pancreatic juice acts with great energy on raw or cooked starch, quickly converting it into dextrin and maltose. It is more energetic than saliva.

On Fats.—Pancreatic juice, when shaken up with fats and oils, reduces the oily matters to a state of fine division and suspends them, forming a milky fluid. It also splits up fats into glycerine and their respective acids.

An artificial pancreatic juice can be made by pounding up fresh pig's pancreas with powdered glass, and adding dilute spirit or glycerine.

If artificial pancreatic juice be added to milk, coagulation takes place ; if the milk is rendered alkaline by carbonate of soda, before the addition of the pancreatic fluid, no curdling takes place ; and at a temperature of about 35° C. the casein is gradually converted into peptone.

Succus Entericus.—This is the secretion of the intestinal glands. It appears to act in a similar way to pancreatic juice. It also contains a ferment which converts cane sugar into invert sugar.

Large Intestine.

The large intestine consists of cæcum, colon, rectum.

Structure—resembles the small intestine, with some modifications.

The **Serous** coat completely surrounds the intestine in the transverse colon; is incomplete elsewhere.

The **Muscular** coat consists of two layers, the *longitudinal* being arranged in three flat bands, except at the rectum. One band is posterior, another anterior, and a third lateral or inferior in the transverse colon; along the latter the appendices epiploicæ are attached. These longitudinal fibres, by being shorter than the intestine, throw it into sacculi, which are marked off from one another by constrictions where the circular fibres are most marked. The *circular* fibres form a thin layer over the intestine, and are best marked at the constrictions.

The **Mucous** membrane is lined with columnar epithelium, and is destitute of villi. It has numerous glands of Lieberkuhn and solitary glands, also retiform tissue.

The junction of the small and large intestine is guarded by a valve, and the termination of the rectum by the sphincter. But little, if any, digestive action goes on in the large intestine; the principal work done is absorption; the contents of the intestine become firmer and harder as they approach the rectum. The contents of the large intestines are acid, from the acid fermentations going on in the fæcal matters.

Movements of the Intestines.

If the abdomen of a recently killed animal be opened, the muscular fibres of the intestines will be seen alternately contracting and relaxing, but working down the intestine in waves so as to propel the contents downwards. This peristaltic action is increased by the presence of food or bile, or by irritation of the vagus nerve. It is checked by irritation of the splanchnic. The exact nervous mechanism is unknown, but it is probably automatic, like the action of the heart. The movements of the large intestine resemble those of the small ; the fæces are lodged in the sacculi during the relaxation of the intestine.

Defæcation.—The sphincter is normally contracted under the influence of a nervous centre in the cord. The sigmoid flexure prevents the fæces from pressing too heavily on the rectum. The act of defæcation consists in an inhibition of the nervous centre in the cord which governs the sphincter, relaxation of the sphincter taking place. At the same time a deep breath is taken, the glottis is closed, the diaphragm and abdominal muscles contract, press upon the descending colon, and eject the contents of the rectum, the sigmoid flexure having previously become filled by peristaltic action.

Summary of Digestive Changes.

The essential work of digestion is performed by a singular group of bodies termed *ferments*. These bodies are found in nearly all the secretions poured into the alimentary canal, and play an exceedingly important part in dissolving the food. These ferments are soluble in water, and differ in this respect from the organised insoluble forms, as the yeast plant. They diffuse through animal membranes, though with difficulty ; they are rendered inert by a heat of 70° C. (160° F.), and they are precipitated by strong alcohol. (*See* p. 187.)

Mouth.—The food is crushed, mixed with saliva, and reduced to a pulp ; a certain amount of starch

Table of the digestive juices and their ferments (Roberts).

Digestive fluid	Ferments	Action
Saliva . . .	Ptyalin or Diastase	Changes starch into dextrin and sugar
Gastric juice .	*a.* Pepsin .	Changes proteids into peptones in the acid solution
	b. Curdling ferment	Curdles casein of milk
Pancreatic juice	*a.* Trypsin .	Changes proteids into peptones in alkaline solutions
	b. Curdling ferment	Curdles the casein of milk
	c. Diastase .	Changes starch into sugar
	d. Emulsive ferment	Emulsifies and partly saponifies fat
Intestinal juice	Invertin . .	Changes cane sugar into invert sugar

converted into maltose and rendered slightly alkaline. Fats and proteids unaltered.

Stomach.—Contents rendered acid, conversion of starch into sugar ceases, connective tissue of fats dissolved, and fats set free. Proteids dissolved and peptones formed. The albuminous foods are dissolved for the most part, and a grumous mixture of peptones, liquid fats, and starches is formed, which is termed chyme, and is gradually passed through the pylorus into the intestine.

In the Intestine.—The chyme mixes with the bile, pancreatic and intestinal juices, becomes alkaline, conversion of starch into sugar recommences, emulsifying of fat begins, and the undissolved proteids are converted into peptones. The diffusible peptones and salts enter the portal vein, the fat in a fine state of division entering the lacteals. In the large intestine the liquid chyme becomes more and more solid, is rendered acid by fermentative changes, and acquires the odour of fæces.

CHAPTER XIV.

ABSORPTION AND NUTRITION.

THE food must be acted upon by the various secretions of the alimentary canal before it can enter the blood-vessels or lacteals with which the walls of the stomach and intestines are well supplied.

The **Albuminous Foods** are crushed and reduced to pulp in the mouth, and converted into the peptones by the action of the gastric, pancreatic, and intestinal juices. By far the greater part of the peptones thus formed enter the capillary blood-vessels of the stomach and villi. Being diffusible through animal membranes, they pass through the walls of the capillaries by osmosis, enter the portal vein, and are conveyed to the liver. In the liver they are either split up into more oxidised bodies, as glycogen, urea, or kreatin, or are reconverted into albumen to assist in the nutrition of the tissues.

In the present state of our knowledge it seems uncertain where or how peptones undergo change, whether before reaching the liver or in their passage through the liver. Some observers have failed to find peptones in the portal vein.

The **Starches** are converted into dextrin and sugar by the action of the saliva, pancreatic, and intestinal juices, and being thus rendered diffusible enter the portal vein, and are conveyed to the liver. The liver probably converts the sugar into glycogen, and stores it up till required to be oxidised for the production of heat and muscular energy. A variable amount of sugar appears to be converted into lactic acid in the intestines.

The **Fats** are crushed and reduced to pulp in the mouth, and their fibrous tissue and vesicular envelopes dissolved in the stomach, so that the oily matters are set free. In the small intestine they undergo two different changes, which are effected by the secretions of the small intestine :—

1. They are emulsified.
2. They are saponified.

The emulsification consists in reducing the fat into fine particles, small enough to readily enter the lacteals. The saponification consists in the formation of soaps : thus olein is decomposed, the glycerine being set free, and the oleic acid forming an oleate with sodium or potassium for a base.

Small quantities of the fatty matters find their way into the portal vein, but by far the major quantity enters the lacteals of the villi. The particles of fat enter the protoplasm of the columnar cells surrounding the villi, so that if these cells be examined during a period of digestion they are seen to be distended with fat particles. They next pass into the retiform tissue of the villi, and thence into the lacteal, which commences in the villus. Finally, the fatty matters forming the chyle pass through the mesenteric glands and into the receptaculum chyli and thoracic duct.

The exact forces in operation which determine the entrance of fat into the lacteals are not thoroughly understood. Animal membranes wetted with bile much more readily allow fatty matters to pass through them than membranes not so treated. The cells surrounding the villi, perhaps, exercise some selective power, as the glandular epithelium does in the convoluted tubes of the kidney. The fat, once within a villus, is driven onwards by the contraction of the muscular fibres present in the villi, compressing the lacteal and forcing onwards its contents, the aspirating power of the thorax supplying the *vis a fronte*. The fatty matters and albuminous materials present in the chyle are gradually, in part, converted during its passage through the mesenteric glands into the elements of fibrin and white blood corpuscles.

The food that has entered the body in the form of meat, starch, sugar, fats, after being digested passes into the blood-vessels in the form of peptones, fatty matters, and sugar. What processes must they undergo before they become formed tissue, such as muscle, nerve, tissue, or gland? But very little is known of such changes. Some of the albuminous and fatty matters are converted into white corpuscles and fibrin, probably through the action of the blood-glands, *i.e*, spleen, lymphatic, lenticular, tonsils, thymus glands; the white corpuscles passing into red or exuding into the tissues to become transformed into the actual cells or fibres of the various tissues.

The albumen, fats, and sugars absorbed from the alimentary canal pass out of the body at the kidneys and lungs as urea, salts, and CO_2. About the intermediate stages our knowledge is scanty.

Summary.

The portal vein absorbs	Peptones	(major part)
	Sugar	"
	Salt	"
	Soaps	"
	Fats	(trace)
	Water	(major part)

Summary—(continued).

The lacteals absorb	Fats	(major part)
	Soaps	(small part)
	Peptones	,,
	Sugar	(trace)
	Salts	,,
	Water	(small part)

CHAPTER XV.

THE LIVER.

THE liver is the largest gland in the body, and weighs 50 to 60 oz. In the fœtus and child it is larger in proportion to the body-weight than in the adult, being 1 in 20 to 30 in the child and 1 in 40 in the adult. The liver receives the blood of the portal vein and hepatic artery, the hepatic veins carrying away the blood from the organ. Its under surface is divided into lobes by five fissures.

The **Fissures** are the *transverse*, where the vessels and nerves enter ; the *longitudinal*, situated between the right and left lobes, is divided into two by the transverse fissure, the anterior part forming the *umbilical* fissure and containing the round ligament, and the posterior the fissure of the *ductus venosus*, containing the obliterated remains of the ductus venosus of the fœtus. The fissure of the *gall-bladder*, or rather fossa, makes the fifth.

The **Lobes** are, *right* and *left*, separated by the longitudinal fissure. The *lobulus quadratus* situated between the gall-bladder and longitudinal fissure. The *lobulus Spigelii* between the fissure for the ductus venosus and inf. vena cava. The *lobulus caudatus* forms a sort of ridge extending from the base of the Spigelian lobe to the under surface of the right lobe.

Structure.—The liver has two coverings, the *serous* and *fibrous coats.*

The **Serous** is derived from the peritoneum, and is reflected round the organ, except where the vessels enter, and at the posterior border.

The **Fibrous** or **Connective Tissue** coat invests the whole gland, and at the transverse fissure becomes continuous with the fibrous tissue which accompanies the blood-vessels into the substance of the liver, and forms the *capsule of Glisson.*

Hepatic Lobules.—On section of the liver its substance will be seen to be composed of closely packed bodies of rounded outline and of about 1 to 2 mm. ($\frac{1}{12}$ to $\frac{1}{20}$ inches) in diameter. These lobules for the most part have a darkish red centre and lighter circumference, and in some animals, at least, are separated by a small quantity of connective tissue. The centre of the lobule is occupied by an *intralobular* vein, which collects the blood from the capillaries of the lobule and empties itself into the *sublobular* ; the latter opens into the hepatic veins. The circumference of the lobule is surrounded by the *interlobular veins*, which are branches of the portal system ; capillaries passing from the circumference to the centre of the lobule connect the interlobular veins with the intralobular.

The **Hepatic Artery** enters the liver at the transverse fissure, accompanies the portal vein and ducts, and supplies the connective tissue of the liver (fig. 75, *a*).

The **Hepatic Cells** are packed in between the network of capillaries in the lobule. They are of rounded or polyhedral form, $\frac{1}{800}$ to $\frac{1}{1000}$ in. in diameter. They have a yellow granular appearance and a well-marked prominent nucleus. Whilst in a quiescent state the liver-cells are larger and more granular than after action. On examining the cells by a high power they may be seen to contain a fine network which extends into the nucleus. They are joined together by an albuminous cement, which contains fine channels for the bile-capillaries ; during digestion they contain minute oil-globules and glycogen.

The **Biliary Ducts** commence by a fine plexus of capillaries which run between and surround the

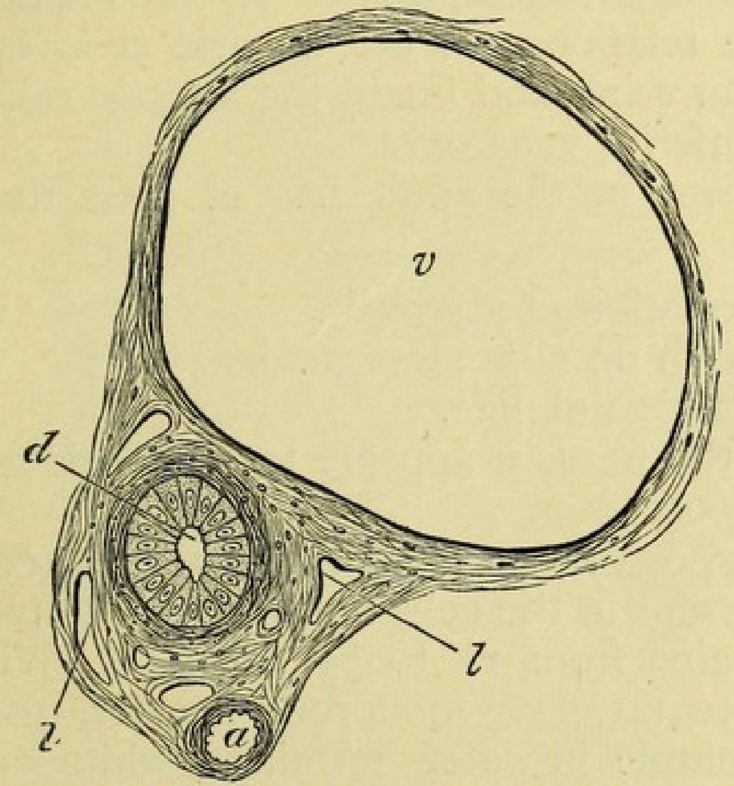

FIG. 75.—Section of a portal canal (Schafer). *a*, branch of hepatic artery; *v*, branch of portal vein ; *d*, bile duct ; *ll*, lymphatics.

cells (fig. 76). In a very thin section minute openings may be seen between the cells, which are the apertures of the capillary ducts. The larger bile-ducts are lined with columnar epithelium, their coats being formed of fibrous and elastic tissue, with a mixture of unstriated muscular fibre.

The branches of the portal vein, artery, and duct accompany one another through the liver, the hepatic veins travelling by themselves (fig. 75).

Functions of the Liver.

The portal vein carries the blood which has circulated through the walls of the stomach and intestines, pancreas, and spleen. It is loaded with material absorbed from the contents of the stomach and intestines. This blood is submitted to the liver before entering the general circulation. In its circulation through the liver it enters the interlobular plexus, travels through the capillaries of the lobule, coming into close relation with the hepatic cells, enters the intralobular veins, and finally the hepatic veins convey it to the inferior vena cava.

The liver in the adult has at least three functions :—

1. Formation of glycogen.
2. Action on albuminous substances.
3. Secretion of bile.
4. In the fœtus it appears to give origin to white blood corpuscles.

1. **Glycogen, or Amyloid Substance** ($C_6H_{10}O_5$), is present in the cells of the healthy liver. The liver contains from $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent. When pure it is a white, tasteless, inodorous powder, insoluble in alcohol, soluble in water, forming a white opalescent solution. It closely resembles starch in appearance, but differs from it in being stained reddish-brown by iodine. Like starch, it is readily converted into sugar by the action of dilute acids or ferments. Besides being present in the liver it is found in living muscle, white corpuscles of the blood, brain, placenta, and most tissues of the fœtus.

Preparation.—Fresh liver is boiled with strong solution of KHO, which dissolves the liver-tissue and the glycogen, and on pouring it into alcohol the glycogen is precipitated tolerably pure. Another method consists in making a decoction of liver, precipitating the albuminous matters with potassic hydrarg. iodide and HCl, and afterwards precipitating the glycogen with alcohol (*see* p. 12).

Origin.—Glycogen is principally formed in the liver from the saccharine elements of the food.

$$C_6H_{12}O_6 - H_2O = C_6H_{10}O_5.$$

Grape sugar—water = glycogen.

Dogs fed on starch or sugar rapidly accumulate large quantities of glycogen in the liver; when fed on

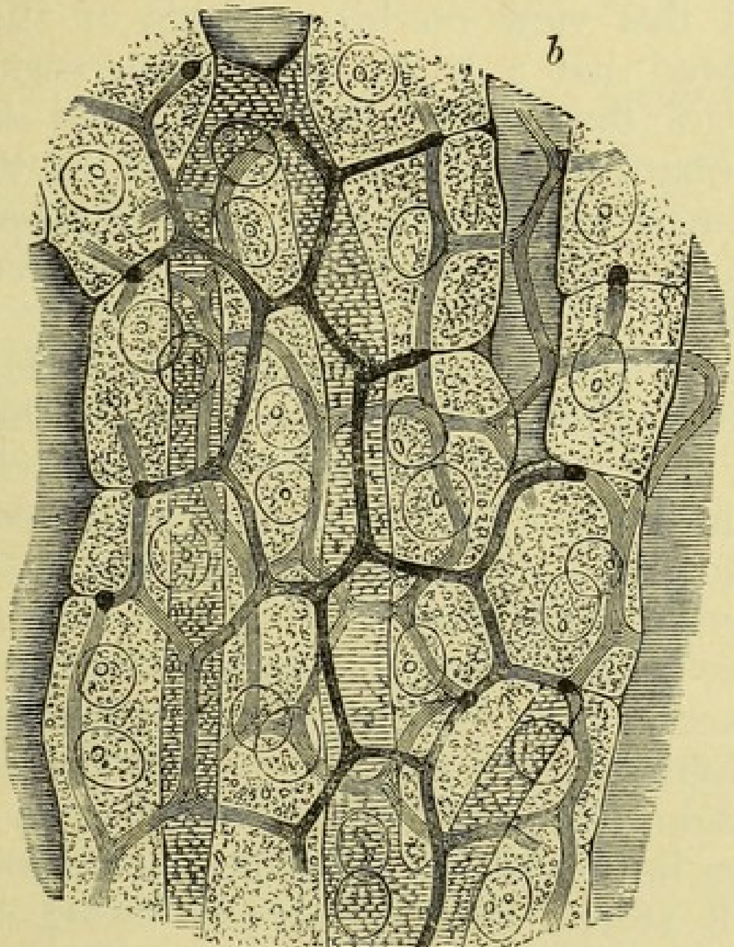

FIG. 76.—Section of rabbit's liver with the intercellular network of bile-canaliculi injected (Hering). Two or three layers of cells are represented. *b*, capillaries.

a purely animal diet very much smaller quantities are found. This appears to show that while glycogen is formed in small quantities from albumen, yet by far the major part originates from the saccharine elements of the food. In badly nourished or half-starved animals no glycogen is found. Fatty foods do not increase the amount.

Destiny of Glycogen.—The fate of glycogen is uncertain. There can be no doubt it serves to store up material rich in C and H ; but the exact manner in which it is utilised is not fully understood. Bernard maintained that it is gradually reconverted into sugar as required, and oxidised in the capillaries of the body to maintain the heat or to supply muscular energy. He based this view on his analysis of the blood, which showed that a larger quantity of sugar existed in the hepatic than in the portal vein. He also found a greater quantity in the arteries than in the veins, which seemed to suggest that sugar disappeared in the capillaries. Pavy maintains that the hepatic veins during life only contain a trace of sugar, and the arteries contain no more than the veins. He argues that the large quantities of sugar found in the hepatic veins after death are due to a post-mortem change of glycogen into sugar, and that during life only traces are to be found. He does not believe that glycogen is reconverted into sugar during life, and that if it were in any quantity, it would run off at the kidneys, as in diabetes. The question is still *sub judice*. Glycogen is doubtless stored in the liver, and is utilised in the system, either entering the blood as sugar or as glycogen in the white corpuscles, or in some other way. It is stored also in muscle, testes, brain, as carbo-hydrate material ready for use. That it cannot enter the blood as sugar in any large quantity is certain, as, if it did, it would certainly be excreted in the urine, as in diabetes. Bernard found 1 grm. per 1,000 in the arteries, and 3 to 7 grms. per 1,000 in the hepatic veins. This quantity seems too small to be of any great use in maintaining the energy of the body, and not improbably the glycogen may be utilised in some other way.

Diabetes is a disease characterised by an abnormal quantity of sugar in the urine. Its immediate cause is a rapid conversion of glycogen into sugar in the liver, depending probably on some disturbed innervation of the blood-vessels. In can be induced artificially in animals by puncture with a needle of the vaso-motor centre of the medulla. This leads to dilatation of the blood-vessels of the liver, an increased supply of arterial blood, and an increased conversion of glycogen into sugar, which makes its appearance in the urine.

2. **Action on Albuminous Substances.**—(*a*) Preparation of the peptones for assimilation. (*b*) Splitting up of various bodies into urea, &c.

(*a*) The portal vein contains the peptones which have been absorbed from the alimentary canal. These bodies disappear during their passage through the liver, being probably converted into serum-albumen.

(*b*) The liver probably splits up various substances, as albumen, kreatin, leucin, and tyrosin, the products being glycogen, urea, and uric acid. In certain diseases, as acute yellow atrophy of the liver, the urea in the urine is lessened, and tyrosin and leucin appear to take its place.

3. **Secretion of Bile.**—In all probability the pigments and biliary acids are formed in the liver, and not merely separated from the blood. No trace of either of them has been found in frogs whose livers have been extirpated. To what extent the secretion of bile gets rid of effete matters from the system is uncertain. The biliary acids are in large part reabsorbed after having taken part in the digestion of the contents of the small intestine.

4. **Fœtus.**—The relative size of the liver in early fœtal life is about half the body-weight; at full time

it is about 1 in 18. It receives blood from two sources—(*a*) the umbilical vein, a portion of which escapes through the ductus venosus directly into the inf. vena cava; (*b*) the portal vein, which carries venous blood resembling that of the body generally. The functions of the fœtal liver differ from those of the adult, principally in its being a blood-making organ. After the formation of the placenta the umbilical vein brings various nutritive materials from the maternal system; the liver seems, out of these materials, to produce numerous colourless nucleated corpuscles which are poured into the blood. Probably before birth it ceases to do so, the spleen and lymphatic glands taking its place.

The biliary secretion (meconium) of the fœtus is purely excrementitious in character.

CHAPTER XVI.

THE KIDNEYS.

The kidneys are situated in the lumbar region opposite the last dorsal and two or three upper lumbar vertebræ. They are about 4 inches in length, and weigh 4 to 5 oz. each.

Structure.—The kidneys are invested by a thin fibrous capsule, which is attached by connective tissue and blood-vessels. It is easily stripped off. On making a longitudinal section through a kidney the glandular structure will appear to be divided into two portions: (1) the outer or cortical portion, for the most part occupying the surface, except at the hilus; (2) the medullary portion, consisting of a number of pyramids separated from one another by cortical substance.

1. The **Cortical Substance** occupies the greater part of the gland, being $\frac{1}{3}$ to $\frac{1}{2}$ inch in depth at the surface, and extends into the centre of the gland between the pyramids; the cortical portion between the pyramids being termed the columns of Bertini. It is of a light red colour, and more or less distinctly striated in appearance, the striations being due to the interlobular vessels and bundles of straight tubes which pass from the base of the pyramids to the capsule. The Malpighian bodies may be seen as reddish points, or some times standing out from the surface like grains of sand. The bundles of straight tubes are called the *medullary rays* (fig. 77, *m*).

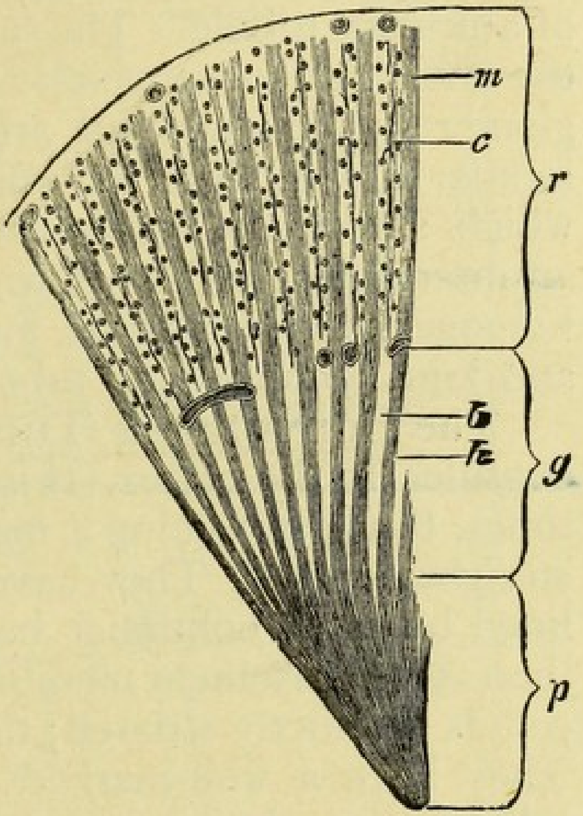

FIG. 77.—Section through part of the dog's kidney (Ludwig). *r*, cortical layer; *g*, boundary layer; *p*, papillary layer; *h*, bundles of tubules in the boundary layer prolonged into the cortex as the medullary rays *m*; *b*, spaces containing vasa recta (not represented in the figure); *c*, portion of cortex between the medullary rays containing interlobular vessels, glomeruli, and convoluted tubes.

2. The **Medullary Portion** occupies the centre of the gland, and consists of 8 to 12 of the pyramids of Malpighi. These pyramids are surrounded at their bases and sides by cortical substance, while their apices project into the dilated portion of the ureter at the hilus, which forms the pelvis. The pyramids are divided by Ludwig into two layers or zones—the *boundary* layer (fig. 77, *g*), and the *papillary* layer (*p*). The boundary layer has well-marked striations, this appearance being due to the vasa recta (fig. 79, *ab*, *vb*),

and to the bundles of tubules (fig. 77, *h*) passing down the pyramid towards the papilla. The papillary layer is of a more uniform dull red colour.

The **Malpighian Bodies** are about $\frac{1}{120}$ inch in diameter, and are situated in the cortical portion between the medullary rays. They consist of a tuft of capillary vessels in a capsule formed by the dilated end of a urinary tubule. The tuft is termed the *glomerulus*, the membranous envelope—*Bowman's capsule.* The glomerulus receives an arterial twig from an interlobular artery, and its efferent vein joins a plexus which surrounds the convoluted tube before joining an interlobular vein. Bowman's capsule consists of a homogeneous membrane, lined by flattened epithelium, and joins a convoluted tube by a constricted neck.

The **Convoluted Tubes** (fig. 78) commence as capsules in the cortex, twist upon themselves several times, then, on joining a medullary ray, take nearly a straight course. They have a distinct lumen, and are lined by short columnar cells, narrower at the lumen than at the basement membrane. The outer part of the cell is distinctly striated; their inner part is granular. They have a well-marked nucleus. The convoluted tubule passes into a *spiral tubule* of *Schachowa*, which is situated in the medullary rays; these are more or less spirally arranged: the epithelium is the same as in the convoluted tubes. The spiral tubule on entering the boundary layer becomes narrower, and forms the *descending loop-tube of Henle*; the epithelium is here flattened, with a prominent nucleus. The *ascending loop-tube*, which has re-entered the boundary layer, is wider than the descending, and is lined by a layer of polyhedral fibrillated cells. It next enters the cortex, is somewhat narrower and wavy, and passes upwards in a medullary ray. It then leaves the medullary ray and forms an *irregular tubule.* Its shape is irregular, its lumen small, and its epithelium consists of short, columnar, fibrillated cells. The irregular tubule passes into the *second convoluted tube,* closely resembling the first convoluted tube.

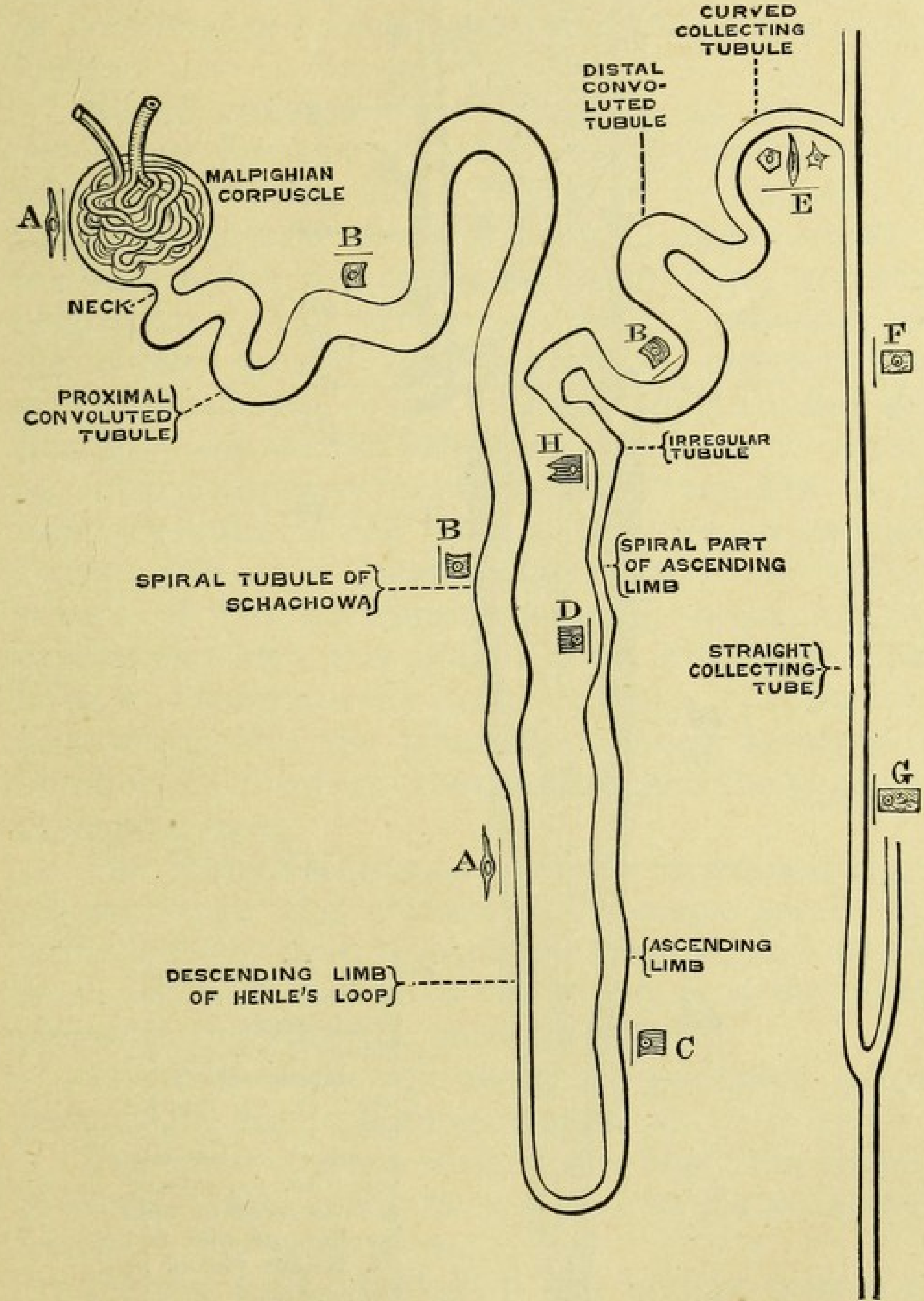

FIG. 78.—Diagram of the course of the uriniferous tubules (Gray's Anatomy).

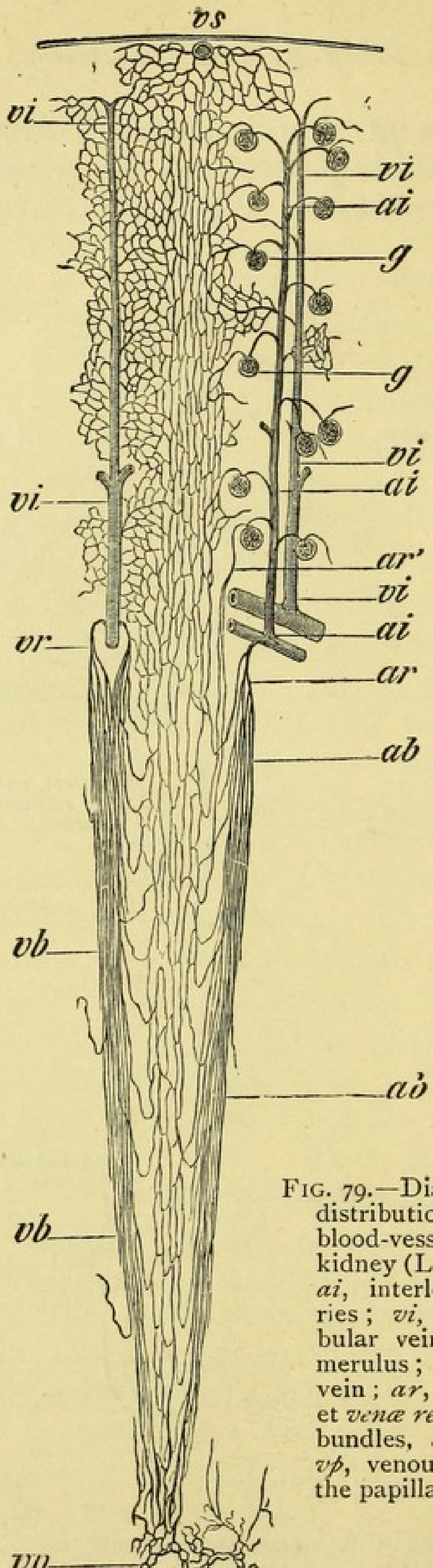

FIG. 79.—Diagram of the distribution of the blood-vessels in the kidney (Ludwig). *ai*, *ai*, interlobular arteries; *vi*, *vi*, interlobular veins; *g*, glomerulus; *vs*, stellate vein; *ar*, *vr*, arteriæ et *venæ rectæ* forming bundles, *ab* and *vb*; *vp*, venous plexus in the papillæ.

It then passes into a more or less wavy collecting tube before it joins a *straight collecting tube.* The collecting tubes commence in the cortex and pass through the boundary layer into the papillary layer, are lined by columnar or cubical epithelium, and have a distinct lumen.

Blood-vessels.—The renal artery, on entering the kidney, breaks up into numerous primary branches, which travel along the columns of Bertini, and are called the *arteriæ propriæ renales.* These divide at the base of the pyramids and form arches with their neighbours ; these arches give off (1) branches into the cortex termed the *interlobular arteries*, from which the afferent vessels to the Malpighian tuft arise (fig. 79) ; the afferent vein from the glomerulus breaks up into a capillary network which ramifies on the urinary tubules in the cortex, and after an extended course joins the interlobular veins ; the efferent vessels of the lowermost glomeruli break up into capillaries, which pass straight down into the boundary layer, and surround the straight tubules : (2) branches downwards into the pyramids running between the bundles of collecting tubes, and termed the *vasa recta* or *arteriæ rectæ.*

The **Renal Veins.**—The *venæ interlobulares* correspond with the arteries and receive some veins termed *stellate* from beneath the capsule, and also the small veins which receive the blood from the minute plexus surrounding the convoluted tubes.

The *venæ rectæ* run along the pyramids accompanying the corresponding arteries.

The *venæ propriæ renales* pass along the columns of Bertini after having been joined by the venæ interlobulares and venæ rectæ.

Pelvis and Ureter.—The ureters convey the urine to the bladder, the upper dilated portion forming the pelvis. The pelvis is divided into two or three primary divisions, and these again divide into shorter ones termed *calices* or *infundibula*, which receive the papillæ or apices of the pyramids of Malpighi. The collecting tubes open at the papillæ and discharge their contents into the pelvis. The pelvis and ureters are lined by transitional epithelium.

Urine.

The urine is a clear yellow fluid of specific gravity 1020, of peculiar odour and acid reaction. It is constantly being secreted by the kidneys, and is collected in the bladder. On an average 52 oz. (1,500 c.c.) are passed per diem. The solids amount to about 4 per cent. The principal constituents are the following, with their amounts, in 24 hours :—

Urea	500 grs., or	33 grammes,	2·2 per cent.
Uric acid	7–8 ,,	·5 gramme,	·03 ,,
Kreatinin	14 ,,	·9 ,,	
Hippuric acid	6 ,,	·4 ,,	
Chlorides	105 ,,	·7 ,,	

Sulphates	
Phosphates	
Sodium	
Potassium	Smaller quantities.
Ammonia	
Earthy salts	
Pigment, &c.	

Urea.—Properties, tests, &c. (see p. 3).

Quantity of the Urine.—The average quantity of the urine amounts to about 50 oz., or 1,500 c.c. The amount varies at different ages and under different circumstances. In infants the amount passed is about 10 oz. in the 24 hours. In children generally the amount passed is less than in adults. The temperature and moisture of the surrounding atmosphere by its action on the skin greatly influences the secretion of urine. In a Turkish bath, or in summer, where the skin is acting freely, small quantities of concentrated urine are passed, while on the other hand exposure to a dry east wind causes the secretion of large quantities of pale limpid urine. The amount of fluid ingested, as well as an increased or decreased blood-pressure, influences the amount of the urine.

Colour of the Urine. — The colour varies according to the degree of concentration of the urine. The pale golden yellow colour is caused by the presence of a pigment, *urobilin*, derived from the hæmoglobin of the blood. In some conditions of anæmia the urine is pale though its solid contents may not be low. In children it is paler than in adults.

Specific Gravity.—The average specific gravity is 1,020, though it may vary from 1,002 to 1,040, according to the amount of fluid ingested as well as the amount of perspiration taking place. In infants the specific gravity is 1,003 to 1,006.

Acidity.—Normal urine is slightly acid, due to the presence of acid phosphates. This acidity is increased after muscular exercise and much animal food. After much vegetable food, or organic acids, as tartrates and citrates or alkalies, the urine becomes neutral or alkaline.

Sources of Urea.—The greater part of the effete nitrogen of the body passes out of the system in the form of urea, a much smaller quantity in the uric acid, kreatinin, hippuric acid, and other minor constituents. The stages by which the albumens and peptones are converted into urea are ill understood. It is not, indeed, certain whether the urea is simply excreted from the blood by the kidneys, or whether the epithelium of the convoluted tubes does not convert the kreatin present in the blood into urea, to be thrown off into the urine. The two most probable sources of urea are—

1. From kreatin.
2. From leucin and tyrosin.

1. Kreatin is found in the blood, and in most of the tissues of the body. Muscle contains from ·2 to ·4 per cent., while urea does not exist in muscle, and only to a very small extent in the various organs. It is possible that kreatin represents the waste product of the albumen of the tissues; that, in consequence of the changes necessitated by life, there is a constant formation of kreatin in all the tissues of the body, and that this kreatin passes into urea in the blood, the liver, or in the kidneys. The small increase of urea in the urine after active exertion would, on this view, represent an increased wear and tear, leading to an increased formation of kreatin and urea.

2. If the amount of nitrogenous food be increased in quantity, the amount of urea excreted in the urine is also increased. This would indicate that a certain part of the albumen of the food is split up into urea, &c., without its having taken part in the formation of any tissue. Leucin and tyrosin are found in the small intestine, and are formed when pancreatic juice acts upon albuminous foods. It is probable that the leucin and tyrosin enter the portal veins, and are converted into urea in the liver. This is rendered the more probable from the fact already mentioned, that in acute yellow atrophy of the liver, leucin and tyrosin replace urea in the urine.

Amount of Urea.—About 500 grains of urea escape through the kidneys during 24 hours; but this amount varies according to circumstances, the amount being increased after large quantities of animal food, slightly after exercise, and also during fevers. The urea is diminished after vegetable food or fasting, and in certain forms of kidney disease.

Uræmia.—In certain conditions of the body, such as Bright's disease, and in fevers, there is a greater accumulation of effete material in the body than can be carried off by the kidneys. Certain toxic effects, such as convulsions and coma, result. This is probably, though not certainly, due to the accumulation of kreatin in the blood.

Estimation of Urea.—There are two methods: (1) Liebig's; (2) Russell and West's.

1. Liebig's method depends upon the fact that urea forms an insoluble precipitate with mercuric nitrate. Before the estimation can be made, the sulphates and phosphates present are precipitated by baryta water, and the liquid filtered. A certain quantity of the filtrate is taken, and a solution of mercuric nitrate of known strength (10 c.c. = ·1 gramme of urea) is dropped into the urine with frequent agitation; a white precipitate falls. From time to time, as the mercuric solution is added, a drop of the liquid is tested on a white slab with a drop of solution of sodic carbonate; when all the urea is precipitated and free mercuric nitrate present in the solution, a yellow precipitate occurs with the sodic carbonate. The amount of mercuric solution added is read off, and the corresponding amount of urea estimated. If great accuracy is required, the amount of Cl present must be estimated, and an allowance made in estimating the urea, as no precipitate of urea occurs until all the chlorine present has combined with the mercury.

2. Russell and West's method depends upon the fact that urea is decomposed by hypobromous acid into CO_2, N, H_2O. The CO_2 is absorbed in passing through a solution of NaHO and the N measured in a graduated tube (see fig. 80). The amount of N

given off indicates the amount of urea present in the urine (see p. 5).

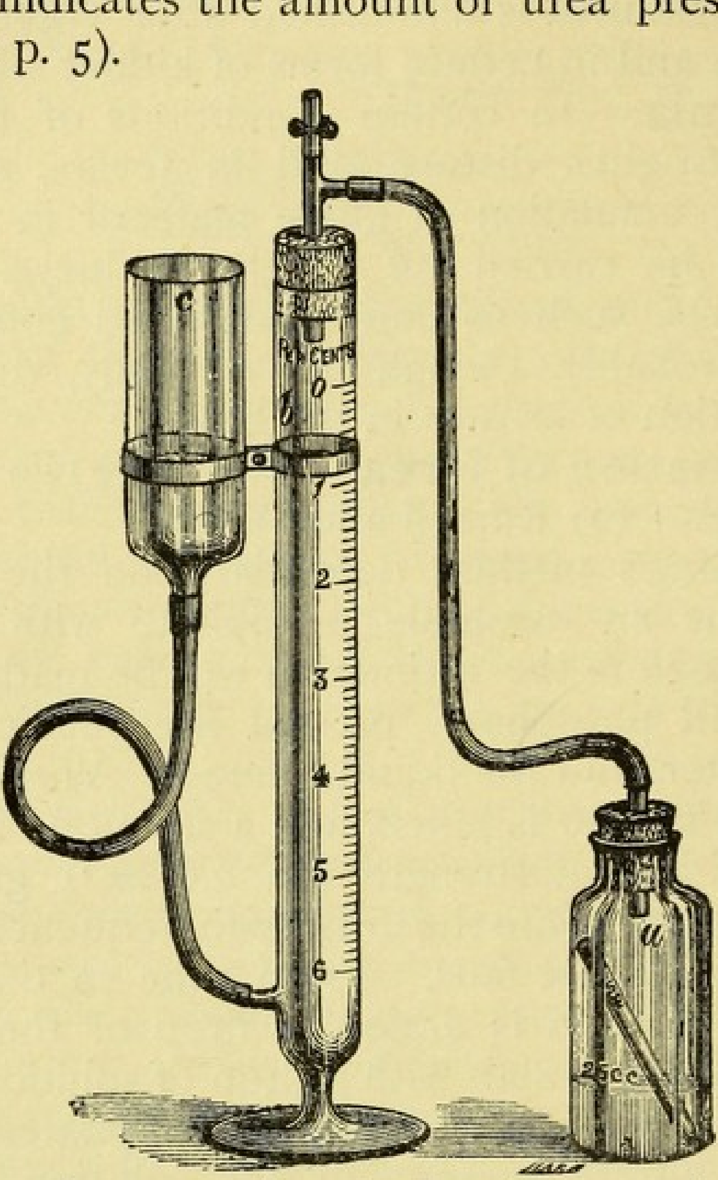

FIG. 80.—Gerrard's apparatus for estimating the amount of urea in urine. *a* is a wide-mouthed bottle connected to *b* by means of a flexible tube and T-shaped glass tube; *b* is a cylindrical vessel graduated so as to measure the amount of gas given off from *a*; *c* is a vessel connected to *b* by a flexible tube below, and arranged to slide up and down. To use the apparatus both *c* and *b* are nearly filled with water, and *c* is raised or lowered so that the water stands at a level marked 0 on *b*; 25 c.c. of a solution of hypobromite of soda is placed in the bottle *a*, and 5 c.c. of urine in a test-tube, the latter being placed without spilling by means of forceps in *a*, and the india-rubber stopper placed in the bottle. On shaking the latter so as to mix the urine and hypobromite solution, nitrogen gas is evolved, the carbonic acid being absorbed by the excess of soda present. The gas collects in the graduated cylinder, and the amount is indicated by the marks on the side. The reservoir *c* is lowered so that the water in both stands at the same height before being read off. The hypobromite solution is made by adding 25 c.c. of bromine to 250 c.c. of a 40 per cent. solution of NaHO.

Uric Acid.—Some 7 to 8 grains of uric acid are excreted daily in the urine, for the most part in the form of urates of potassium, sodium, or ammonium. The amount varies, being increased after animal diet, and in certain diseases, as gout. Its source is uncertain, being, like urea, a waste product formed from the breaking up of nitrogenous compounds. It is probable that in certain derangements of the liver uric acid is formed instead of urea. It represents a less oxidised form than urea (*see* p. 5).

Kreatinin.—Some 14 grains daily of kreatinin escape by the kidneys. Probably the greater portion of kreatin formed in the body has been converted into urea, a small amount being converted into the kreatinin which escapes with the urine (*see* p. 7).

Hippuric Acid.—Only about 6 grains of hippuric acid are secreted daily in man, though a very much larger amount is present in the urine of the herbivora (*see* p. 6).

Pigments.—The yellow colour of the urine is due to several pigments, *urobilin*, *urochrome*, *urorubin*, the nature of which is ill understood. *Indican* also occurs in the urine in variable quantities ; it is known by the presence of a blue colour due to the formation of indigo, when strong acids are added to the urine (*see* p. 8).

Inorganic Salts.—These are numerous, the most abundant being sodium chloride, smaller quantities of potassium, magnesium, calcium in the form of phosphates, sulphates, chlorides, and carbonates. The amount and variety of the salts in the urine differ according to the food taken, the alkalies being increased during a vegetable diet, the urine becoming alkaline, the earthy salts being increased when animal food is taken.

Secretion of Urine.

The Malpighian bodies, and that portion of the urinary tubules known as the convoluted tubes, are both engaged in the separation of the urine from the blood. The Malpighian bodies, as before explained, consist of a tuft of capillaries fitting inside a capsule communicating with the convoluted tubes, and are probably engaged in secreting the greater part of the water and inorganic salts of the urine, the process consisting in a simple transudation depending upon the pressure in the capillary tuft.

The convoluted tubes are lined by glandular epithelium, and are surrounded by a plexus of capillaries. The epithelium lining them appears to exercise a certain selective influence in secreting the urea and uric acid and pigment. These substances, having been separated from the blood and entered the urinary tubules, are washed down by the water and salines transuding through the capillary tufts into the capsule above.

Secretion of Urine by the Glomerulus.

The amount and character of the urine largely depend upon the blood-pressure in the glomeruli of the kidney. If the pressure be increased, larger quantities of water will be passed, and under certain circumstances, as in nephritis, albumen, blood, and fibrinous material.

The passage, however, of fluid from the capillary tuft is not a mere filtration, inasmuch as the urine must pass through the wall of the capillary and through the epithelium covering it. Injury to, or an alteration in the epithelium may possibly allow albumen or other constituents of the blood to pass.

The experiments of Roy have shown that the volume of the kidney readily undergoes change, the dilatation of the arteries causes increase, and the contraction of the arteries decrease, of volume. If this alteration in volume be registered by a suitable apparatus on a moving surface, a curve will be produced resembling the blood-pressure curve, both respiratory undulations and pulse being well marked. The arteries of the kidney are supplied with vaso-motor nerves, and thus the blood-supply to the kidney and the blood-pressure in the glomeruli are regulated.

As the amount of urine depends so largely on the blood-pressure in the glomeruli, it will be well to state concisely the conditions upon which this depends. According to Foster the blood-pressure in the glomeruli is increased—

1. By an increase of the general blood-pressure, brought about (*a*) by an increased force of the heart's beat; (*b*) by the constriction of the arteries supplying the skin or other part.

2. By a relaxation of the renal artery.

It may be diminished—

1. By a lowering of the general blood-pressure (*a*) by diminished force of the heart's beat; (*b*) by a dilatation of the arteries of the skin or other areas.

2. By a constriction of the renal artery.

Section of the *renal* nerves causes a dilatation of the renal arteries and a copious secretion of watery urine. Stimulation of the renal nerves has an opposite effect.

Section of the *splanchnic* nerves is followed by an increased flow. Stimulation arrests the flow.

Stimulation of a sensory nerve produces constriction of the renal vessels and diminished urine.

Section of the cord, below the medulla, leads to a general dilatation of the arteries of the body, lowers the general blood-pressure, and arrests the secretion of urine.

Stimulation of the cord produces a similar effect by constricting the renal arteries. The rise in general blood-pressure is not sufficient to overcome the resistance offered by the constricted renals.

Injection of urea into the blood causes first a constriction, and then a dilatation of the renal arteries, followed by an increased flow of urine.

Some diuretics, as sodium acetate, cause a dilatation of the vessels and an increased flow at once. These diuretics appear to act directly on the vessels, as they increase the urine after the nerves are divided.

Secretion by the Renal Epithelium.

Whilst the secretion of the watery and saline constituents of the urine takes place at the glomerulus, and is largely dependent upon blood-pressure, the urea, uric acid, and other substances present in the blood are apparently secreted or separated from the blood through the agency of the epithelium lining the convoluted tubes. Even after the medulla has been divided, and the urine, in consequence, has ceased to flow, the injection of urea, sodium acetate, and some other bodies, is followed by a free secretion of urine. So that it would appear that certain substances in the blood excite the renal epithelium to an unusual activity.

From these facts it appears probable that the secretion of urine takes place both through the medium of the glomerulus and through the capillary plexus, and the epithelium lining the convoluted tubes. The primary work carried on by the former is to discharge water from the blood, and flush, as it were, the convoluted tubes. The amount of urine secreted being dependent upon blood-pressure, the primary office of the epithelium lining the convoluted tubes is to select certain substances circulating in the blood, and secondarily a secretion of sufficient water to enable them to pass through the epithelium and tubes.

The pressure under which urine is secreted has been determined in the dog by placing a manometer in the ureter. It amounted to 60 mm. of mercury, the pressure in the aorta at the same time being 100 mm.

The Urinary Bladder.

The bladder has an average capacity of about 20 oz., but is capable of becoming distended to a much greater extent. It is situated in the pelvis, its base or fundus being seated on the rectum or vagina in the female. When completely distended its apex rises out of the pelvic cavity.

Structure of the Bladder.—The bladder is composed of a serous, muscular, submucous, and mucous coat.

The **serous** coat only partly invests it, covering the upper half or more of the posterior wall, and being reflected from the sides and apex to the surrounding parts.

The **muscular** consists of unstriated fibres arranged in three layers. The *external* or *longitudinal* is most distinctly marked on the anterior and posterior surfaces of the organ. This layer forms what is sometimes called the *detrusor urinæ* muscle. The *circular* or *middle* layer surrounds the bladder in a more or less oblique direction ; it is more circular in direction towards the base and around the neck ; it consists of a dense layer of fibres, which forms the *sphincter vesicæ.* The *internal* layer is thin and more or less longitudinal in direction.

The **submucous** coat is formed of connective tissue and blood-vessels.

The **mucous membrane** is pink and smooth ; it is thrown into wrinkles or rugæ, except at the trigone, where it is adherent to the muscular layer beneath.

It is lined by transitional epithelium (p. 21) resembling that of the ureters, and consisting of three layers, the most superficial being cubical; the second more or less pear-shaped, fitting into the layer above; the deepest more or less rounded or oval, sending processes into the mucous membrane beneath.

Micturition.

The urine trickles drop by drop down the ureters into the bladder, where it collects and gradually distends it. The exit from the bladder is opposed by the sphincter vesicæ, or, as some believe, by the elastic and muscular fibres of the urethra. The urine is expelled by the contraction of the walls of the bladder, more especially by the detrusor vesicæ, and is assisted when much distended by the contraction of the abdominal walls. Micturition is a reflex act, but one which (with the exception of infants) is under the influence, if not under the control, of the will.

The mechanism appears to consist of an automatic centre in the lumbar part of the cord, maintaining the constant contraction of the sphincter (fig. 81, MS), a second centre, which when stimulated excites contraction in the detrusor MD. These centres are antagonistic, so that an afferent impulse from the bladder *s* excites the detrusor centre, at the same time inhibiting the sphincter centre.

These centres are normally under the control of the will, so that although an afferent impulse may ascend from the bladder to the centres of the cord and up to the sensorium, yet by an effort of will the sphincter centre may be assisted and the detrusor inhibited, or *vice versâ*. Thus when the bladder becomes distended an afferent impulse from the bladder reaches both lumbar centre S and brain; if the opportunity is favourable for micturition the controlling influence of the will is removed, the reflex contraction of the detrusor taking place, assisted perhaps by the voluntary abdominal muscles.

In animals when the cord is divided, or in man injured above the lumbar centre, so that the controlling influence of the will is cut off, an involuntary emptying of the bladder takes place. In children, when sleeping heavily, or when the spinal centres are unduly irritable, a distended bladder or the irritation of worms in the bladder or rectum will cause incontinence of urine. In animals or man, when the lumbar centres are injured or destroyed, the urine may dribble away as it is formed, in consequence of relaxation of the sphincter. At other times urine accumulates, distends the bladder, and then escapes in drops, from failure of the detrusor to act.

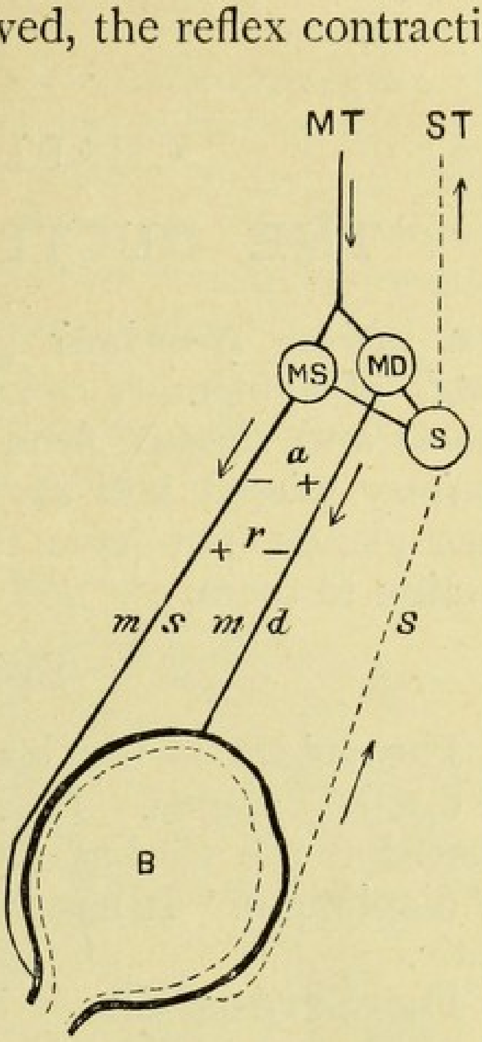

FIG. 81.—Diagram showing probable plan of the centre for micturition (after Gowers). MT, motor tract; ST, sensory tract in the spinal cord; MS, centre, and *ms*, motor nerve for sphincter; MD, centre, and *md*, motor nerve for detrusor; *s*, afferent nerve from mucous membrane to S, sensory portion of centre; B, bladder; at *r* the condition during rest is indicated, the sphincter centre in action, the detrusor centre not acting; at *a* the condition during action is indicated, the sphincter centre inhibited, the detrusor acting.

CHAPTER XVII.

THE DUCTLESS GLANDS.

THE *spleen*, *lymphatic* glands (including *lenticular glands* of alimentary canal and *tonsils*), *supra-renals*, *thymus* and *thyroid*, form the ductless glands. The *pituitary*, *pineal*, and *coccygeal* bodies are not in any sense glands, nor have they probably any analogous function to them.

Spleen.

The spleen is the largest and most important of the ductless glands. It is a soft, red, vascular organ, situated at the cardiac end of the stomach beneath the diaphragm. It has two coats, a serous and fibro-elastic.

The **Serous** closely invests its surface, except at the hilus and at the spot where it is reflected to the stomach and diaphragm.

The **Fibro-elastic** or **Tunica propria** is a strong capsule surrounding the organ, and, passing into its substance at the hilus, forms a sheath for the vessels and trabeculæ, which divide the gland into spaces occupied by the pulp. It consists of white and yellow fibrous tissue, and non-striated muscular fibre, the latter well marked in the pig and dog, but more scanty in man. The capsule is highly elastic, and capable of great distension.

The **Spleen Pulp** occupies the spaces between the trabeculæ, is of a dark-red colour and semi-solid consistence. The pulp, when examined in thin section beneath the microscope, is seen to consist of a network of branched connective tissue corpuscles (fig. 82, *p*)—

the supporting cells of the pulp—the branches joining one another, and forming a fine retiform tissue. Many of these connective tissue corpuscles contain a clear oval nucleus, and some contain yellowish pigment granules, possibly derived from the blood corpuscles. The spaces between these branched cells contain (1) red corpuscles, (2) white corpuscles of various sizes and more or less granular, (3) transitional forms between red and white corpuscles, (4) cells containing red corpuscles, (5) pigment granules.

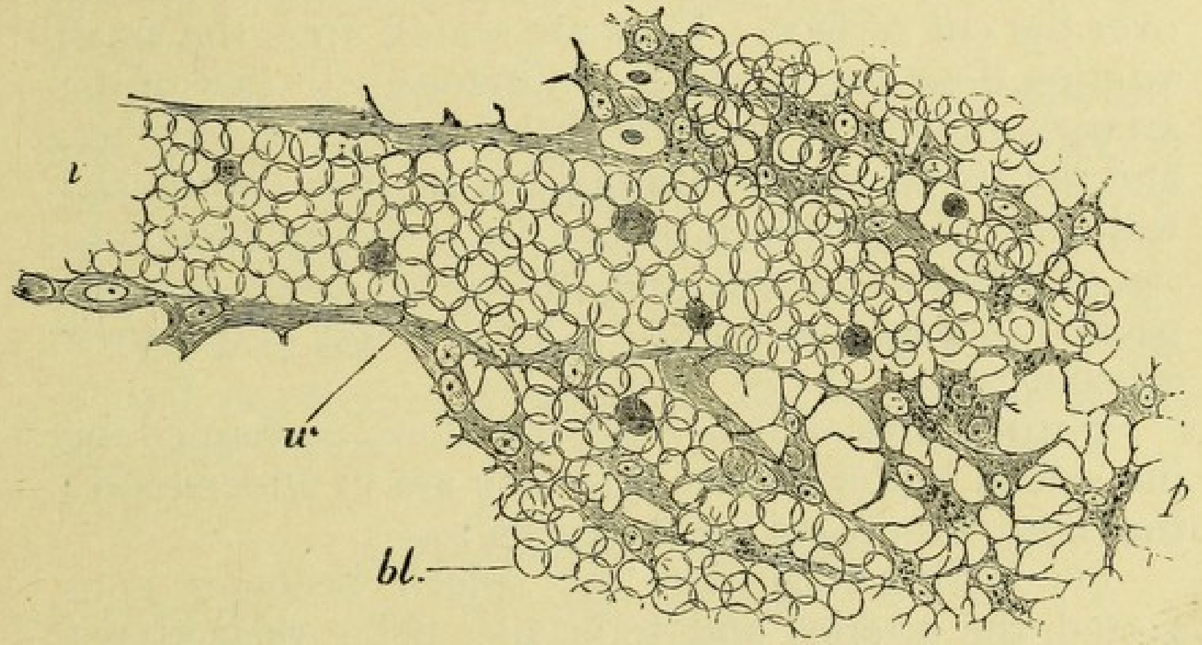

FIG. 82.—Thin section of spleen pulp, showing the origin of a small vein (Quain's Anatomy). *v*, vein filled with blood corpuscles, which are in continuity with others; *bl*, filling up the interstices of the retiform tissue of the pulp. At *p* the blood corpuscles have been omitted from the figure, and the branched cells are better seen; *w*, wall of the vein.

The **Splenic Artery** enters the spleen by dividing into six or more branches, which ramify in the interior, supported by the trabeculæ, and break up in the pulp into fine branches. The small arteries terminate in capillaries, the walls of which eventually are lost, their cells becoming gradually transformed into the connective tissue corpuscles of the pulp, and their contained blood wanders freely through the retiform tissue of the pulp. The minute veins arise in a manner similar to that in which the arteries terminate, and eventually empty themselves into the splenic vein. Thus the blood in its course through the spleen, after leaving the arteries, wanders freely through the pulp before entering the veins (fig. 82). The terminal arterial branches do not anastomose with one another.

The **Malpighian Corpuscles** are small bodies, about $\frac{1}{60}$ in. in diameter, and may readily be seen in the child's spleen as small white dots scattered thickly over the cut surface. They are seated upon the small arteries, their sheath being continuous with that of the arteries, though in man the sheath is not very distinct, and the tissue of the Malpighian body is continuous with that of the spleen pulp. In structure they consist of lymphoid tissue, the leucocytes being densely packed in a fine network. A small artery enters their substance.

Functions.—The exact functions performed by the spleen in the animal economy are ill understood; the most certain are the following:—

(1) During digestion the spleen becomes congested, the arteries and trabeculæ being relaxed, the elastic tissue yielding, and the organ containing more blood. This has been attributed, by some, to the necessity of having an excessive quantity of blood in the portal system during digestion, the spleen acting as a reservoir, but more probably it is connected with important changes going on in the spleen pulp. Rapid contraction of the spleen takes place when the vagus or splanchnics are stimulated; it also contracts on galvanising the medulla. Rhythmical contractions of the spleen have been noted in the cat and dog.

(2) The spleen is a source of white blood corpuscles to the blood, the splenic vein containing 1 white to 60 red, whereas in ordinary blood it is 1 to

400. The blood in passing through the pulp comes into close relation with the lymphoid tissue, and new corpuscles are formed.

(3) Red corpuscles are probably broken up and disintegrated in the spleen. The spleen pulp shows yellowish granular matter, which may be derived from the hæmoglobin of the red corpuscles. This colouring matter may be converted into pigment in the liver.

(4) The conversion of white corpuscles into red has been attributed to the spleen, but this is very uncertain.

(5) The spleen has been successfully removed from a dog, and no great change has been noted in the animal. In some cases the lymphatic glands have become enlarged after the removal of the spleen. The human spleen has been removed successfully.

(6) The spleen is apt to be enlarged in some morbid conditions, as anæmia, leucocythæmia, ague, and some fevers.

Lymphatic Glands

Have already been referred to (p. 112).

Supra-renals.

The supra-renals are two small bodies of a somewhat triangular shape which surmount the kidneys.

They are about 1½ in. in height and 1¼ in. in width. They weigh 1 to 2 drms. each.

Structure.—They are invested by a fibrous coat which surrounds each organ. On section they are seen to consist of a *cortical* portion, forming the greater part of the organ, of firm consistence and yellow colour, and a *medullary* portion, which is soft and pulpy, and of a brownish black colour.

The **Cortical portion** consists of a fibrous stroma, in the meshes of which are cells arranged in columns which radiate from the centre of the gland.

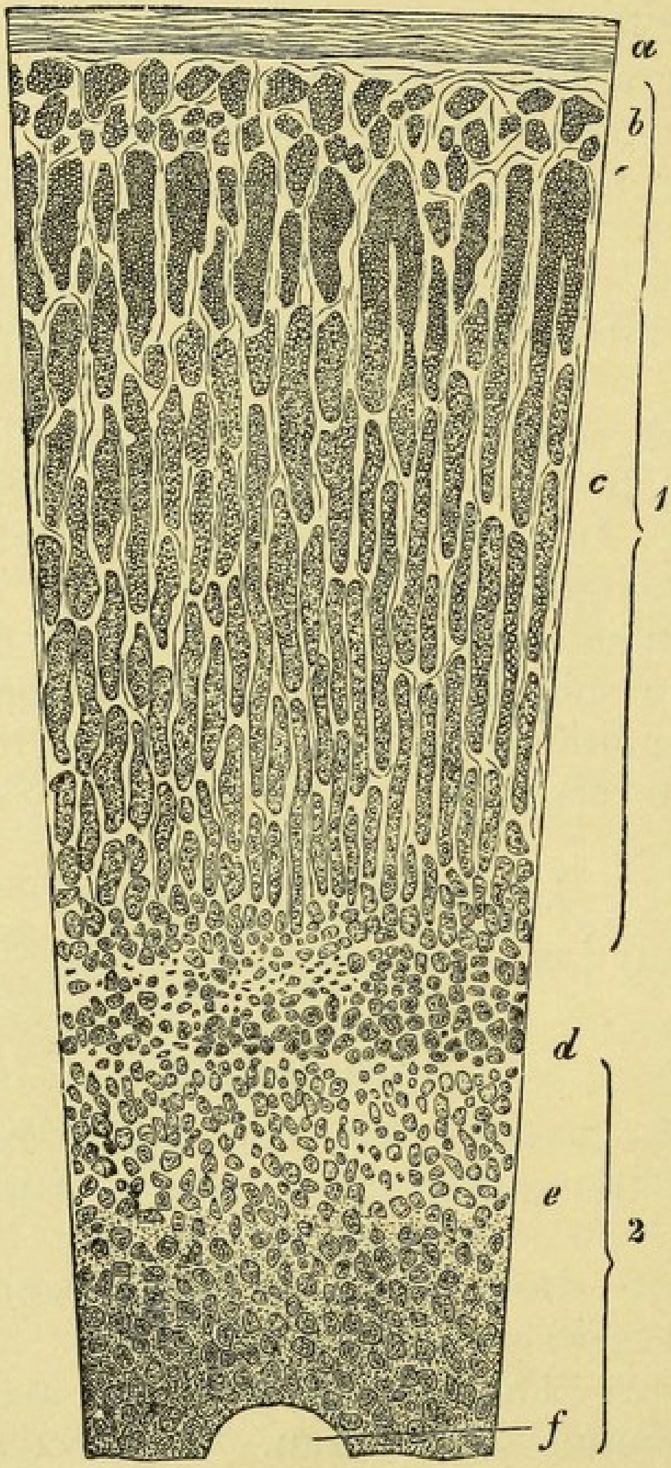

FIG. 83.—Vertical section of supra-renal body (Eberth). 1, cortical substance; 2, medullary substance. *a*, capsule; *b*, zona glomerulosa; *c*, zona fasciculata; *d*, zona reticularis; *e*, groups of medullary cells; *f*, section of a vein.

The cells are granular, yellow, and nucleated, and are about $\frac{1}{1500}$ in. in diameter, and contain minute oil-globules. Small arteries run between the columns.

The **Medullary part** is separated from the cortical by a layer of connective tissue, and is best marked in the supra-renals of young animals. It consists of a stroma, in the meshes of which are enclosed groups of cells which are coarsely granular, have no oil-globules, and some of them are branched.

Nerves.—Bundles of nerves run through the cortex, and form a network in the medullary part.

Function.—Nothing is known for certain regarding the function of these bodies. The most interesting point is their connection with Addison's disease, in which tuberculosis of the supra-renal capsules is accompanied by a bronzed tint on the skin, vomiting, and progressive emaciation. Some maintain that, like the spleen, they exercise some influence on the elaboration of nutritive material in the blood. Others believe them to be connected with the nervous system, and the cells of the medullary portion to be nerve-cells.

Thyroid Gland.

The thyroid gland consists of two lateral lobes situated on either side of the trachea and larynx, and joined by an isthmus which crosses in front of the trachea at the third and fourth rings. It is soft, of a reddish colour, and weighs from 1 to 2 oz., and is larger in the female than in the male.

Structure.—It is invested by a layer of fibrous tissue which connects it with the surrounding parts. It is composed of a number of closed vesicles, which are from $\frac{1}{800}$ in. in diameter to the size of a millet-seed. Each vesicle is surrounded by a plexus of capillaries, and lined by a single layer of epithelium.

They normally contain a clear yellow viscid fluid, and sometimes white corpuscles and degenerated red corpuscles. The organ is very vascular, receiving a large blood-supply (fig. 84).

Function.—But little is known concerning the function of the thyroid body. It has been supposed that, like the spleen, it pours white corpuscles into the blood. It is enlarged in certain diseases, as in *goître*, which is common in Derbyshire and the valleys of

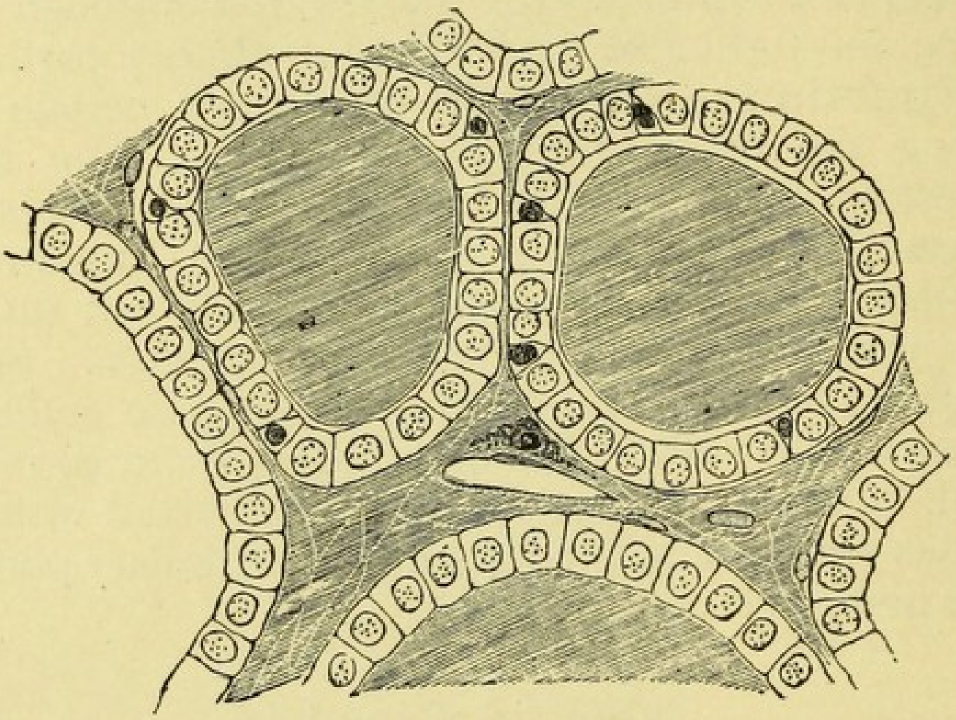

Fig. 84.—Section of the thyroid gland of a child (Quain's Anatomy). Two complete vesicles are seen. In the middle of one of the spaces a blood-vessel is seen. Between the epithelium there are small cells like lymph corpuscles.

Switzerland, and seems to be connected with the constant use of water impregnated with magnesian limestone; and in *exophthalmic goître*, a disease characterised by enlarged thyroid, prominence of the eyeballs, and irregular action of the heart. Horsley's experiment in removing the thyroid in monkeys and dogs produces tremors of the muscles; a diminution of the red blood corpuscles, so that profound anæmia results; the white blood corpuscles are increased in number ; the subcutaneous tissues and the salivary glands become distended with mucin. The symptoms produced resemble myxœdema as seen in the human subject.

Thymus Gland.

The thymus gland reaches its full development at the end of the second year of life, and then gradually dwindles away. When examined in an infant it is seen to be an elongated, soft, pinkish body lying behind the sternum, and in front of the pericardium and great vessels : it extends into the neck some distance, being covered in by the sterno-hyoid and thyroid muscles. It consists of a capsule of fibrous tissue, sending trabeculæ into the gland, dividing it into lobes and lobules. These lobules are again divided into *follicles.* These follicles are irregular in shape, and contain a central portion or medulla and an external cortical portion. The follicle consists of lymphoid tissue in some respects resembling a solitary gland ; in the cortex there is a retiform network, the meshes being filled with lymphoid cells. In the medulla the retiform tissue is coarser and the cells fewer, but it contains peculiar bodies, known as the *concentric corpuscles of Hassall.* The thymus is probably a lymph gland.

CHAPTER XVIII.

NERVOUS SYSTEM.

THE nervous system is divided into—

1. The Cerebro-spinal system.
2. The Sympathetic system.

1. The CEREBRO-SPINAL includes the brain, spinal cord, certain ganglia, motor and sensory nerves. The motor nerves are supplied to the striated or voluntary muscles ; the sensory are distributed to the organs of sense, skin, and other parts endowed with sensibility. The nerve-fibres are mostly of the medullated kind.

2. The SYMPATHETIC consists of a series of ganglia and nerves, which supply the involuntary muscular fibre of the uterus, stomach, intestines, ducts, and blood-vessels. The sympathetic system has a less symmetrical arrangement than the cerebro-spinal; the nerves are of a reddish colour, and are composed, for the most part, of non-medullated or grey fibres.

These two sections of the nervous system are intimately connected with each other—indeed, they can hardly be regarded as distinct systems ; the sympathetic may be regarded as that portion of the nervous system which supplies the internal organs and blood-vessels.

STRUCTURE OF THE NERVOUS MECHANISM :—

I. Purely conducting organs, nerves.
II. Terminal end organs.
III. Central organs, as brain, cord, ganglia.

I. Nerves.

The nerves consist of bundles of nerve-fibres bound together by a common tissue sheath. This

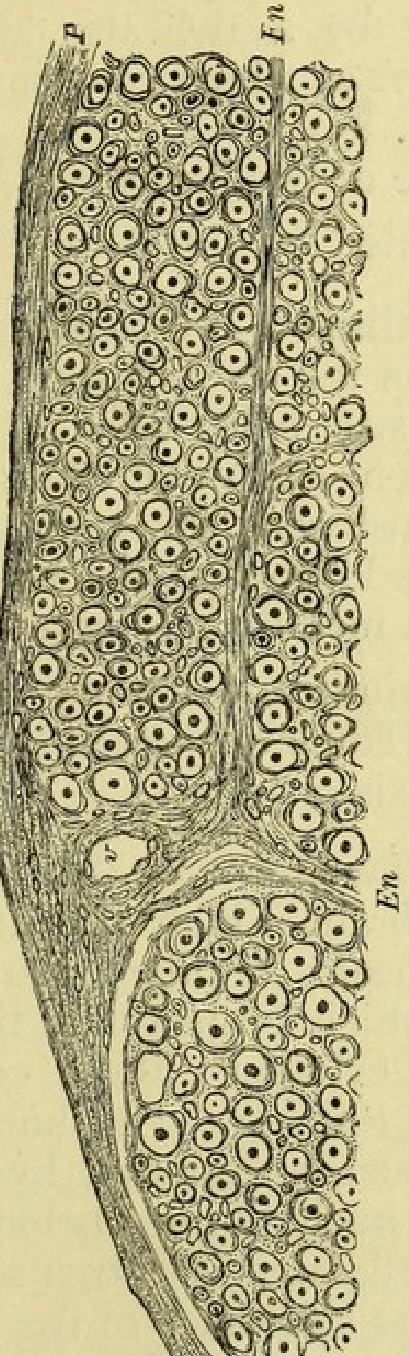

FIG. 85.—Part of a section of one of the nerve-bundles of the sciatic nerve of man (Quain's Anatomy). *P*, perineurium, consisting of a number of closely arranged lamellæ. *En*, processes from the perineurium passing into the interior, and becoming continuous with the endoneurium or delicate connective tissue between the fibres. The nerve-fibres are cut across, and are represented by a ring with a dot in the centre. The dot is the axis cylinder cut across; the ring is the cut section of the primitive nerve-sheath; the clear space between represents the medullary sheath.

sheath, which is called the *epineurium*, surrounds the whole nerve and binds its bundles or fasciculi together. It contains blood-vessels, lymphatics, connective tissue cells, and adipose tissue. Each nerve-ciculus bundle or ~~funicul~~us is surrounded by a special sheath of its own, termed the *perineurium* (fig. 85, P). Between the lamellæ of the perineurium there are distinct lymph spaces. The nerve-fibres are separated from one another by a delicate connective tissue called the *endoneurium*, which contains many connective tissue cells (fig. 85).

Nerve-fibres are of two kinds :—

(*a*) Medullated. (*b*) Non-medullated.

(*a*) The **Medullated Nerve-fibres** are present, for the most part, in the cerebro-spinal system. They vary very much in size, being from $\frac{1}{5000}$ to $\frac{1}{10000}$ in. in diameter. When examined shortly after death, they appear as translucent, glistening threads, with a dark border. On addition of various reagents, it can be made out that a medullated nerve consists of :

(1) Primitive nerve-sheath.
(2) Medullary sheath.
(3) Axis cylinder.

(1) The *primitive nerve-sheath* or *neurilemma* is a thin hyaline membrane which surrounds the nerve-tubule. In this sheath annular constrictions may be seen at intervals, which project into the nerve-tubule as far as the axis cylinder ; these constrictions are called the nodes of Ranvier. On the inner surface of the sheath are nuclei surrounded by finely granular protoplasm ; these nuclei do not belong to the neurilemma. The neurilemma is absent in the nerves which form the white substance of the brain and cord, optic and acoustic nerves. Many of such nerve-fibres are *varicose*, owing to small accumulations of fluid between the axis cylinder and medullary sheath.

(2) The *medullary sheath* or white substance of Schwann is semi-fluid during life but coagulates after

death. It consists of fatty matters, soluble in ether, which when squeezed out of the primitive sheath appear like bright drops with a dim contour. When the white substance has coagulated, the nerve, which immediately after death appears to have a single outline, becomes dark-bordered. According to Klebs, the axis cylinder and medullary sheath are separated by a narrow space, called the *periaxial space*, containing a cement substance. The medullary sheath is stained black by osmic acid. It is absent at the nodes of Ranvier (fig. 86).

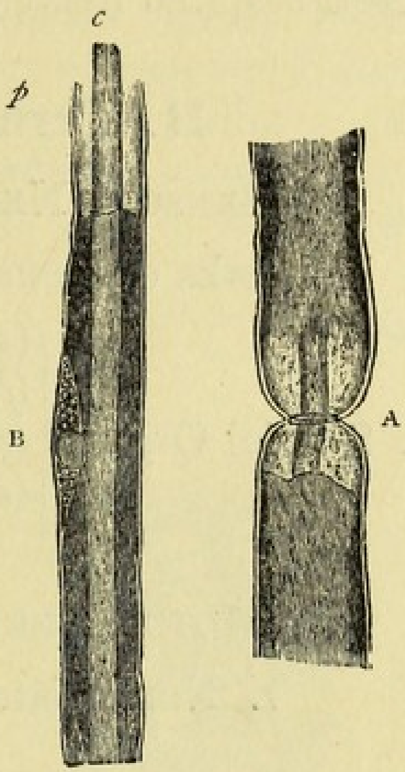

FIG. 86.—Two portions of medullated nerve-fibres, after treatment with osmic acid, showing the axis cylinder and the medullary and primitive sheaths (Quain's Anatomy). A, node of Ranvier; B, middle of internode with nucleus; *c*, axis cylinder, projecting at the broken end; *p*, primitive sheath within which the medullary sheath, which is stained dark by osmic acid, is somewhat retracted.

(3) The *Axis cylinder* is a narrow thread which runs through the centre of the nerve. It is albuminous in nature, is continuous with the poles of nerve-cells, and stains with carmine, logwood, chloride of gold, or, better than all, aniline blue-black. In places it can be seen to be distinctly fibrillated.

Medullated nerves when coming near their terminations lose their medullary sheath. Some medullated nerves, especially in the optic nerve, possess more or less regular varicose enlargements.

(*b*) **Non-medullated Nerves** consist of—

(1) Primitive nerve-sheath.
(2) Axis cylinder.

They closely resemble the medullated nerves, but the white substance of Schwann is wanting. They vary in size from $\frac{1}{3000}$ to $\frac{1}{6000}$ in. in diameter. They are present for the most part in the nerves of the sympathetic system, but they are also present in the cerebro-spinal nerves.

II. Terminal End Organs.

(A) Sensory Nerves end in—

1. Networks or plexuses.
2. Special Organs—
   - (*a*) Pacinian bodies.
   - (*b*) End-bulbs.
   - (*c*) Touch corpuscles.
   - (*d*) Rods and cones, taste-buds, &c. &c.

(B) Motor Nerves—

1. Non-striated. 2. Striated muscle.

1. **Sensory Networks or Plexuses.**—The nerve-bundles as they approach their terminations divide and re-divide till the branches consist of only one or two tubules. In the *skin* and *mucous membrane*, when the nerves are approaching the surface epithelium, they lose their medullary sheath, join together, and form the *subepithelial* plexus. From this plexus fine fibrils are given off, which, according to Klein, pierce the rete mucosum, and end beneath the cells of the horny layer, or, according to some, in the epithelial cells themselves.

In the *cornea* there are two terminal plexuses, superficial and deep. The superficial forms a subepithelial plexus, which gives off minute fibrils, which end in the interstitial substance *between* the epithelial cells on the surface. The deep plexus is situated in the substance of the cornea ; some of the fine fibrils are said to end in the corneal corpuscles.

2. **Special Organs**—(*a*) **Pacinian Bodies** are ovoid in shape, about $\frac{1}{10}$ to $\frac{1}{25}$ in. in diameter, and are found attached to the digital, plantar, pudic, infra-orbital nerves, and mesenteric nerves of cat. These bodies consist of a number of concentric membranes placed inside each other, enclosing a clear space in the centre, which contains the termination of a nerve. Each capsule consists of a hyaline membrane marked with fine transverse fibres, and lined on its inner surface by a layer of endothelial cells. There is no fluid between the layers, as sometimes described. The central clear mass contains a hyaline matrix and an axis cylinder, the sheath and white substance of Schwann being lost before the nerve enters the clear space. Besides the nerve a minute artery enters the Pacinian body, and distributes capillaries between the capsules.

Fig. 87.—Tactile corpuscle within a papilla of the skin of the hand, stained with chloride of gold (Quain's Anatomy). *Ep*, epidermis. The convolutions of the nerve-fibres within the corpuscle are well seen.

(*b*) **End Bulbs** exist in man in the conjunctiva, lips, mucous membrane of mouth, soft palate, genital organs. They are about $\frac{1}{600}$ in. in diameter, and consist of an ovoid corpuscle, in which a medullated nerve-fibre terminates. They are surrounded by a capsule continuous with the perineurium surrounding the nerve. The matrix is a granular mass containing oval nuclei. The nerve loses its medullary sheath and after branching ends in bud-like processes.

(*c*) **Touch Corpuscles** or **Tactile Corpuscles** occur in the papillæ of the corium of the volar side of the hands and feet in man (fig. 87). They are about $\frac{1}{300}$ in. long. They are connected with one or two medullated nerve-fibres. The nerve-fibre winds round the corpuscles several times, then loses its medullary sheath and penetrates into its substance where the axis cylinder divides, is more or less coiled, and ends in slight enlargements. (*d*) Other end organs, as the rods and cones, taste-buds, organ of Corti, will be described in connection with sight, taste, &c.

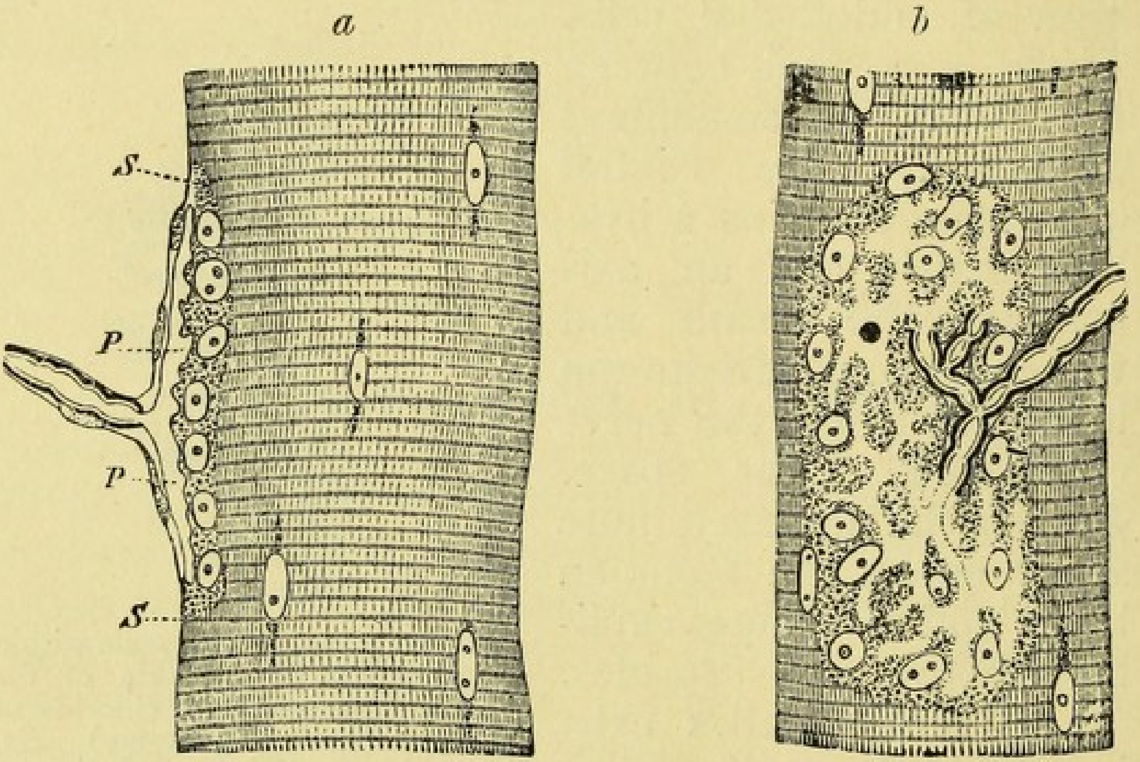

Fig. 88.—Nerve ending in muscular fibre of a lizard (Quain's Anatomy). In *a*, the end-plate is seen edgeways; *b*, from the surface; *s*, *s*, sarcolemma; *p*, *p*, expansion of axis cylinder. In *b* the expansion of the axis cylinder appears as a clear network.

(B) **Terminations in Muscles.**—1. Non-striated muscles are supplied with non-medullated nerves, which form plexuses; these plexuses give off the primitive fibrils which run in the interstitial substance between the cells; and, according to some, give off fine branchlets, which enter the nuclei of the cells themselves.

2. **Striated Muscle.**—Nerves surrounded by their perineurium run in the connective tissue forming the sheath of the muscle. Branches are given off which form a plexus, other branches containing two or three nerve tubules form an intermediate plexus for the supply of the smaller bundles of fibres. The nerve-tubules enter the muscular fibres, the primitive sheath becomes fused with the sarcolemma, while the axis cylinder loses its medullary sheath and passes through the sarcolemma ; the axis cylinder ends on the surface of the muscle substance, becoming imbedded in a flat granular mass, the *end-plate* of Kühne. The end-plates viewed in profile form Doyère's prominences (fig. 88).

III. Structure of the Central Organs.

The **Grey Matter** is present on the surface of the convolutions of the cerebrum, cerebellum, in the

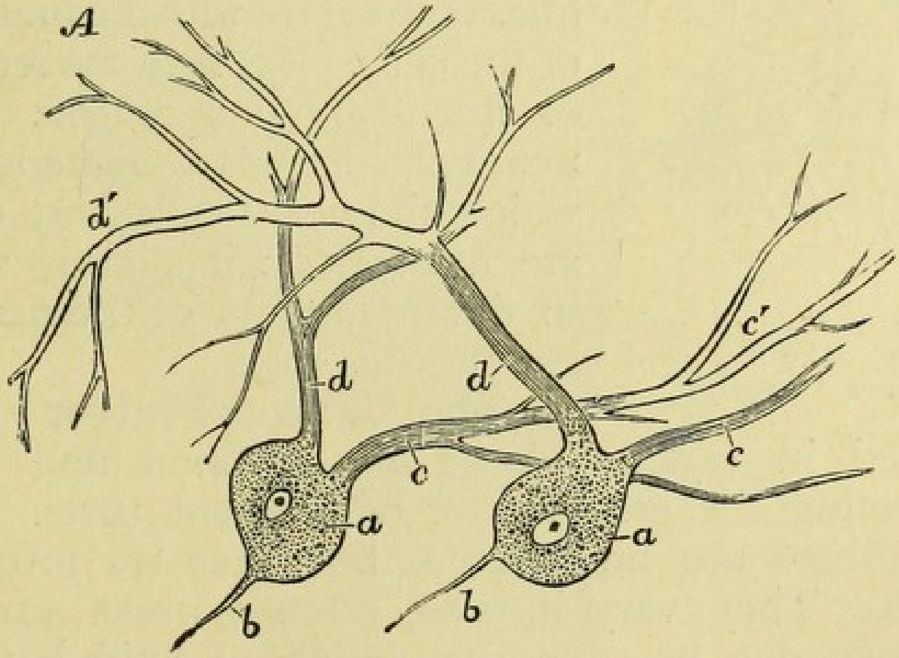

FIG. 89.—Two nerve-cells from the cortical grey matter of the cerebellum (Quain's Anatomy).

central parts of the spinal cord, corpora striata, optic thalamus, corpora quadrigemina, ganglia, &c.

It consists of: 1. Nerve-cells. 2. Nerve-tubules. 3. Pigment. 4. Blood-vessels. 5. Neuroglia.

White Substance consists of: 1. Nerve-tubules. 2. Blood-vessels. 3. Neuroglia.

1. **Nerve Cells** are small, rounded, or branched bodies, destitute of a cell wall, formed of finely granular protoplasm, in reality consisting of a fine network of fibrils. Each cell contains a nucleus, having a well-defined capsule, fine network, and a nucleolus. They sometimes contain pigment. The cells are surrounded by a perivascular space. In shape they are *apolar*, *unipolar*, *bipolar*, or *multipolar*, according to the number of processes they possess. Each process is continuous with the axis cylinder of a nerve (fig. 89).

Neuroglia.—This name is given to the framework of the grey and white matter of the cerebrum, cerebellum, and cord. It consists of—(1) Branching nucleated cells. (2) A fine network of fibrils connected with the branches of the cells. (3) A homogeneous or finely granular matrix. The neuroglia forms a material in which the nerve cells and fibres are imbedded; it slightly varies in different parts of the nervous system (fig. 90).

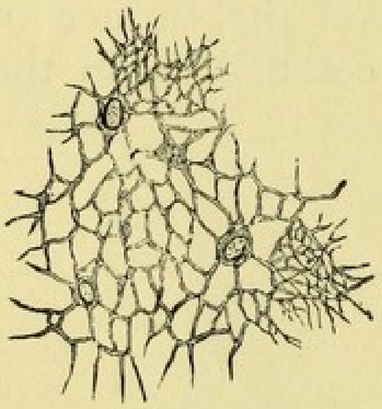

FIG. 90. Part of reticulum of spinal cord (Quain's Anatomy).

The **White Matter** is distributed in various places in the brain and cord, connecting the grey matter of different parts. The nerve-fibres are medullated, but have no primitive sheath. They vary in size, often possess varicose swellings, due to an accumulation of fluid between axis cylinder and medullary sheath.

GANGLIA.—These consist of rounded or elongated bodies found in various situations in connection with nerves. They are present in the following places:—

1. **Cerebro-spinal.** On the posterior roots of the spinal nerves; on the roots of the fifth (Gasserian),

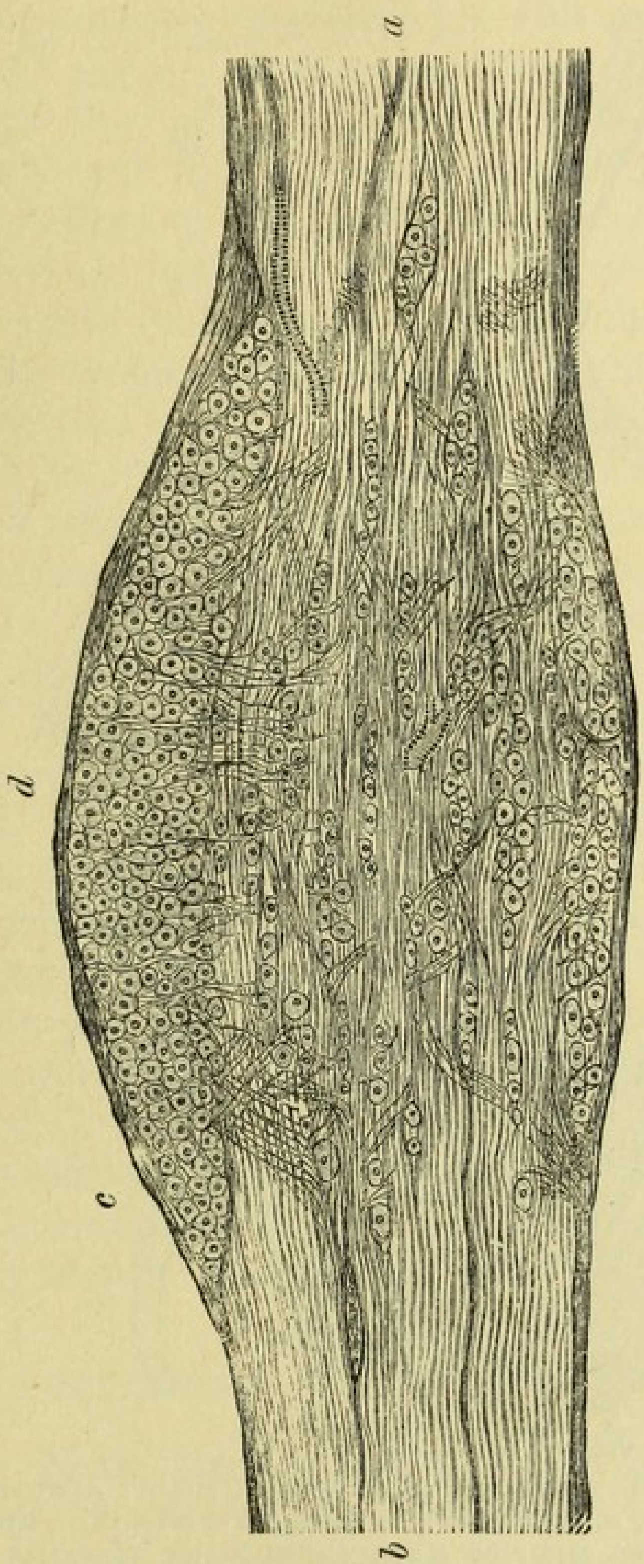

Fig. 91.—Longitudinal section through the middle of a ganglion on the posterior root of one of the sacral nerves of the dog (Quain's Anatomy). *a*, nerve-root entering the ganglion; *b*, fibres leaving the ganglion; *c*, connective-tissue coat; *d*, principal nerve-cells, with fibres passing from the cells to form a T-shaped junction.

facial, vagus, glosso-pharyngeal; in several other situations, as the ophthalmic, Meckel's, the otic, and submaxillary. These ganglia are surrounded by a fibrous sheath continuous with the nerve with which they are connected; from this sheath prolongations are sent

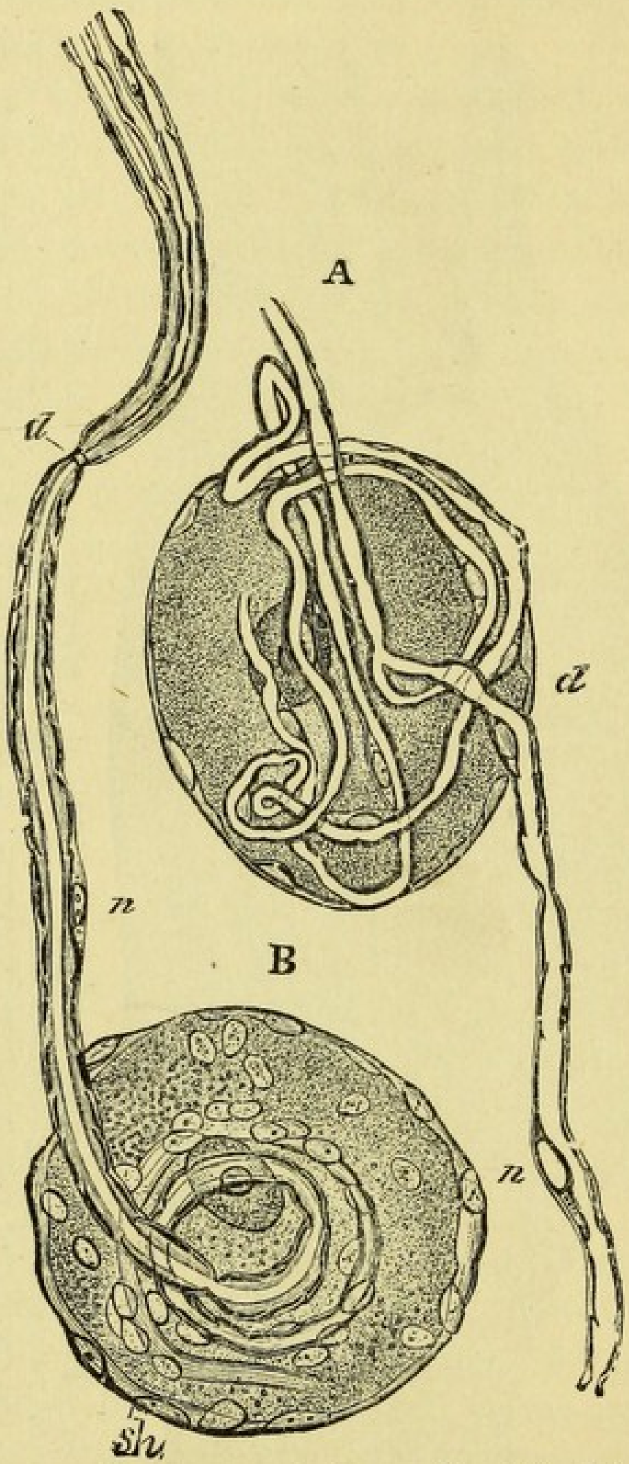

FIG. 92.—Two nerve-cells from a spinal ganglion (Quain's Anatomy). *sh*, nucleated sheath; *n*, *n*, nuclei of primitive nerve-sheath. From each cell a nerve-fibre arises, and after a convoluted course bifurcates opposite *d*, from which point they separate.

into the substance of the ganglion. On examining a section under a low power (fig. 91) the nerve-fibres will be seen entering the ganglion at *a*, and leaving at *b*, the principal mass of nerve-cells being present at the periphery, but they are also present in the more central parts. Some nerve-fibres apparently pass through the ganglion without being connected with any cell; all the cells are, however, connected with a nerve-fibre. The cells differ in size, are *unipolar*, rounded or pyriform in shape, are surrounded by a sheath, and have a large oval nucleus and nucleoli.

The single nerve-fibre with which they are connected (fig. 92) divides after leaving the cell, and passes in opposite directions. This bifurcation is often T-shaped. The nerve-cells are not all unipolar in the cerebro-spinal ganglia, for in the otic, spheno-palatine, submaxillary, and ophthalmic there are multipolar cells.

2. **Sympathetic.** There are numerous ganglia in connection with the sympathetic system, some of which, as the semilunar, are of considerable size; others, as those situated in the walls of the bladder or heart, are microscopic. The principal set are (*a*) forming a chain by the side of the vertebral column; (*b*) in numerous places in the walls of the heart, intestines, uterus, and in connection with the plexus.

In these ganglia the cells may be unipolar, bipolar, or multipolar. They are mostly oval or pyriform, with a sheath, nucleus, nucleoli.

PROPERTIES AND FUNCTIONS OF NERVES.

1. **Nutrition.**—Nervous matter receives a rich supply of blood; the network of capillaries in the grey matter is closer than in the white. The nerve-cells receive their nourishment from liq. sanguinis which has exuded from the vessels. Active nerve-cells absorb O and eliminate CO_2. Some nerve-

centres exercise an important influence over the nutrition of certain nerves; thus, if a motor nerve of the spinal cord is cut off from the grey matter in the anterior cornua, it undergoes fatty degeneration, and the muscle it supplies becomes atrophic. If a sensory nerve is divided, the part attached to the posterior ganglion remains normal; that part which has been separated from the ganglion degenerates.

When a nerve is cut in a mammal, the ends often reunite in a few weeks.

2. Nervous Excitability and Conductivity. Nerves, like muscles, are irritable or excitable. If one end of a nerve is irritated by the application of a

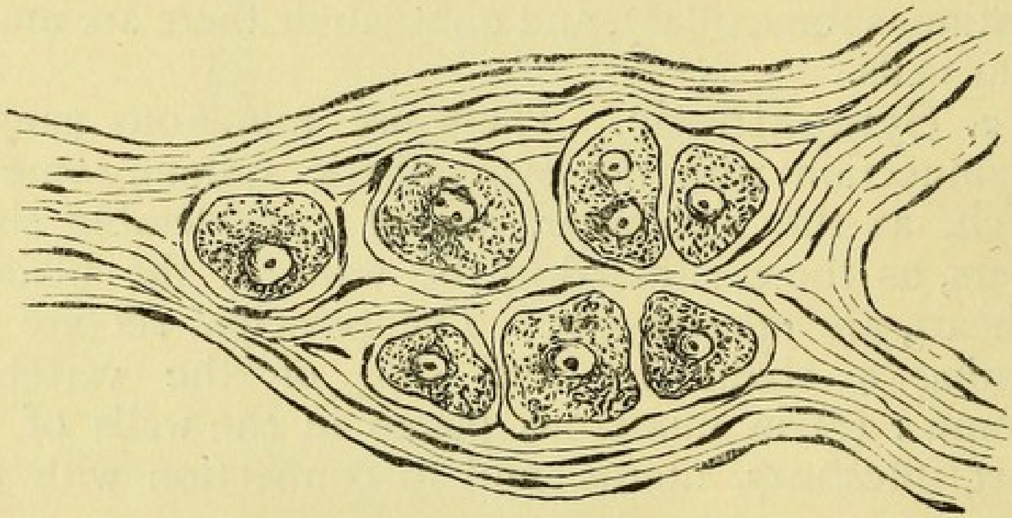

FIG. 93.—A group of ganglion cells interposed in a bundle of sympathetic nerve-fibres from the bladder of a rabbit (Klein).

stimulus, such as the application of heat, the electrodes of a battery, or by other means, the irritation or excitation is conveyed along the nerve to its farthest extremity. If the nerve is attached to muscular fibre, a *contraction* is produced; if the nerve ends in a sensory centre, a *sensation* is produced, or the secretion of a gland poured out if the nerve terminates there. The nerves receive impressions through the medium of certain terminal organs, as the touch corpuscles, rods and cones of retina, and convey the impression produced to a certain sensory centre, and a sensation is felt ; or they receive an impulse from certain motor centres, and convey the impulse to their terminations in the end plates of the muscles, and a muscular contraction ensues.

If the nerves are too frequently excited they become fatigued, and a certain amount of repose is necessary for them again to conduct impressions.

There are several methods of measuring the velocity of the nerve-current. The ordinary method in motor nerves of frog consists in applying the electrodes directly to the *muscle*, and measuring the time that elapses before the contraction, the contracting muscle recording its movements by means of a lever on a revolving drum (a chronograph marking time) ; then, if the electrodes be applied to the *nerve*, at some distance from the muscle, and the time again measured, it is evident that the difference between the two will be the time that the nerve-current took to travel through the nerve (fig. 30).

The velocity of the nerve-current has been calculated to be about 80 ft. per sec. in the frog, and 100 to 120 ft. per sec. in man, though some have placed it at 200. Sensory impressions in man have been measured in the following way :—Arrangements are made for a person to give a signal—the moment he feels a prick, say, on his great toe—and the time noted between the prick being administered and the signal given. Another experiment is made in the same way by pricking a point nearer the brain, say the knee, and the time measured. The difference between the two will be the time the impression takes to travel from toe to knee. It has been found that the velocity is about the same as in motor nerves—110 to 120 ft. per sec. This method is, however, open to many objections.

3. **Electrical Phenomena of Nerves.**—Elec-

trical currents are present in living nerves. If a piece of a nerve be cut out and placed upon the electrodes of a galvanometer, so that the surface of the nerve touches one electrode and the cut end the other, a current will be observed to pass from the surface through the galvanometer to the cut end. The nerve-currents exactly resemble the muscle-currents. When the nerve is excited there is a diminution or negative variation of the normal current.

Electrotonus.—If a constant current be passed along a nerve, the nerve is thrown into a peculiar state termed electrotonus. If the current travel in the direction of the natural nerve-current, the latter is increased; if in the contrary direction, it is diminished.

While a portion of nerve is traversed by the constant current, its properties are to some extent altered; the portion in the neighbourhood of the positive pole is said to be in an *anelectrotonic* state, while the portion of nerve in the neighbourhood of the negative is in a *cathelectrotonic* state. The position of the neutral point between the two varies with the strength of the current passing through the nerve. With a current of *medium* intensity, the neutral point is midway between the poles; with a *weak* current the neutral point is nearer to the positive than the negative; with a *strong* current the neutral point is nearer the negative than the positive. When a nerve is in the anelectrotonic state, its natural nerve-currents are increased, but its excitability and conductivity are diminished; when in the cathelectrotonic, its natural nerve-current is diminished, but its conductivity and excitability are increased.

Pflüger's Law of Contraction.—When a constant current of medium strength is passed along a motor nerve, no effect is produced upon the muscle, except on opening and closing the current. The contraction of the muscle is influenced (1) by the direction, (2) by the strength of the current—that is, the strength of the contraction on making and breaking contact varies not simply according to the strength of the current applied, but also to the direction, whether the current is passed downwards in a direction from the spinal cord to the muscle, or in an upward direction from the muscle to the cord. The following is a brief statement of the facts :—

Strength of Current	Descending		Ascending	
	Make	Break	Make	Break
Very weak	C	R	R	R
Weak	C	R	C	R
Medium	C	C	C	C
Strong	C	R	R	C

C—contraction. R—rest.

From this table it will be seen that, if either a weak or a strong current is passed along a motor in a downward direction, there will be a contraction at making only. With a strong ascending current there is a contraction on breaking only.

Functions and Classification of Nerves.

Nerves may be divided into :—

I. **Efferent** or **Centrifugal** nerves.
1. *Motor*, supplying the voluntary or involuntary muscles.
2. *Vaso-Motor*, supplying the muscular fibres of the blood-vessels.
3. *Secretory*, supplying glandular epithelium.
4. *Inhibitory*, which modify the action of nerve-centres.
5. *Trophic*, regulating the nutrition of a part.

II. **Afferent** or **Centripetal** nerves.	1. Nerves of common sensation, pain, touch, &c. 2. Nerves of special sense. 3. Nerves taking part in reflex actions, and which cause no sensation.
III. **Intercentral** nerves.	1. Connecting motor centres. 2. Connecting sensory centres.

1. **Motor Nerves.**—Each muscle in the body has its 'nerve-supply,' or its nerve which connects it with motor centres on the surface of the brain. Stimulation of the nerve evokes a muscular contraction.

2. **Vaso-Motor Nerves.**—These nerves are divided into vaso-constrictor and vaso-dilator or vaso-inhibitory. Stimulation of the cervical sympathetic produces contraction of the arteries supplied to the ear and face; stimulation of the splanchnic, contraction of the arteries of the kidneys—such nerves are vaso-constrictor. Stimulation of the chorda-tympani causes dilatation of the vessels supplied to the sub-maxillary gland; stimulation of the nerves supplied to the arteries of corpora cavernosa causes dilatation of the vessels and turgescence of the erectile tissue: such nerves are termed vaso-dilator or vaso-inhibitory.

3. **Secretory Nerves.**—The chorda-tympani is not only a vaso-inhibitory nerve, but also contains fibres which stimulate the glandular epithelium of the submaxillary gland. There are also nerves supplying the mammary and lachrymal glands, which, when stimulated, increase secretion.

4. **Inhibitory Nerves.**—Certain centres in the brain or medulla exercise a depressing or hindering

action on other centres. The nerves which connect these centres are called inhibitory nerves. The brain exercises an inhibiting or controlling influence over the centres for defæcation and micturition in the cord. The vagus is the inhibitory nerve supplying the heart, inasmuch as when stimulated the heart's action is slowed, and if the stimulus be sufficiently strong it stops in diastole.

5. **Trophic Nerves.** The nutrition of the body is dependent, to a certain extent, upon the nervous system. Thus in certain diseases of the spinal cord, bedsores very rapidly form over the sacrum. While the nervous system exercises an important influence over the nutrition of a part, it is doubtful if there are any nerves whose sole office consists in regulating the nutrition of a part.

Sensory Nerves.—Many divisions may be made in this group. Thus there are nerves which convey sensations of pain, touch, temperature, or of special sense. The nerves of common sensation connected with the spinal cord pass through the posterior roots, and have a ganglion situated in their course, just outside the cord. If sensory nerves are divided, a sensation of pain is experienced if the central end is irritated.

Eccentric Reference of Sensations.—The mind refers the origin of every sensation that reaches it through a sensory fibre to the end organ of that fibre, even though stimulation has been applied to the trunk of the nerve. Thus, persons whose arms or legs have been amputated often feel sensations which they refer to their fingers or toes. Any stimulation of the optic nerve, mechanical or electrical, the mind refers to the action of light upon the retina.

Functions of Terminal Organs.—Probably all nerves end at their peripheral distribution in some form of terminal organ. The optic nerves are connected with the rods and cones of the retina, and other sensory nerves are connected with taste-bulbs, olfactory corpuscles, tactile corpuscles, or epithelium. Motor nerves end in end-plates inside the sarcolemma. Light will not affect the optic nerves, except through the medium of the rods and cones ; sensations of touch will not be received at the brain if the skin is stripped off the fingers. The terminal organs seem to play the part of receivers of impressions, and awaken an excitation in the nerves connected with them.

Functions of Nerve Centres.

Groups of nerve-cells, which form the nerve-centres, are arranged in the body in two systems, the cerebro-spinal and the sympathetic system consisting of ganglia scattered through the body. The centres may be classified in various ways, according to their functions ; thus, on the surface of the brain there are *motor* or *discharging* centres, *centres of special sensations*, as of *sight*, *touch* ; in the medulla there are *inhibitory* and *accelerating centres*. They all, however, fall into two great divisions, though it is not always easy to say to which class they belong ; these are *automatic* centres and *reflex* centres.

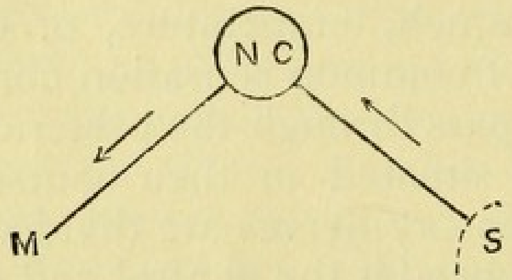

FIG. 94.—Diagram representing a simple reflex act. M, muscle ; NC, nerve-centre ; S, sensory surface.

Automatic Actions are actions which are evoked in the absence of any influence external to the nerve-centre. The brain is the seat of the higher automatic centres, those connected with volition and intelligence. In the medulla the respiratory centres, cardiac centres, vaso-motor centres, are in a certain sense automatic. So are also the intrinsic ganglia of the heart, and the small ganglia found in the walls of the intestines. At the same time it must be remembered that many of the centres enumerated above are influenced by sensory or afferent impulses, and are reflex as well as automatic ; indeed, some would deny them their automatism, and believe that no motor impulses can be generated in the absence of all eccentric influences.

Reflex Actions.—For reflex actions the following apparatus is required :—

(1.) A sensory surface in connection with an afferent nerve (fig. 94, S).

(2.) A nerve centre, NC.

(3.) An efferent nerve connected at its central end with the nerve-centre, and by its peripheral end with some muscle, or muscular tissue, or gland, M. The sentient surface or end organ being excited, the impulse travels along the afferent nerve to the centre, and is reflected from the centre along the efferent nerve to the muscle.

The stimulus may be of various kinds ; it may be a simple tickling of the skin, or a bright light, or a hair in the glottis. Some reflex actions are performed without one being conscious of them, as the contraction of the pupil or the changes in the calibre of the arteries. Others, as winking or swallowing, are attended with consciousness. Some reflex acts can be influenced or controlled by the will, as micturition or coughing ; others are entirely beyond the control of the will, as the second and third acts of swallowing. The excitability of the centres in the cord is increased by severance from the centres in the brain. Thus, reflex movements are more active during sleep, or in a decapitated frog, than in an uninjured one. Strychnine in toxic doses increases the irritability of the centres of the cord, while the bromides, chloral, and atropine diminish their excitability.

In some cases the reflex act seems to be adapted to a purpose, as in the efforts made by a decapitated frog to wipe away a drop of acetic acid placed on its back.

The following instances of reflex acts may be taken as examples :—

(1.) Contraction of iris : *aff. nerv.*, the optic ; *nerv. centr.*, the corpora quadrigemina ; *eff. nerv.*, third.

(2.) Winking : *aff. nerv.*, the fifth or optic ; *nerv. centr.*, the corpora quadrigemina ; *eff. nerv.*, seventh.

(3.) The first respiration after birth from impression of cold on the skin : *aff. nerv.*, the sensory of skin ; *nerv. centr.*, the medulla ; *eff. nerv.*, phrenics, intercostals, &c.

(4.) Vomiting from tickling fauces : *aff. nerv.*, the glossopharyngeal, fifth ; *nerv. centr.*, the medulla ; *eff. nervs.*, phrenics, nerves to abdominal muscles, vagi.

(5.) Sneezing from a draught of cold air : *aff. nerv.*, the nasal branches of fifth ; *nerv. centr.*, the medulla ; *eff. nerv.*, intercostals, nerves to abdominal muscles, phrenics, &c.

(6.) The secretion of saliva is a good example of a reflex act, in which a more complicated mechanism is brought into action, than in some of the examples given. In the secretion of saliva from the submaxillary salivary gland, the *afferent* nerves capable of stimulating the nerve-centre are as follows :—(1) The nerves of taste ; (2) the sensory branches of the fifth nerve supplied to the mucous membrane of the mouth ; (3) nerves of smell ; (4) optic nerves ; (5) gastric branches of the vagus. The *nerve-centre* for secretion of saliva is situated in the medulla. The *efferent* nerve is the chorda tympani, which contains two sets of fibres, vaso-dilato and secretory fibres ;

so that when this nerve is stimulated reflexly or directly, the artery supplying the gland dilates and the cells of the gland are stimulated to secrete (fig. 95).

Reflex actions are also seen in various forms of disease or abnormal conditions, such as vomiting

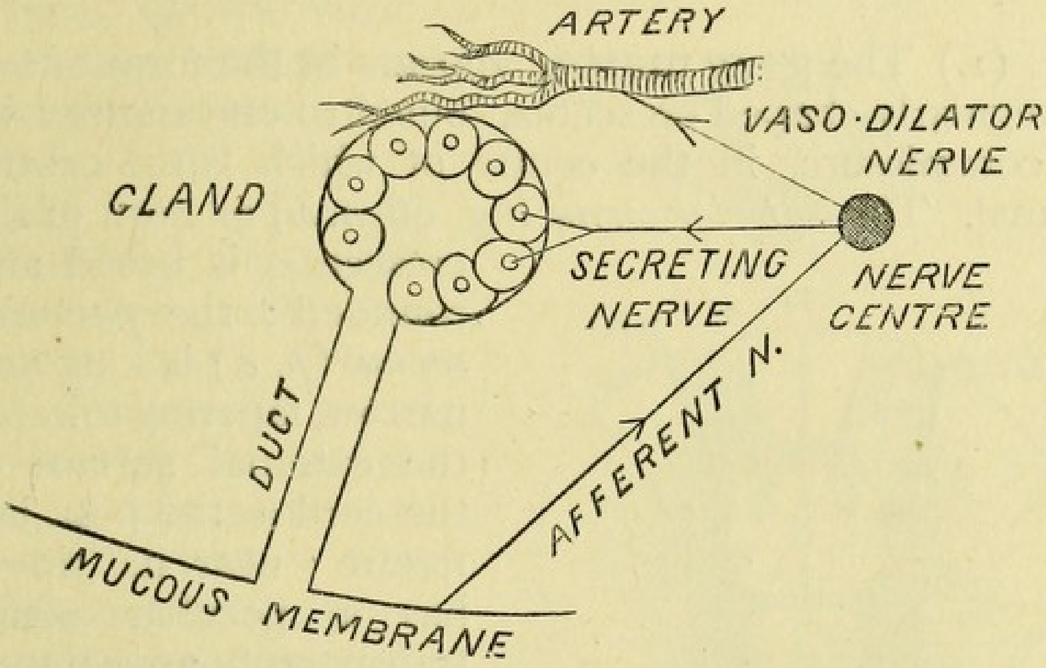

FIG. 95.—Diagram illustrating innervation of salivary glands.

from cerebral tumour, vomiting of pregnancy, grinding of teeth from irritation of worms, palpitation of heart, &c.

Time occupied in Reflex Acts.—The rapidity with which a reflex act is performed varies from ·05–·06 second. The stronger the stimulus applied the shorter will be the time.

Spinal Cord.

The spinal cord has its upper limit at the margin of the occipital foramen, and extends downwards to the lower border of the first lumbar vertebra. It is fifteen to eighteen inches in length, and presents two enlargements, the cervical and lumbar. It ends below in the cauda equina, which consists of a bundle of nervous cords.

Structure.—The cord consists of—

(1) The grey matter in the centre.
(2) The white substance externally.

(1.) The **grey matter** appears in the form of two irregularly-shaped crescents, joined to one another by a commissure, in the centre of which is the central canal. The *anterior cornu* (fig. 96, *a. c.*) or horn of the crescents, is broad and rounded; the *posterior cornu* (*p. c.*) is long and narrow, tapering towards the external surface of the cord at the post. lat. fissure; near its tip it has a peculiar semi-transparent appearance—the *substantia gelatinosa.* Near the outer surface of each crescent, the grey matter is less sharply marked off from the white than elsewhere, its prolongations forming a sort of network—the *processus reticularis* (*p. r.*). A somewhat pointed projection of the grey matter in the lateral region is called the *inter-medio-lateral tract* (*i*). The grey crescents vary in shape in different parts of the cord, being narrow in the dorsal; the ant. cornua are large and broad in the cervical and lumbar regions.

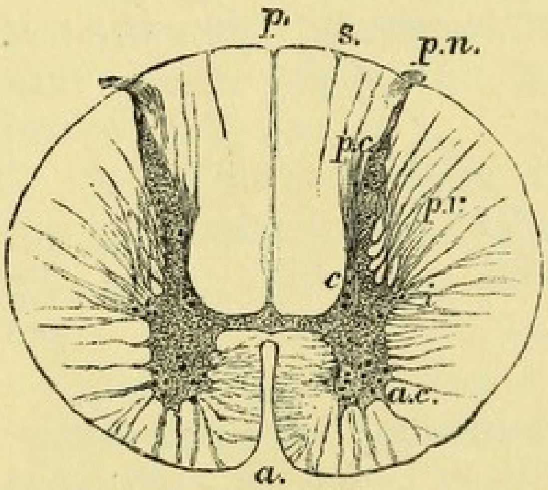

FIG. 96.—Section of spinal cord in upper dorsal region (Quain's Anatomy). *a*, anterior median fissure; *p*, posterior median fissure; *p. n.*, posterior nerve-roots; *a. c.*, anterior cornu of grey matter; *p. c.*, posterior cornu; *i*, inter-medio-lateral tract; *p. r.*, processus reticularis; *c*, posterior vesicular column of Clarke; *s*, boundary of the post. med. column.

The nerve cells of the grey matter are collected into three groups or rather columnar tracts. (1) *Vesicular column of the anterior cornu.* These, for the most part, are multipolar, and vary in size from $\frac{1}{400}$in. to $\frac{1}{200}$in. They are directly connected by their processes with the motor nerve fibres. (2) *Posterior vesicular column of Clarke* (fig. 96, *c*), largest in the dorsal region. (3) *Column of the inter-medio-lateral tract*, or *posterio-lateral group* (*i*).

(2.) The **white matter** is divided into two halves by the anterior median and posterior fissures. Each lateral half is again divided by two lateral fissures, which are merely grooves along the line of attachment of the anterior and posterior branches into an anterior, lateral, and

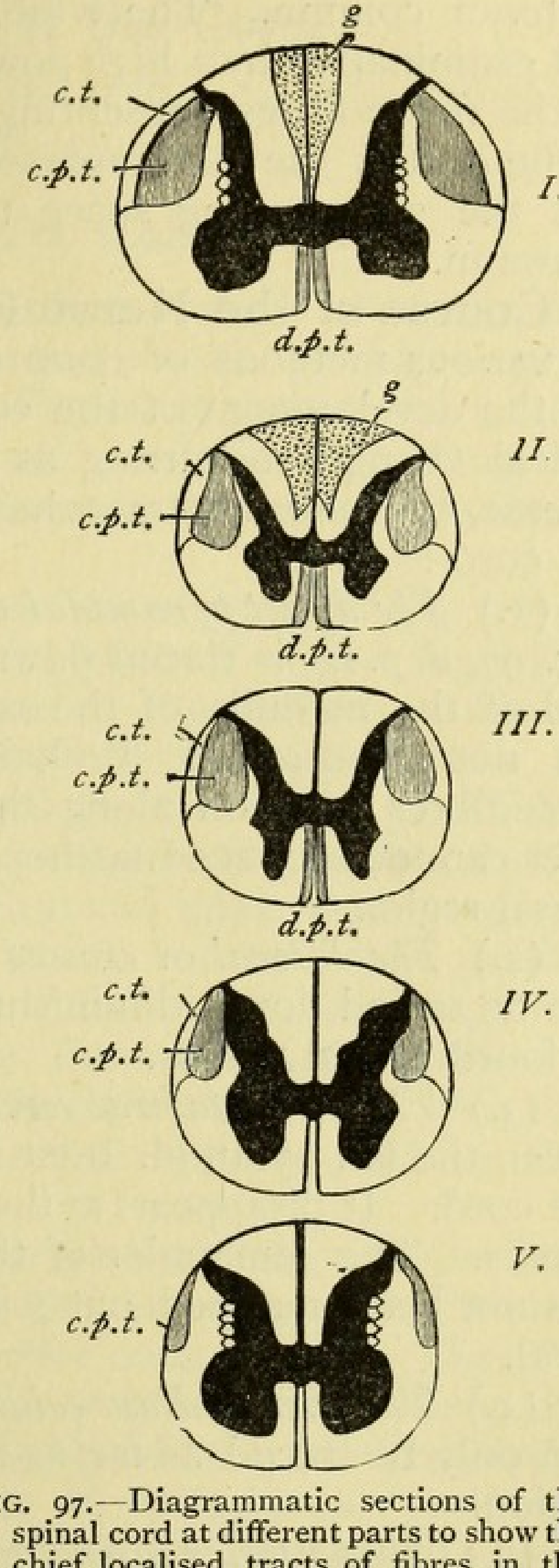

FIG. 97.—Diagrammatic sections of the spinal cord at different parts to show the chief localised tracts of fibres in the white substance (Quain's Anatomy). *I.*, at the level of the sixth cervical nerve; *II.*, of the third dorsal; *III.*, of the sixth dorsal; *IV.*, of the twelfth dorsal; *V.*, of the fourth lumbar. *d.p.t.*, direct pyramidal tract; *c.p.t.*, crossed or lateral tract; *c.t.*, direct cerebellar tract; *g*, post. median column.

posterior column. The white substance on section, and examination by a high power, displays the cut ends of the nerve-fibres, presenting small rings with a dot in the centre, the dot representing the axis cylinder, and the surrounding space the white substance of Schwann.

Course of the Nerve Fibres in the Cord.— By various methods of research, especially by studying the development of the cord, and certain pathological changes occurring as the result of injury or disease, the following tracts have been distinguished in the cord :—

(1.) *The direct pyramidal tract*, or *column of Türk* (fig. 97, *d. p. t.*), is traced down from the anterior pyramid of the medulla of the same side, and, therefore, has not decussated. Probably the decussation of these fibres goes on along their whole course. This tract cannot be traced farther than the middle of the dorsal region.

(2.) *The lateral* or *crossed pyramidal tract* (*c. p. t.*) can be traced down, diminishing as it goes, to the third or fourth sacral nerves.

(3.) *The direct lateral cerebellar tract* (*c. t.*) lies between the lat. pyramid. tract and the outer surface of the cord. It disappears at the second or third lumbar nerves. The remainder of the antero-lateral column has not been mapped out ; it is, probably, commissural.

(4.) *The post-median column*, or *tract of Goll* (*g*), can only be traced as far as the middle of the dorsal region.

(5.) The *posterior lateral column* is sometimes called *Burdach's column*, or *fasciculus cuneatus*.

(6.) The anterior division of the lateral column is called the *anterior radicular zone*.

Functions of the Cord.

(1.) As a conductor of impressions and impulses.
(2.) As a series of nerve-centres.

The Cord as a Conductor.

(1.) The spinal cord forms a channel of communication between the brain and nerves, passing to the periphery of the body. The exact path of the motor and sensory nerves is not satisfactorily settled, as there are discrepancies between the results obtained by different observers.

Motor Path.—Motor impulses travelling from the brain along the anterior pyramid of the medulla, for the most part decussate in the medulla, crossing to the crossed pyramidal tract of the opposite side. A minor portion travelling along the direct pyramidal tract (fig. 97, *d.p.t.*) decussates by crossing to the crossed pyramidal tract in the cervical and upper dorsal region. Decussation is therefore going on not only in the medulla but in the cervical and upper dorsal regions. The motor impulses pass from the lateral columns into the anterior cornua, become connected with the ganglionic cells there, and leave the cord by the *anterior* root.

Sensory Path.—The sensory path enters into the cord by the *posterior* roots, crossing at once to the opposite side by the posterior commissure. There is some uncertainty as to the route it takes along the cord to the brain. It is believed by some that tactile impressions pass upwards in the posterior columns (fig. 98), and that other sensory impressions pass upwards along the lateral columns in front of the crossed pyramidal tract. It is quite certain that the sensory path is a devious one, the nerve-fibres being connected with nerve-cells, and perhaps occupying different columns of the cord on their route.

If one lateral half of the spinal cord be divided there will be loss of motion on the *same* side, and loss of sensation on the *opposite*

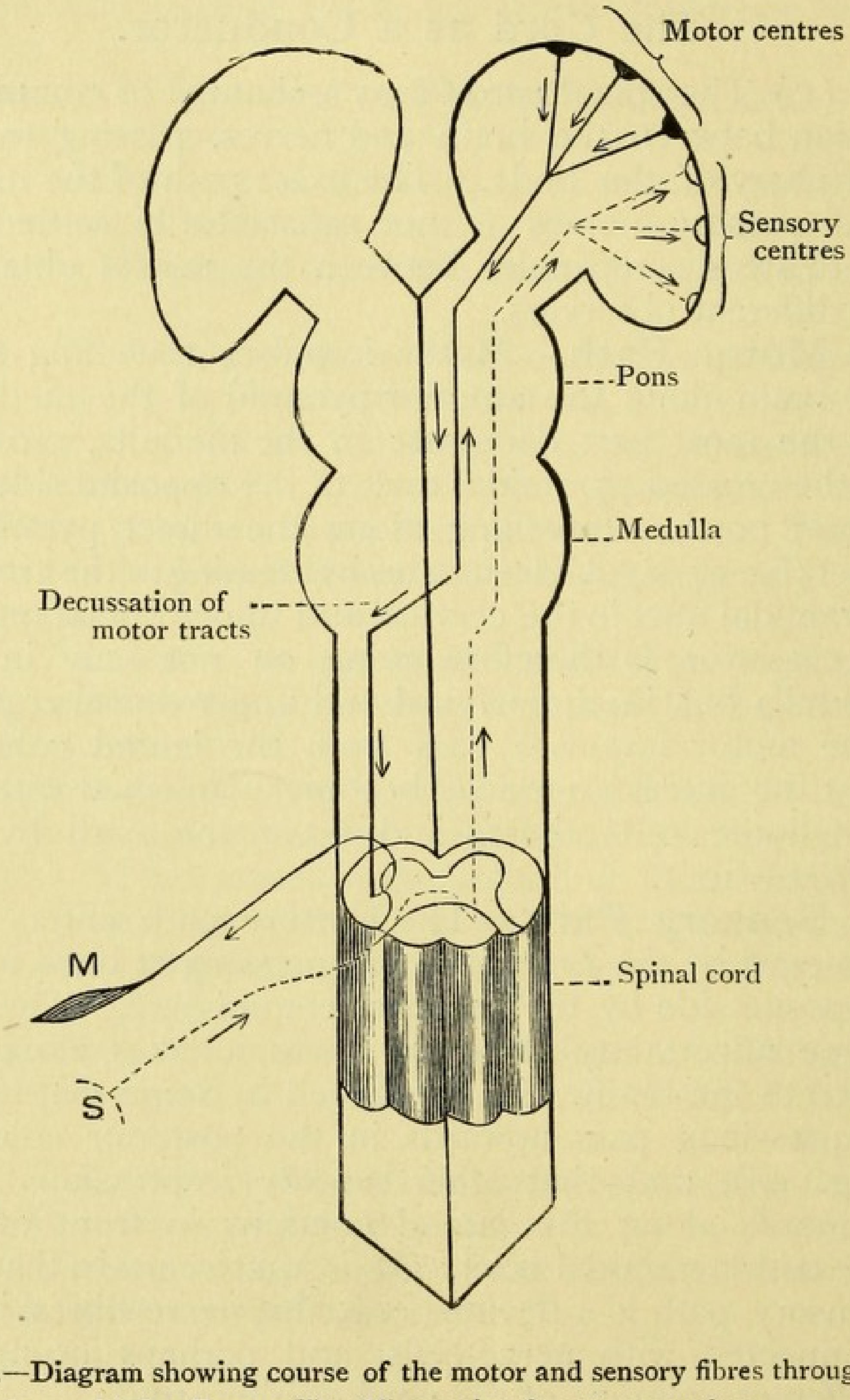

FIG. 98.—Diagram showing course of the motor and sensory fibres through the cord (after Bramwell). M, muscle; S, sensory surface.

Reflex Functions of the Spinal Cord.

(2.) **Frog.**—If the spinal cord of a frog be divided immediately below the occipital foramen, the frog will retain its usual sitting attitude, with the exception of sinking down into a somewhat less erect position, the fore limbs being more spread out. It will exhibit no respiratory movements. If one of the hind legs be pulled out straight and let go, it will be drawn up again to its normal position. If the skin of one flank be tickled, the muscle beneath will contract. Pinch the same spot, or apply a drop of acetic acid, and the leg of the same side will make a sweeping movement to clear away the source of irritation ; if the leg of the same side be held or cut off, the leg of the other side will repeat the movement. Place the frog on its back, it will make no effort to regain its position. The above actions of the brainless frog are complicated, co-ordinated, purposeful in character ; but, however stimulated, the animal never leaps.

In the Mammal.—For some days after the division of the cord in a dog, very feeble reactions are given by the nervous mechanism of the cord. After some weeks movements of a varied character are evoked by tickling or pinching the toes.

In man, when the cord is crushed from the effects of accident or disease, the legs will start up on tickling the soles or in passing water. In the normal condition it is generally possible to evoke reflex actions of the cord by gentle stimulation of the skin by a touch or light stroke. Tickling the soles of the feet, more particularly during sleep, will cause a slight withdrawing movement of the muscles of the foot, called the 'plantar reflex.' The centre for this movement is situated in the lower part of the lumbar enlargement. Irritation of the skin of the buttock will often produce a contraction of the glutei (gluteal reflex), the nerve-centre being situated at the origin of the 4th or 5th lumbar nerves. Irritation of the inner side of the thigh will cause a contraction of the cremaster (cremasteric reflex), drawing up the testicles, the centre being connected with the 1st and 2nd lumbar nerves. There is also an abdominal reflex and an epigastric reflex, which may be produced by stroking the side of the abdomen and side of the chest respectively. The 'patellar reflex' is obtained by allowing the knee to swing freely, and then sharply tapping the patellar tendon, the leg jerking forward; this movement is probably due to the stimulus reaching the muscle direct, the time occupied being too short for a reflex act, but it nevertheless depends upon the integrity of a nerve-centre situated in the upper part of the lumbar enlargement of the cord.

Inhibition of Reflex Actions.—The brain exercises a powerful influence in restraining or inhibiting reflex actions. A brainless frog exhibits reflex actions better than one with brain intact. If the experiment be tried of suspending a frog with cerebral hemispheres only removed, with its toes dipping in dilute acid, and the time which elapses before their withdrawal noticed, and the same experiment repeated, stimulating the optic lobes at the same time, the time elapsing before the withdrawal will be prolonged, showing the optic lobes have inhibited the reflex centres.

Man, by an effort of will, can prevent the withdrawal of his feet if the soles are tickled.

Special Centres in the Spinal Cord.

(1.) Centre for maintaining tonus of the muscles.
(2.) Centre for sphincter of bladder.
(3.) Centre for sphincter of rectum.
(4.) Centre for contractions of uterus.
(5.) Centre for erection of genital organs.
(6.) Cilio-spinal centre.

(1.) The muscles of the body are kept in a constant state of contraction or tonus ; this effect is due, probably, not to an automatic but to a reflex mechanism constantly in action.

(2.) (3.) The centres for micturition and defæcation appear to exist in the lumbar region of the spinal cord.

(4.) (5.) The centres that govern the movements of the uterus and erectile tissues are situated in the lumbar region of the cord.

The above centres are to be considered reflex rather than automatic.

The Medulla Oblongata.

The medulla is bounded above by the lower border of the pons Varolii, and is continuous below with the spinal cord at a level with the foramen magnum.

Structure.—The medulla is divided on the surface by fissures into short columns, which have received different names ; each lateral half having from before backwards :—

Anterior pyramid.
Olivary body.
Lateral tract.
Fasciculus cuneatus.
Posterior pyramid, or *fasciculus gracilis.*

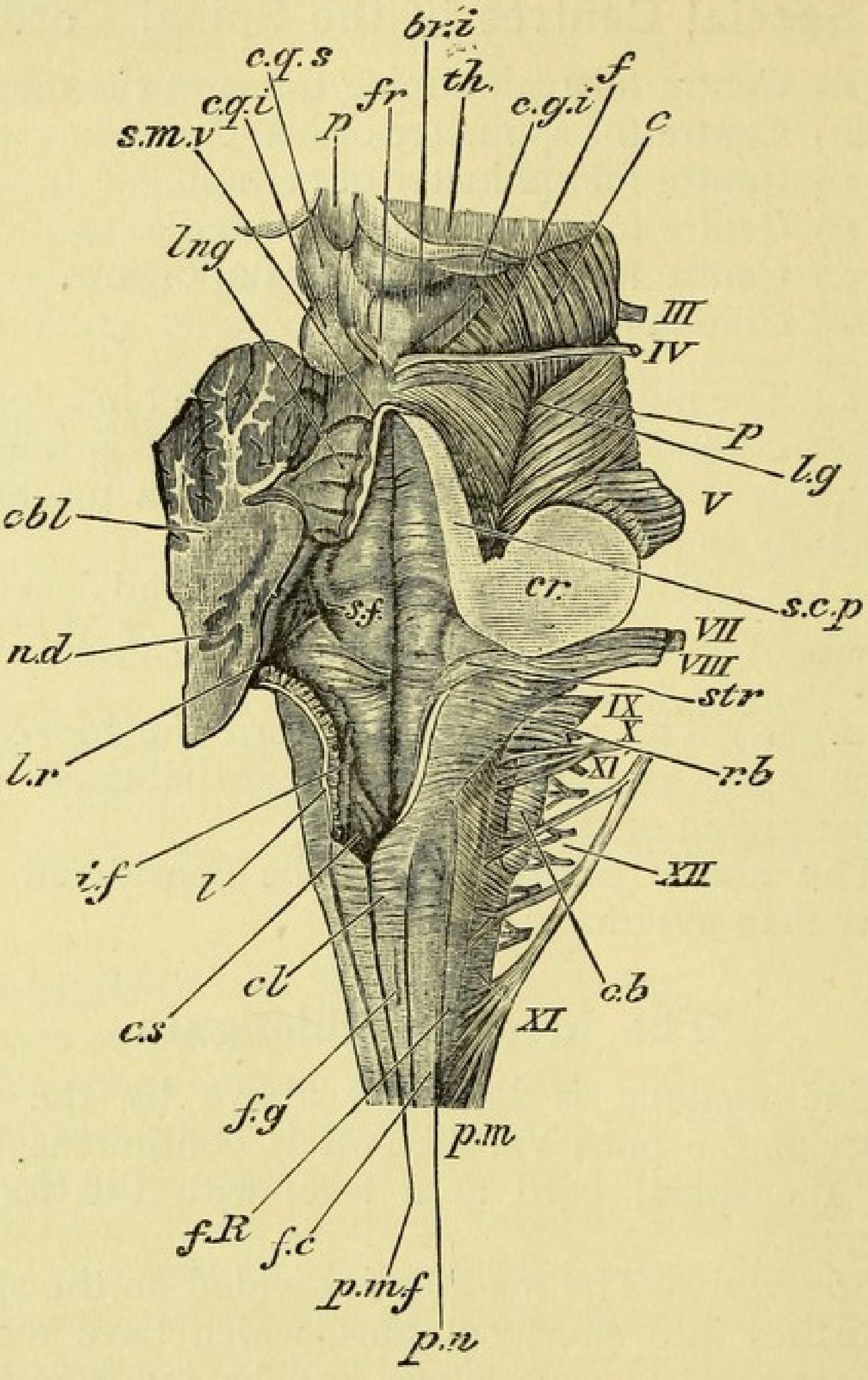

FIG. 99.—Posterior and lateral view of the medulla oblongata, fourth ventricle and mesencephalon (Quain's Anatomy). The cerebellum and part of the superior medullary velum have been cut away, and the fourth ventricle exposed. *p.m.f.*, posterior median fissure; *f.g.*, posterior pyramid or funiculus gracilis; *f.c.*, funiculus cuneatus: *r.b.*, restiform body; *c.b.l.*, cut surface of the cerebellum; *s.c.p.*, superior cerebellar peduncle; *c.q.s.* and *c.q.i.*, corpora quadrigemina. The fasciculi teretes are seen in the floor of the fourth ventricle. The roman numbers indicate the corresponding nerves.

White Matter of the Medulla.—The anatomical connections of the cord and medulla are very complicated. The following table shows the principal connections :—

Cord.	*Medulla.*	*Upward prolongation.*
Direct pyramidal tract (*motor*)	ant. pyramid same side	continuous with the crust
Lateral pyramidal tract (*motor*)	ant. pyramid opposite side	continuous with the crust
Antero-lateral column, exclusive of above (*sensory*)	longitudinal fibres of the formatio reticularis	pass upwards, and join the tegmentum
Direct cerebellar tract	restiform bodies	form the inferior peduncles of the cerebellum
Posterior internal column	posterior pyramid	join in grey matter of the medulla
Posterior external column	funiculus cuneatus	join in grey matter of the medulla

Grey Substance of the Medulla. — The medulla contains various nuclei ; two masses of grey matter which receive the posterior pyramids and funiculus cuneatus, called the nucleus gracilis and nucleus cuneatus. The lower part of the fourth ventricle contains the nuclei of the hypo-glossal, spinal accessory, vagus, glosso-pharyngeal, and auditory.

Functions of the Medulla.

(*a*) Conductor of impulses and impressions.
(*b*) As a collection of nerve-centres.

(*a*) The Medulla as a Conductor.

The **Motor** impulses travel through the anterior pyramids, decussating to the lateral column of the opposite side of the cord.

The **Sensory** path is not so well known, but not improbably it lies along the longitudinal fibres of the formatio reticularis.

(*b*) Nerve Centres in the Medulla.

(1.) Respiratory centres.
(2.) Vaso-motor centre.
(3.) Cardiac centres.
(4.) Centres for deglutition.
(5.) Centre for voice.
(6.) Centre for mastication.
(7.) Centre for expression.
(8.) Centre for salivary secretion.

(1.) The **Respiratory Centres** consist of an inspiratory and expiratory centre, and are both reflex and automatic. Ordinary respiration is a reflex act; a venous condition, *i.e.* a want of O in the blood circulating through the capillaries of the lungs, stimulates the terminal fibres of the vagus, the vagus transmits the impression to the medulla, it is reflected along the phrenics, intercostals, &c., to the muscles of inspiration, and a fresh supply of air is drawn into the lungs. The more venous the blood the more vigorously are the terminal fibres of the vagus excited, and the more muscles brought into play. If the vagi are divided the number of respirations sink to at least one-third, but they are still continued, and the animal does not die of asphyxia. It is probable that the venous blood supplied to the medullary centre itself excites it, or, like the intracardiac ganglia, it acts in an automatic manner.

(2.) The **Vaso-Motor Centre** is the centre of the sympathetic system supplied to the muscular fibre of the blood-vessels, intestines, ducts, &c. If stimulated, the vessels all over the body contract, and the arterial tension is raised; if paralysed or inhibited they dilate, and arterial tension is lowered. The vaso-motor centre keeps the blood-vessels of the body in a state of tonic contraction, it acts reflexly, and any influence which inhibits it will dilate the vessels.

(3.) **Cardiac Centres.**—The rhythmical contraction of the heart is caused by the action of its own intrinsic ganglia, but its action is regulated by ganglia situated in the medulla. There are two extracardiac ganglia, one *accelerating*, acting on the heart through the sympathetic, and the other *inhibitory*, associated with the vagus. (*See* page 93 and fig. 99*a*).

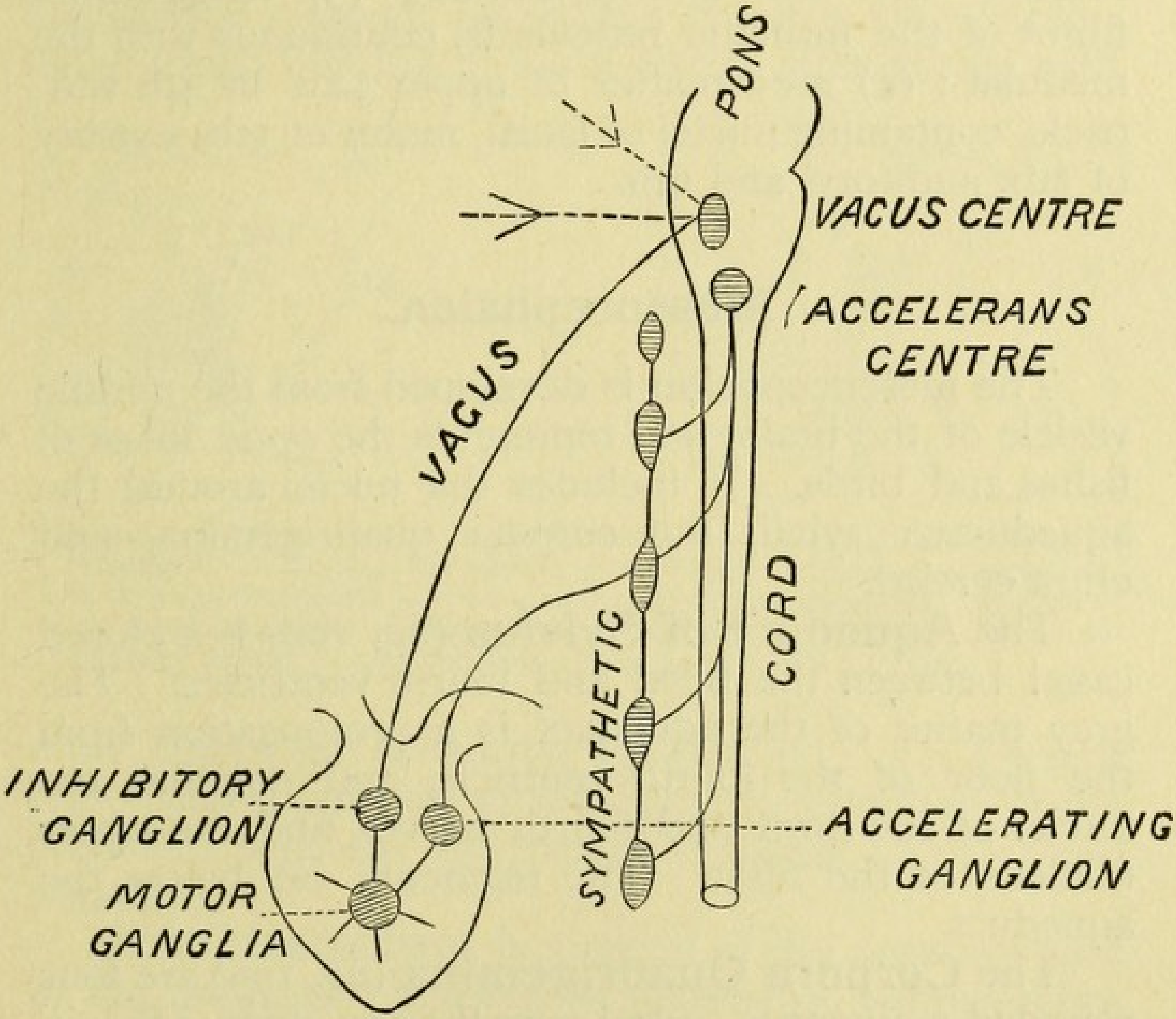

FIG. 99*a*.—Diagram illustrating cardiac nerve-centres in medulla, accelerating and inhibitory.

The presence of the above ganglia renders the medulla of vital importance to the living mammal. Death immediately results by destroying it. This can readily be accomplished by 'pithing,' *i.e.* by thrusting an awl-shaped instrument into the medulla, passing it between the occiput and atlas, and breaking up the nervous substance.

Pons Varolii.

The pons shows, on transverse section, (1) superficial and deep transverse fibres, derived from middle crura of cerebellum; (2) longitudinal fibres continuous with the ant. pyramids; (3) longitudinal fibres of the formatio reticularis, continuous with the medulla; (4) grey matter of upper part of 4th ventricle, containing nuclei of facial, motor of 5th, sensory of 5th, auditory, and 6th.

Mesencephalon.

The mesencephalon is developed from the middle vesicle of the brain, and represents the optic lobes of fishes and birds. It includes the nuclei around the aqueductus sylvii, the corpora quadrigemina, and crura cerebri.

The **Aqueduct of Sylvius** (fig. 100) is a closed canal between the third and fourth ventricles. The grey matter of the aqueduct is a prolongation from the floor of the fourth ventricle, and contains the nuclei of the third and fourth nerves, and the upper nucleus of the fifth. The tegmenta lie below the aqueduct.

The **Corpora Quadrigemina** (fig. 100) are four rounded eminences seated over the aqueductus Sylvii. Each of these bodies is covered with the layer of white matter; the lower or posterior pair contain a grey nucleus, and are separated by a band of white matter, the *fillet*, from the grey matter of the aqueduct. The superior pair have a layer of grey matter beneath the white layer on the surface, and underneath the former is a longitudinal tract of fibres—the *stratum opticum*.

The **Crura Cerebri** (fig. 100) lie beneath the corpora quadrigemina, and consist of (1) an inferior or anterior layer of longitudinal fibres called the *crusta* (*cr.*), and is a direct prolongation upwards of the pyramid bundles of the pons, and passes upwards to the internal capsule; (2) the *substantia nigra* consists of a centre nucleus of grey matter, the cells containing pigment (*sn*); (3) superior or posterior longitudinal bundles of nerve-fibres, interspersed with

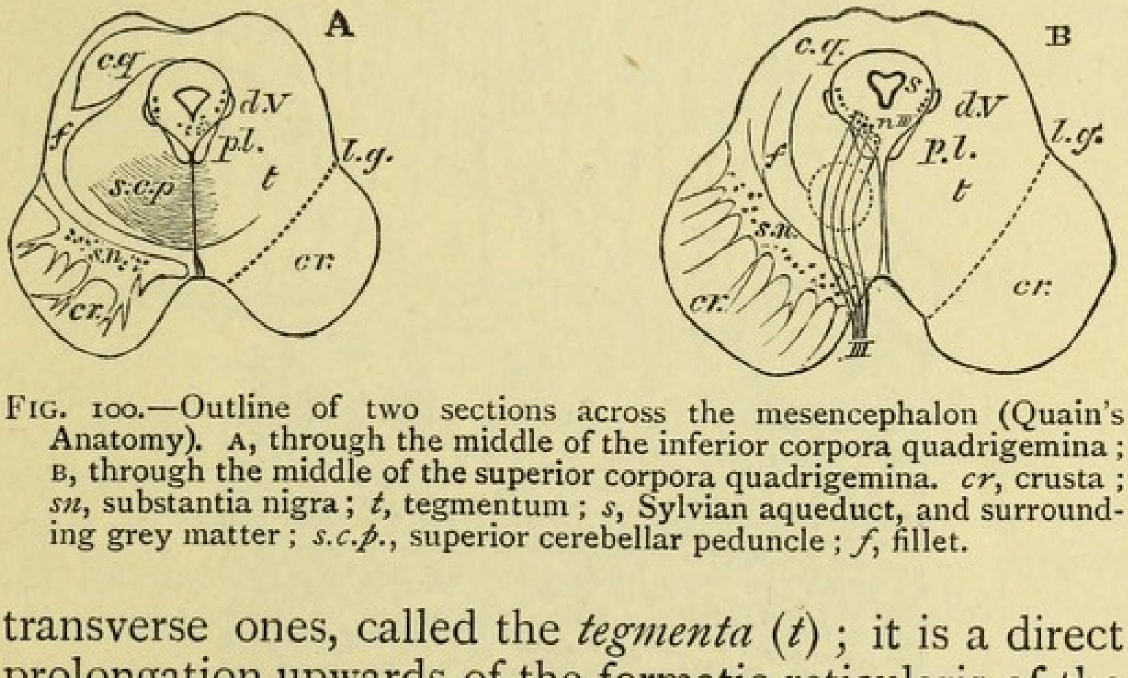

FIG. 100.—Outline of two sections across the mesencephalon (Quain's Anatomy). A, through the middle of the inferior corpora quadrigemina; B, through the middle of the superior corpora quadrigemina. *cr*, crusta; *sn*, substantia nigra; *t*, tegmentum; *s*, Sylvian aqueduct, and surrounding grey matter; *s.c.p.*, superior cerebellar peduncle; *f*, fillet.

transverse ones, called the *tegmenta* (*t*); it is a direct prolongation upwards of the formatio reticularis of the pons and medulla, and passes upwards to the optic thalamus.

The **Cerebellum** is situated at the posterior part of the brain, and consists of peduncles, various lobes and processes. The peduncles are three in number, the superior, middle, and inferior; they serve to connect the cerebellum with the cerebrum, pons, and medulla respectively.

The cortical portion consists of grey matter, and the central portion of white substance, with a nucleus of grey, the *corpus dentatum*.

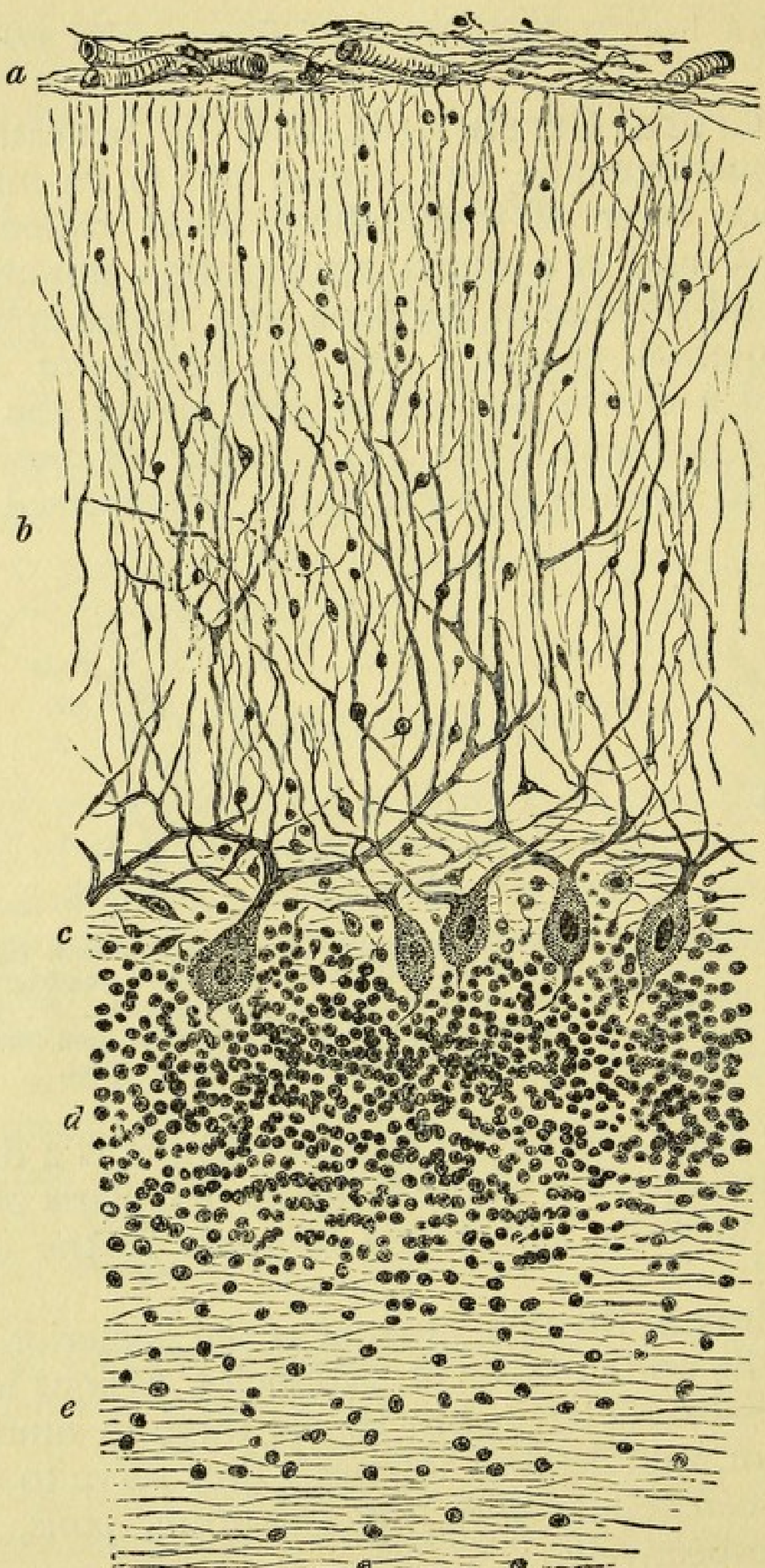

FIG 101.—Structure of cortex of cerebellum (Quain's Anatomy). *a*, pia mater ; *b*, external layer ; *c*, layer of corpuscles of Purkinje ; *d*, inner or granule layer ; *e*, medullary centre.

The cortical substance has three layers (fig. 101)—

(1.) *External.*—Consists of small cells sparingly distributed, some rounded, others irregular in shape, with various processes; fibres which are for the most part processes of the large cells of the middle layer and run at right angles to the surface (*b*).

(2.) *Middle.*—Consists of cells of Purkinje arranged in a single layer. They are pyriform in shape, nucleated, and have long processes running into the external layer, and are $\frac{1}{800}$th to $\frac{1}{1000}$th inch in diameter (*c*).

(3.) *Inner* or *granule* layer.—Consists of small round granular corpuscles, about the size of white blood corpuscles, arranged in dense masses, which in stained specimens form a well-marked coloured layer (*d*).

Phenomena Exhibited after Removal of Cerebral Hemispheres.

Frog.—After the removal of the cerebral hemispheres, the animal maintains its normal attitude. If laid on its back, it will turn over and regain its feet. If its foot is pinched, it will hop away. If thrown into water, it will swim, reach the edge, clamber up, and sit perfectly still. If its back is stroked it will croak. If placed in water and the temperature raised, it will make efforts to escape. If it jump away after a stimulus has been applied, it will avoid any object in its path. It will never move without some stimulus being applied. All spontaneous action has departed. It will not feed itself, but will sit still till it decomposes (fig. 101*a*).

Fish exhibit similar phenomena: they swim about in the water; the movements are not voluntary, but result from the stimulus of the water in contact with the body.

Pigeon with cerebral hemispheres removed sits on its perch and balances itself perfectly. When thrown in the air it flies, when pinched it moves forward. If not meddled with it appears to be in a profound sleep, though occasionally it will dress its feathers or yawn. Its pupils contract normally. It resists any efforts made to open its beak, but swallows when food is placed in its mouth. It makes no spontaneous movements ; the yawning and dressing itself are probably the result of the irritation of the wound.

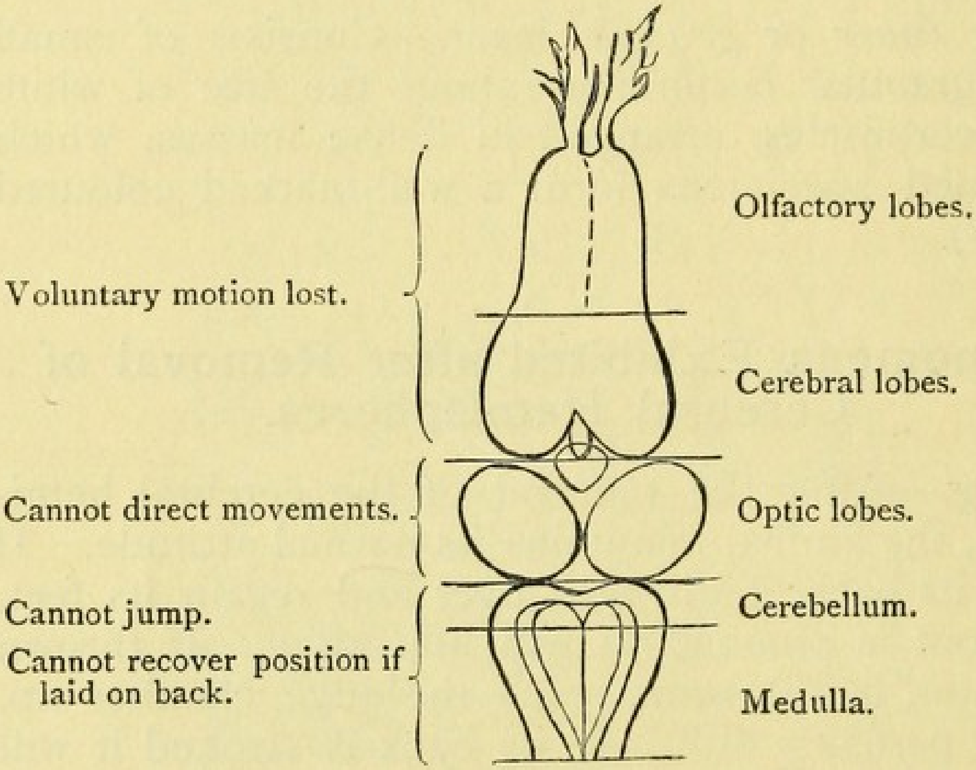

FIG 101*a*.—Diagram illustrating higher nerve-centres of the frog (after Lauder Brunton).

Rabbit.—When the cerebral hemispheres are removed, the animal is at first prostrate ; after a while it can use its legs, though the fore ones are weak. If pinched it springs forward ; but, unlike frogs in a similar condition, will strike itself blindly against any obstacles in its path. When pinched severely it utters cries.

In higher animals, as cats and dogs, motor paralysis is so marked after the removal of the hemispheres, that no conclusions concerning equilibrium and co-ordinated movements can be drawn.

At first sight it would appear that consciousness was necessary for the performance of complicated movements, and the avoidance of objects in the path; the cries elicited on pinching would appear to indicate the sensation of pain. Probably they are the result of a reflex mechanism, and are similar to walking during sleep, or the cries elicited from patients when under chloroform. The medulla contains centres for reflex actions more complicated than the cord, and the corpora quadrigemina and cerebellum contain centres for still more complex acts, as the reflex expression of emotion, the avoidance of an object when leaping, or the co-ordination of many contracting muscles.

Functions of Corpora Quadrigemina.

In man they contain (*nates or subjacent structures*)—

(1.) Centres for co-ordination of the movements of the eye-balls.
(2.) Centre for the contraction of the pupils.

In some of the lower animals they contain—

(3.) Centres for co-ordination of retinal impressions with certain muscular movements.
(4.) Centre for maintenance of equilibrium.

Ferrier found, on applying a weak interrupted current to the surface of the nates in the monkey, that irritation of one side caused the opposite pupil to become widely dilated, followed by dilatation of the pupil of same side. The eyeballs are directed upwards and to the opposite side, and the ears retracted. The legs become extended, the jaws retracted, and angles of mouth retracted. Irritation of the testes produces similar results, but in addition cries are elicited.

Functions of the Cerebellum.

Removal of the cerebellum in a pigeon renders co-ordinated movements, such as walking, flying, turning round, imperfectly performed. There is no

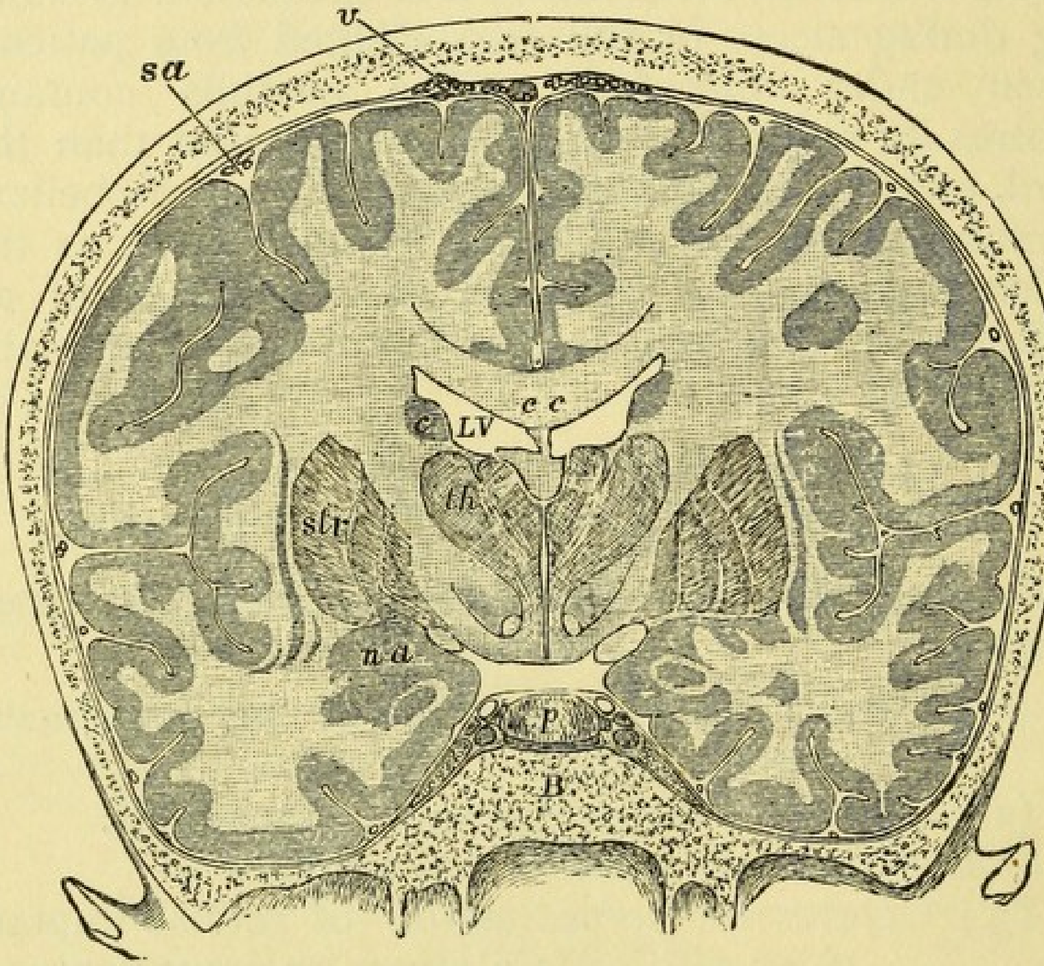

FIG. 102.—Transverse section through the brain (Quain's Anatomy). *c c* corpus callosum ; *LV*, lateral ventricle ; *th*, thalamus ; *str*, lenticular nucleus of the corpus striatum ; *c*, caudate nucleus of the same ; between *th* and *str* is the internal capsule ; outside *str* is a thin grey band, the claustrum ; outside this is the fissure of Sylvius, and island of Reil ; *sa*, *v*, vessels on the surface ; *p*, pineal gland ; *B*, basilar process.

loss of muscular power or of sensation ; the bird struggles to get on to its legs and flaps its wings in its endeavour to fly, but its movements are awkward and irregular. Injury or a tumour of the middle lobe of the cerebellum in man gives rise to a staggering gait, not unlike that of a drunken man; there is a difficulty in maintaining the equilibrium, especially when the eyes are closed, and in turning sharply round.

Section of the middle lobe of the cerebellum in monkeys gives rise to difficulty in maintaining the equilibrium; injury of the anterior extremity of the middle lobe causes the animal to tumble forwards, while when the posterior end is injured there is a tendency to fall backwards.

From these observations it would appear that in man the middle lobe of the cerebellum is in some way or another connected with the co-ordination of muscular movements, especially with those movements which maintain the equilibrium of the body. Paralysis and muscular contractures often are present in cerebellar tumours, but these are probably due to the cerebellum compressing the motor tracts in the pons, or giving rise to distension of the lateral ventricles in consequence of pressing on the vena galeni.

The functions of the lateral lobes of the cerebellum are unknown ; they are connected by means of the fibres of the superior and inferior with the cortex of the hemispheres, and according to Gowers they are in some way connected with mental processes.

Basal or Central Ganglia.

These consist of the corpus striatum and optic thalamus ; passing in close relation with them is the internal capsule.

The **corpus striatum** consists of two parts—an intra-ventricular portion, projecting into the lateral ventricle of the same side as an elongated grey body called the **caudate nucleus** (fig. 102 and fig. 103), and an extra-ventricular portion, the **lenticular**

nucleus, more deeply placed, and is separated from the optic thalamus (see fig. 103) by the internal capsule. On its outer side it is in close proximity to

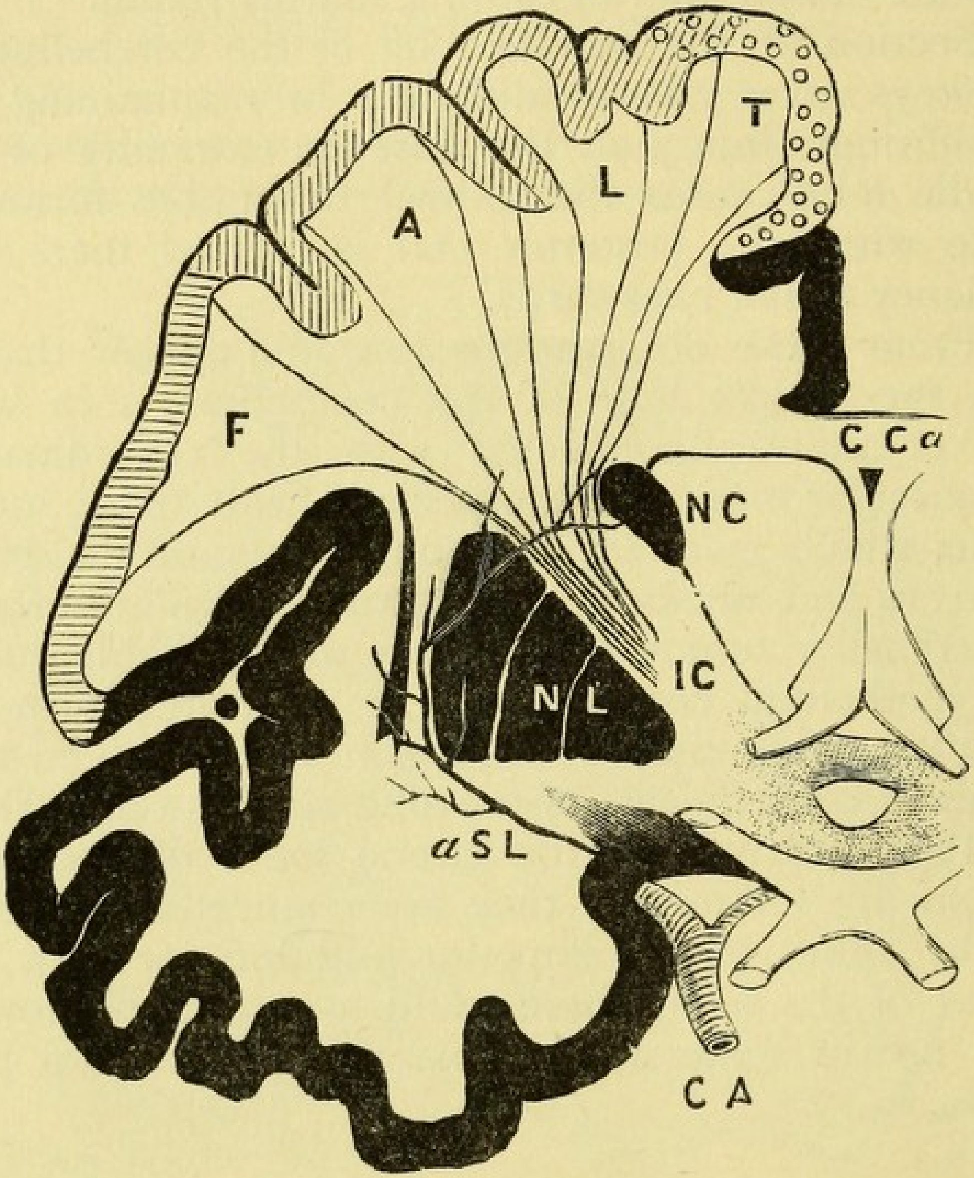

FIG. 103.—Transverse (vertical) section of a cerebral hemisphere, made in front of the optic thalamus (Landois and Stirling). CC*a*, corpus callosum; NC, caudate nucleus (the letters themselves are placed in the lateral ventricle); NL, lenticular nucleus; IC, internal capsule; CA, internal carotid; *a* SL, lenticular striate artery ('artery of hæmorrhage'); F, A, L, T, motor centres governing movements of face, arm, leg, and trunk, the fibres of which converge to pass along the internal capsule.

the island of Reil, the claustrum intervening (see fig. 102 and fig. 103). It consists of three parts. It is uncertain if the corpus striatum has any connection with the cortex, but fibres coming from it enter the internal capsule. It consists of grey matter, and contains many nerve-cells.

The optic thalamus is more or less oval-shaped; it consists of grey matter, containing many nerve-cells; it has a superficial layer of white fibres. On the inner side it projects into the lateral ventricle, being placed posteriorly to the caudate nucleus; on its outer side is the internal capsule. It is connected with the cortex, optic tracts, and with the tegmentum of the crus.

The **internal capsule** is a broad band of fibres which connects the cortex of the brain with the crus, and in which lie both the motor and sensory paths. The anterior limb separates the caudate and lenticular nuclei (see fig. 103), the posterior limb lies between the latter and optic thalamus. It is best seen in horizontal section of the brain; the two limbs are seen to join at an acute angle called 'the knee.'

The functions of the corpus striatum and optic thalamus are not known with certainty. As they lie deeply, and any injury involving either almost certainly injures the internal capsule also, it is very difficult to ascertain their functions. The optic thalamus is in some way related to the sense of sight. According to the older view, the office of the basal ganglia was the co-ordination of muscular movements in the performance of complex acts; thus, to quote Broadbent, 'the corpus striatum translates volition into action or puts in execution the commands of the intellect; that is, selects, so to speak, the motor nerve-nuclei in the medulla and cord appropriate for the performance of the desired action, and sends down the impulses which set them in motion.'

As already stated, the internal capsule contains the motor and sensory paths from and to the cortex, the motor path occupying the anterior two-thirds (fig. 103) and the sensory the posterior third.

The Cerebrum.

The cerebral hemispheres form two ovoid masses of grey and white matter, with convolutions on their surface. The grey matter is mostly present on the surface, and forms a layer from $\frac{1}{4}$ to $\frac{1}{2}$ inch in depth, the amount being greatly increased by the convolutions. The white matter is arranged in various ways: *longitudinal fibres*, as the fornix; *transverse fibres*, as the corpus callosum; *peduncular fibres*, connecting the grey matter on the surface with the corpora striata (corona radiata), and the latter with the pons (crura).

The grey matter of the cerebrum resembles the grey matter elsewhere, though the number and shape of the nerve-cells undergo considerable variation. Five or more layers have been described, but they blend imperceptibly into one another:—

(1.) The most external layer is composed mostly of neuroglia, and contains a few small cells with fine processes.

(2.) Contains a large number of small pyramidal or arrow-head cells.

(3.) Is of greater thickness, and contains large pyramidal or arrow-head cells, with their points to the surface of the convolutions. They are separated by bundles of nerve-fibres running towards the surface.

(4.) A narrow layer of irregular-shaped cells with fine processes.

(5.) Wider than the last, and composed of fusiform and irregular cells, mostly extending parallel to the surface.

The large pyramidal cells present in the third and fourth layers are especially well-developed in the motor centres in the ascending frontal convolution.

In the occipital lobes, and about the calcarine fissure, the large cells are very scanty.

Functions of the Convolutions.—The grey matter on the surface is the seat of the higher processes of mind, including volition, memory, intellect, and the emotions. It also contains perceptive centres of special sense, as sight, hearing, touch, smell, taste. Special motor areas or centres have been localised by Ferrier in the parietal regions, and various perceptive centres in the temporo-sphenoidal lobes. The cere-

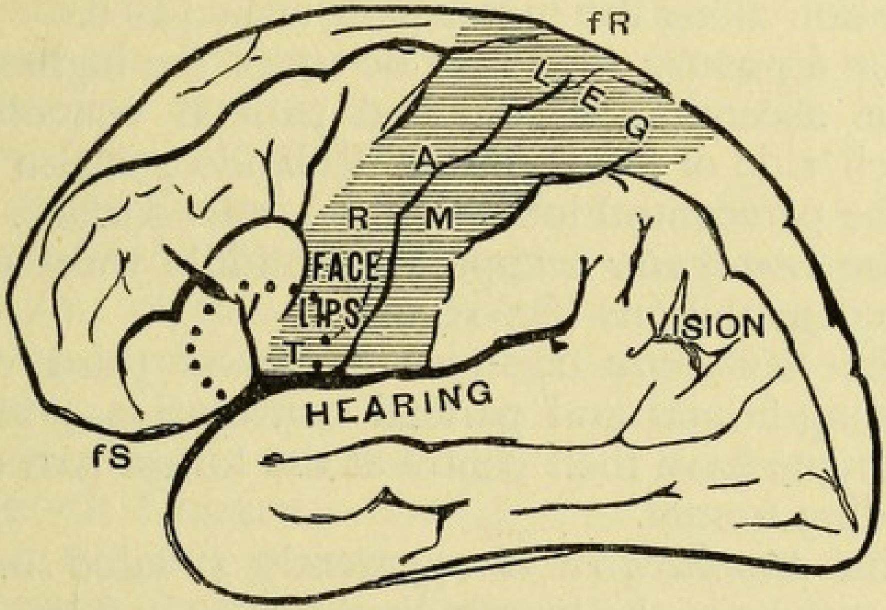

FIG. 104.—Lateral view of left half of brain. Motor areas shaded; dotted area indicates the speech centre (Landois and Stirling).

bral cortex appears to contain a collection of centres, towards which incoming sensations converge from all parts of the body; here they come into relation with one another, and give rise to motor impulses which pass to the corpora striata, and thence to the muscles. Ferrier considers the frontal lobes are connected with the intellectual faculties, and the posterior lobes with the appetites. Reference to fig. 104 will show the motor centres, stimulation of which by a weak Faradic current causes movement in the corresponding group of muscles, or destruction of which causes paralysis.

The perceptive centres of vision and hearing are also mapped out; those of touch, smell, and taste are situated in the convolution on the inner side of the temporo-sphenoidal lobe.

Motor areas.—It is from the motor centres situated at the cortex of the brain that fibres arise which pass through the white surface in the centre of the brain, pass along the internal capsule to the anterior pyramids of the medulla, and on to the pyramidal tracts of the cord. Injury to these centres causes, first, paralysis, and afterwards descending degeneration along the motor path takes place.

The *leg-centre* (fig. 104) occupies the highest part of the ascending frontal and parietal convolutions on each side of the fissure of Rolando; it also occupies the paracentral lobule on the inner surface.

The *arm-centre* occupies the middle third of the above convolutions (fig. 104).

The *face-centre* occupies the lower third of the ascending frontal and parietal convolutions; the lips and tongue have their centre at the lowest part of the ascending frontal.

The *trunk-centre* is apparently situated on the inner surface in the longitudinal fissure in front of the leg-centre.

Sensory Centres.—The position of the centre for sensation of the limbs and trunk has not certainly been defined. According to Flechsig, the fibres of the sensory path of the internal capsule pass upwards to the central convolutions, *i.e.* ascending frontal and parietal convolutions and parietal lobe. If this view is correct, this region contains both motor and sensory centres. Ferrier localised the centre of tactile sensation in the hippocampal region. In cases of injury to the brain followed by loss of motor power and loss of sensation, if recovery takes place sensation returns sooner or later, though the parts paralysed may never regain their power. This return of sensation is, no doubt, due to other parts of the brain taking on the functions of the part destroyed.

Smell.—The olfactory centre is probably situated at the anterior extremity of the uncinate convolution. The experiments of Ferrier, as also anatomical and pathological researches, would seem to indicate this.

Vision.—The *visual area* is seated in the occipital lobes; but the exact spot has not certainly been determined. According to Ferrier's experiments on monkeys, destruction of the angular gyri and occipital lobes cause total and permanent blindness. In man, disease of one occipital lobe causes *hemianopia*, that is, blindness of the lateral halves of both retinæ corresponding to the side of the lesion.

Auditory Centre.—The centre for hearing in man is situated in the first temporo-sphenoidal convolution. Destruction of this region has been followed by loss of hearing on the opposite side, though this was not permanent (Gowers). This convolution has been found atrophied in cases of congenital deafness.

Speech Centre.—The centres connected with speech are in the posterior extremity of the inferior (3rd) frontal convolution of the *left* hemisphere; the island of Reil is apparently also concerned. Damage to this centre is followed by the loss of the faculty of speech—a condition to which the term *aphasia* is applied. The patient may have perfect control over his lips, tongue, &c., and may be able to utter articulate sounds, but he cannot combine the sounds so as to form words by which he can express his thoughts. He can neither express himself in writing nor can he read. In some cases the patient can express his thoughts in writing when he cannot by speech.

Rapidity of Cerebral Operations.—Mental operations occupy a longer period than simple reflex actions. By means of a suitable apparatus and a system of signalling this period can be approximately measured. A stimulus is applied, as an induction shock; and the person experimented on gives a signal the instant he feels it, both being recorded on a moving surface. The interval is called 'the reaction period.' This period includes the time occupied by the impression in travelling along the nerve to the centre, its perception by the mind, and the time occupied by the motor impulse travelling to the muscles giving rise to muscular contraction. The reaction period for feeling is $\frac{1}{7}$ sec., hearing $\frac{1}{6}$ sec., and sight $\frac{1}{5}$ sec. But these figures are likely to vary in different persons.

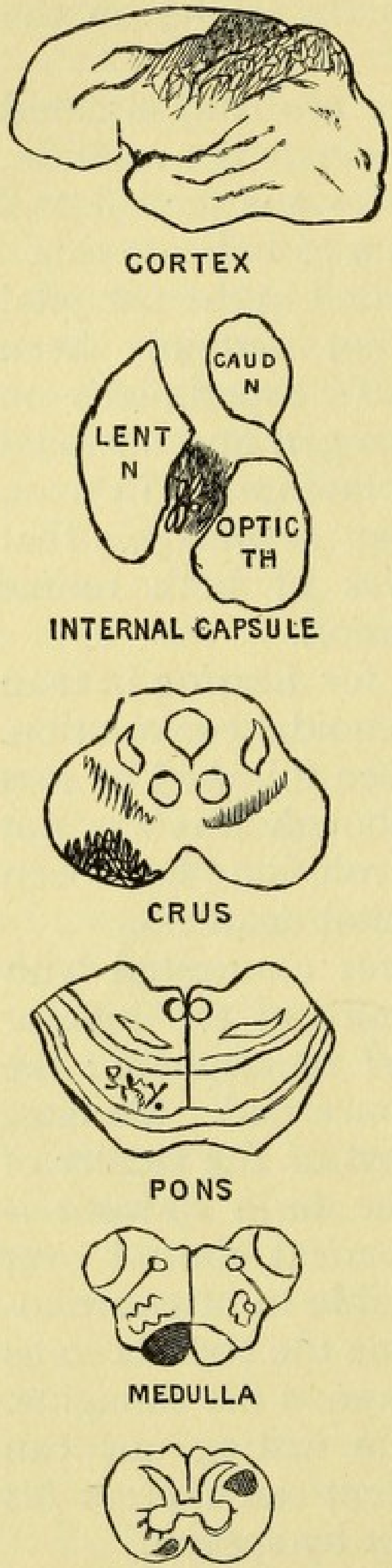

FIG. 104*a*.—Diagram illustrating course of motor path

Course of the Motor Fibres.—The course of the motor path, or pyramidal tract, as it is called, from the parietal convolutions to the muscles is better known than the course of the sensory path. The fibres forming the motor path on leaving the cortical centres pass through the white 'centrum ovale,' and converge to the *internal capsule* (fig. 103), where they occupy the anterior two-thirds or more of the posterior limb; entering the crus cerebri, they pass along the *crusta*, occupying the middle two-fifths, extending from the surface below to the substantia nigra above (fig. 104*a*); passing on to the *pons*, the fibres separate into bundles lying between the superficial and deep transverse layers, and being surrounded by much grey matter; entering the medulla, the motor fibres rejoin one another, forming the *anterior pyramids*; at the lower part of the medulla about three-fourths of the fibres decussate, passing to the opposite side to form the *lateral* or *crossed pyramidal tract* of the cord; those which do not decussate pass down their own side of the cord, forming the *anterior* or *direct pyramidal tract* (fig. 97).

Hemiplegia.—Damage to the motor centres at the cortex, or to any part of the motor path, is followed by paralysis of the face, arm, and leg of the opposite side. In a severe case the face is paralysed, chiefly the lower half; the tongue when protruded points towards the paralysed side, and the arm and leg are completely powerless. For the most part, the muscles of mastication, respiration, and the trunk muscles escape; these muscles, being associated in their action with those of the opposite side, are probably excited to act by the nerve-centres which supply their fellows. The commonest cause of hemiplegia is a rupture of the lenticulo-striate artery and a consequent destruction of the internal capsule (fig. 103). In some forms of hemiplegia the 3rd, 4th, 6th, or other cranial nerves may be involved.

Course of the Sensory Fibres. — Less is known concerning the path of the sensory than the motor fibres. The fibres which enter the cord from the sensory nerves cross almost immediately to the opposite side and ascend along the fibres of the *lateral column* in front of the pyramidal tract, and also along the fibres of the *posterior columns*; probably also along the *grey matter* of the cord. In the medulla and pons, the sensory path is believed to lie in the *formatio* *reticularis*, from which it passes along the *tegmentum* of the crus and enters the *internal capsule*, occupying the posterior third of the hind limb. From the internal capsule the path lies through the centre white substance to the cortex, being distributed to that part of the cortex which lies beneath the parietal bone (Flechsig). Some of the fibres enter the optic thalamus. In the upper part of the pons the path is joined by the sensory fibres from the face (5th nerve), so that the posterior part of the internal capsule contains sensory fibres from the whole of the opposite side of the body. Apparently, also, the fibres from the special organs of sense, taste, hearing, smell, vision, pass through the internal capsule.

Hemianæsthesia.—Destruction of the posterior portion of the internal capsule gives rise to loss of sensation to touch, pain, and temperature of the opposite side of the body ; the organs of special sense are also involved. If the sensory path is destroyed below the pons the parts supplied by the 5th nerve escape. In many cases of hemiplegia there is also more or less loss of sensation.

Functions of the Cranial Nerves.

First or Olfactory.—The olfactory nerve arises from the under surface of the frontal lobe in front of the anterior perforated space by three roots, the external, middle, and internal. It lies on the orbital surface of the frontal lobe, lodged in a sulcus, and swells out into an enlargement, the olfactory bulb. The branches or true olfactory nerves, some twenty in number, pass through the cribriform plate, and ramify upon the upper part of the septum, and the superior and middle turbinated processes. The olfactory bulb or lobe consists of grey substance, the peripheral nerves consist of nerve-fibres, which are non-medullated. The mucous membrane, over which the olfactory nerve is distributed, is softer and more pulpy than the respiratory region. It is of a yellow colour. The epithelial cells are modified so as to form terminal organs for the olfactory nerves. The

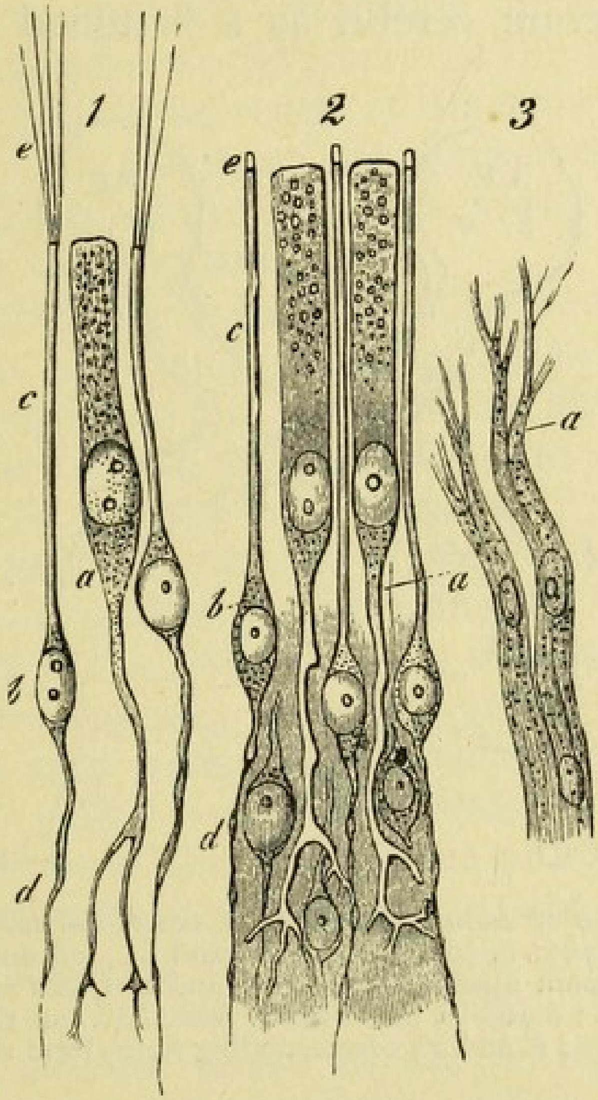

FIG. 105.—Cells and terminal nerve-fibres of the olfactory region. 1, from the frog; 2, from man. *a*, epithelial cell, extending into a root-like process; *b*, olfactory cells; *c*, peripheral rods; *d*, their central filaments. 3, olfactory nerve-fibre in dog. *a*, division into fine fibrillæ. Irritation of the olfactory terminal organs gives rise to a sensation of smell.

columnar cells are continued downwards in a root-like process, and between the cells there are fine threads or rods, connected at their inner extremities with spindle-shaped *olfactory cells*, the cells being apparently connected with filaments of the olfactory nerves. The olfactory nerves do not decussate, and are unlike all other nerves in this respect.

Optic Nerve.—Each optic tract arises from the posterior part of the optic thalamus and the corpora geniculata. Leaving this attachment, it winds forward, crosses the crura cerebri as a flattened band ; then,

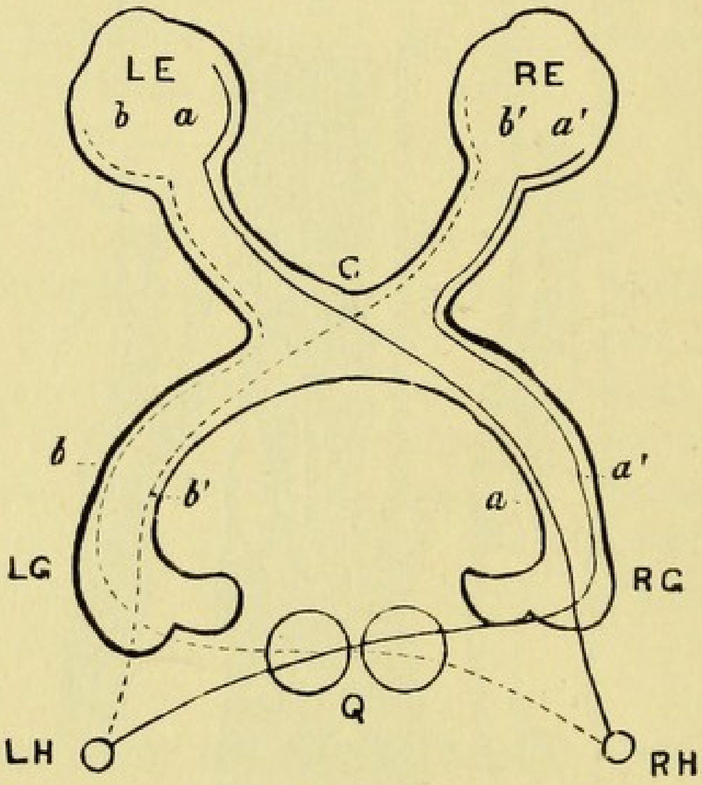

FIG. 106.—Scheme of decussation of optic tracts (Charcot). LE and RE, left and right eyes ; C, commissure ; LG and RG, left and right geniculate bodies ; Q, corpora quadrigemina ; LH and RH, left and right cerebral centre of vision ; *b* and *a*, nerve-fibres from left and right sides respectively of left eye ; *b′* and *a′*, corresponding fibres from right eye.

becoming more cylindrical, it passes forwards, joining its fellow of the opposite side to form the commissure. In front of the commissure the optic nerves, as they are now called, receive a sheath from the dura mater and arachnoid, and pierce the back of the eyeball. Decussation takes place at the commissure, but this decussation is a peculiar one.

According to Charcot the decussation of the optic tracts takes place as represented in fig. 106, there being not only a crossing at the chiasma, but also at the corpora quadrigemina; according to this view a lesion at C would intercept the fibres from both nerve-centres going to the inner side of each retina, and cause blindness of each inner half of the retina, a condition to which the term *double temporal hemianopia* is applied. A lesion in the optic tract behind the chiasma would intercept the fibres going to each lateral half of the retina of the same side—*lateral hemianopia.* A lesion of the cortical centre (angular gyrus) would, according to this view, produce total blindness in the opposite eye.

Gowers dissents from Charcot's views and does not believe that a second crossing takes place in the corpora quadrigemina. In man, as shown by pathological observations, a lesion of the chiasma gives rise to double temporal hemianopia ; a lesion of the optic tract and between the chiasma and the occipital cortex gives rise to lateral hemianopia ; a lesion of the cortex itself at the angular gyrus causes partial loss of vision of the opposite eye, the central portion round the yellow spot remaining sensitive to light. This condition is called *crossed amblyopia.*

Stimulation of the optic nerve produces sensations of light ; thus flashes of light are seen when the electrodes of a galvanic battery are placed on the temples, and the current slowly interrupted. The optic nerve is also the afferent nerve in the reflex contraction of the pupil, in the closure of the eyelids, when a bright light falls on the retina.

Third, or Oculo-motor.—This nerve takes its deep origin in a cluster of cells, situated in the floor of the aqueduct of Sylvius ; its nucleus is joined inferiorly by the nucleus of the fourth nerve (fig. 113). From this nucleus the fibres pass through the crus to its inner side. The third nerve is purely motor, being distributed to all the muscles of the eyeball, except the superior oblique and external rectus ; it also supplies the circular fibres of the iris and the ciliary muscle. Paralysis of this nerve gives rise to (1) *ptosis*, or drooping of the eyelid in consequence of the unopposed action of the orbicularis ; (2) the eyeball is turned outwards and downwards by the ext. rectus and sup. oblique ; (3) the pupil is dilated and fixed ;

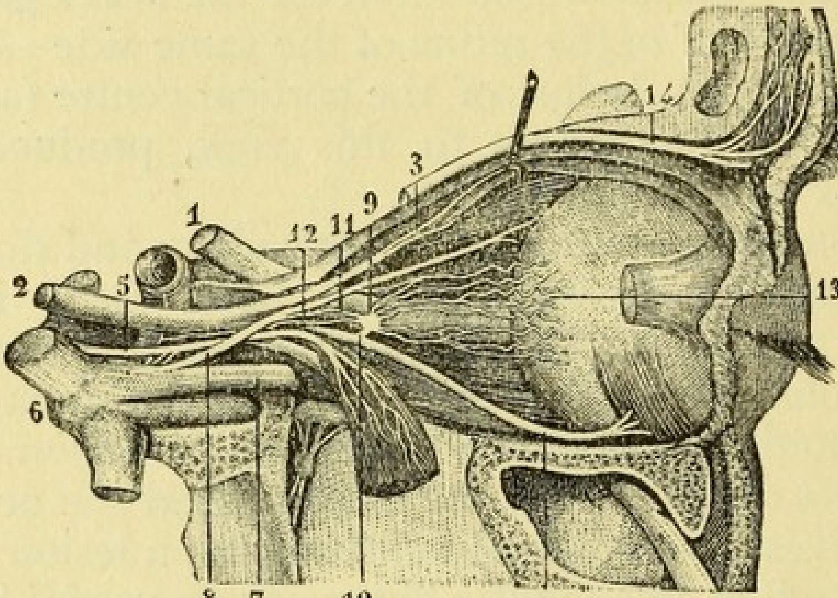

FIG. 107.—Nerves of the orbit from the outer side (Quain's Anatomy). The external rectus has been cut and turned down ; 1, optic nerve ; 2, the trunk of the third nerve ; 3, its upper division passing to the levator palpebræ and superior rectus ; 4, its long lower branch to the inferior oblique muscle ; 5, the sixth nerve ; 6, the Gasserian ganglion ; 7, the ophthalmic nerve ; 8, its nasal branch ; 9, the ophthalmic ganglion ; 10, its short or motor root ; 11, long sensory root from the nasal nerve ; 12, sympathetic from the carotid ; 13, ciliary nerves ; 14, frontal branch of ophthalmic.

(4) the eye cannot be accommodated to near objects ; (5) there is also double vision.

Fourth Nerve.—This nerve arises from a nucleus immediately below that of the third in the floor of the aqueduct. The fibres pass downwards and backwards, emerge at the upper part of the valve of Vieussens, and wind round the crus to the base of the brain. It is purely motor, and supplies the superior oblique. Paralysis of the fourth nerve causes squint, the eye being directed upwards and inwards, and double vision.

Fifth or Trigeminal Nerve. — This nerve emerges from the side of the pons Varolii, and consists of two roots, the smaller being the motor. The *motor* root arises from a nucleus (fig. 113, V_1), immediately in advance of the 7th nucleus. The sensory root arises from two nuclei, the middle (V_2) and inferior (V_3) of the 5th. The fibres pass through the pons, and appear at the surface. The sensory root becomes connected with the Gasserian ganglion, from the fore part of which the three primary divisions proceed They are (*a*) *Ophthalmic*, purely sensory to the eye and forehead, eyelids, conjunctiva, tip of nose; secreto-motor branches to the lachrymal gland (fig. 108). Injury to this nerve causes ulceration and sloughing of the cornea. (*b*) *Superior Maxillary* or *second division* (fig. 108) is purely sensory to skin of face, mucous membrane of the nose, and teeth of upper jaw. Pungent odours, as of ammonia, are perceived through this nerve. (*c*) *Inferior* or *third division* (fig. 108) is sensory to the tongue, mouth, teeth, and skin covering lower jaw. It confers tactile sensibility on the tongue, and through it pungent and acid tastes, as of pepper, vinegar, and mustard, are perceived. Motor filaments are supplied from its anterior division to the muscles of mastication, including the buccinator, anterior belly of digastric, and mylohyoid.

There are four ganglia in connection with the fifth nerve :—

1. The **ophthalmic** or **lachrymal ganglion** (fig. 107). *Motor* root from inferior division, third; *sensory* from nasal; *sympathetic* from carotid. It gives off sensory motor and vaso motor branches to the eye.

2. The **spheno-palatine** or **Meckel's gan-**

glion (fig. 108). *Motor* root from the facial through the greater superficial petrosal; *sensory* root from second division of the fifth; *sympathetic* root from

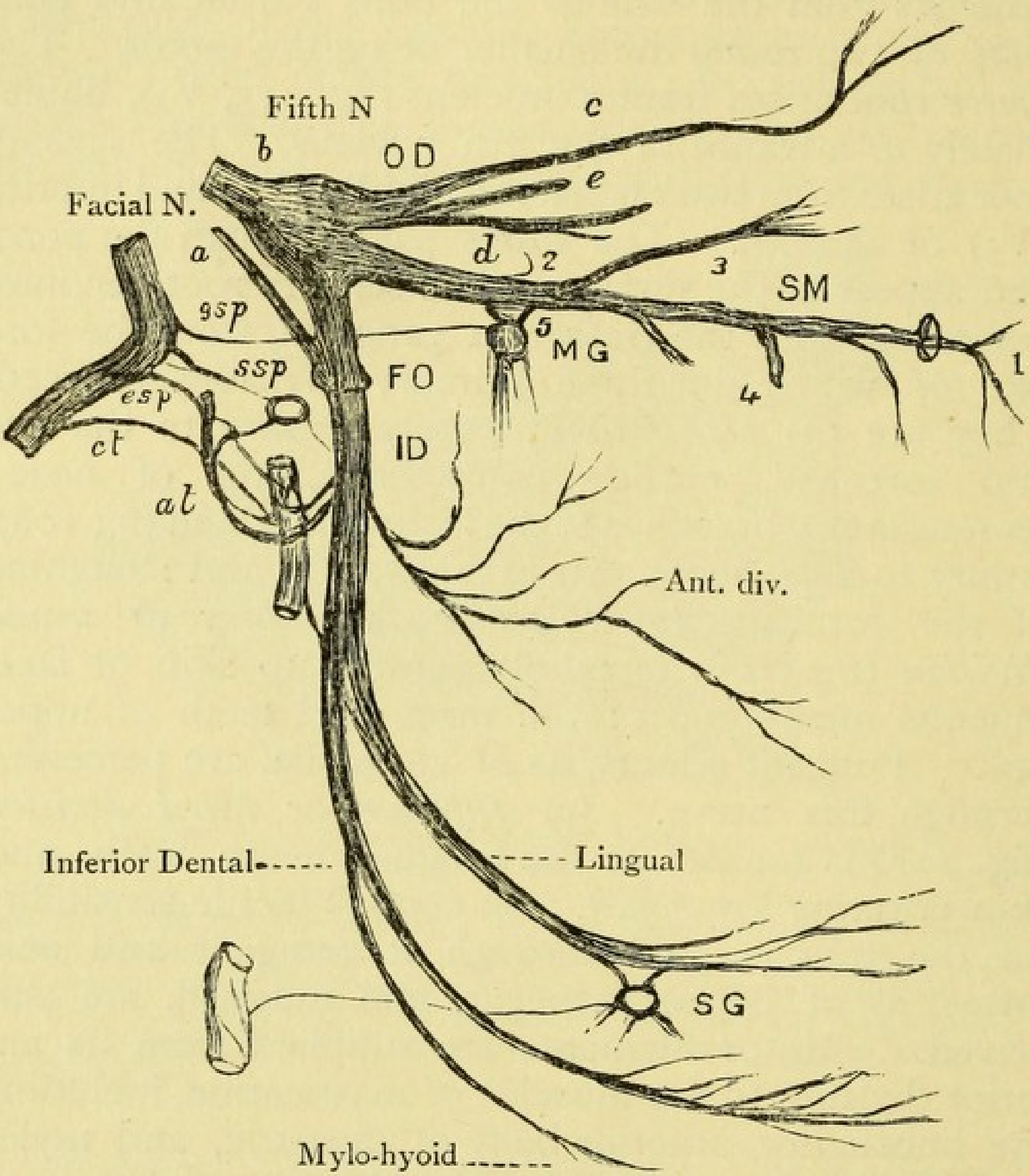

FIG. 108.—Diagram of the fifth nerve, its connections and branches. O D, ophthalmic division; *c*, frontal; *e*, lachrymal; *d*, nasal. S M, superior maxillary: 1, terminal branches, nasal, labial and palpebral; 2, recurrent; 3, orbital; 4, dental; 5, to Meckel's ganglion. I D, Inferior division: *a*, motor division joining anterior division, mostly motor, terminal branch to the mucous membrane of mouth: posterior division; *at*, auriculo-temporal; lingual to tongue; inferior dental; mylo-hyoid branch to digastric and mylo-hyoid.

carotid. It gives off motor fibres to the levator palati and azygos uvulæ; sensory fibres to the mucous membrane of the nose and palate.

3. The **otic ganglion** (figs. 108 and 109). *Motor* root from inferior division of fifth ; *sensory* root from the glosso-pharyngeal through lesser superficial petrosal ; *sympathetic* root from the middle meningeal artery. It gives off motor fibres to the tensor tympani and tensor palati ; *secretory* fibres to the parotid gland.

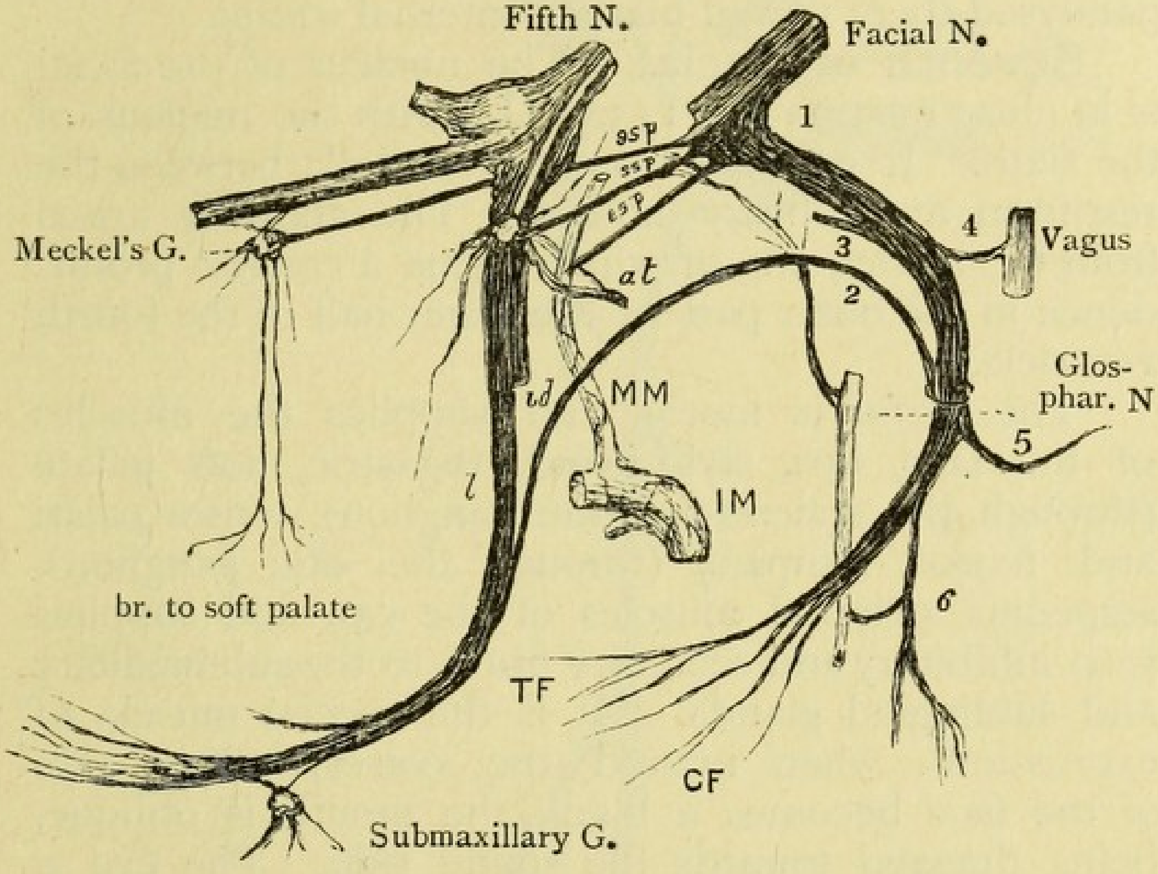

FIG. 109.—Diagram of the facial nerve and its connections (after Young). Facial nerve : 1, geniculate ganglion ; *g.s.p.*, great superficial petrosal passing to Meckel's ganglion ; *s.s.p.*, small superficial petrosal passing to the middle meningeal ; 2, chorda tympani, joining lingual ; 3, nerve to the stapedius ; 4, communicating branch with ganglion of the root of the vagus ; 5, posterior auricular nerve ; 6, branch to stylo-hyoid and digastric. MM, middle meningeal artery ; IM, internal maxillary artery ; *at*, auriculo-temporal nerve ; *l*, lingual ; *id*, inferior dental.

4. The **submaxillary ganglion** (fig. 108). *Motor* root from the facial through the chorda tympani ; *sensory* root from lingual of the fifth ; *sympathetic* root from facial artery. It gives off vaso-inhibitory fibres from the chorda tympani to the submaxillary gland ;

secretory fibres also from the same source to the glands.

Sixth or Abducent Nerve.—This nerve arises from a nucleus in the floor of the pons (fig. 113, VI.), close to the nuclei of the seventh and motor of the fifth; it emerges between the medulla and pons. It supplies the external rectus. When this muscle is paralysed there is well-marked internal squint.

Seventh or **Facial.**—The nucleus of the facial is in close relation (fig. 113, VII.) with the nucleus of the sixth. It emerges from the medulla between the restiform and olivary bodies. The auditory arises from the nuclei, one of which forms a convex prominence in the outer part of the lower half of the fourth ventricle.

The *facial* is motor, and supplies the muscles of the face, lips, stylo-hyoid, digastric, soft palate (through the spheno-palatine ganglion), tensor palati and tensor tympani (through the otic ganglion), stapedius, external muscles of the ear, and supplies vaso-inhibitory and secretory fibres to the submaxillary and sublingual glands. It is the special muscle of expression: when injured the corresponding side of the face becomes a blank, the mouth is oblique, being dragged towards the sound side. The eye is wide open and cannot be closed, and tears run down the cheek; food accumulates between the gum and cheek, and the pronunciation of labial consonants is rendered difficult, and movements of the nostril cease. Should injury to the nerve occur above the origin of the chorda tympani and petrosal nerves (fig. 109), there will be an interference with the sense of hearing, through paralysis of the stapedius and tensor tympani; dryness of one side of the tongue, owing to the implication of the chorda and submaxillary glands; relaxation of the soft palate and pointing of the uvula to the sound side in consequence of paralysis of the azygos and soft palate.

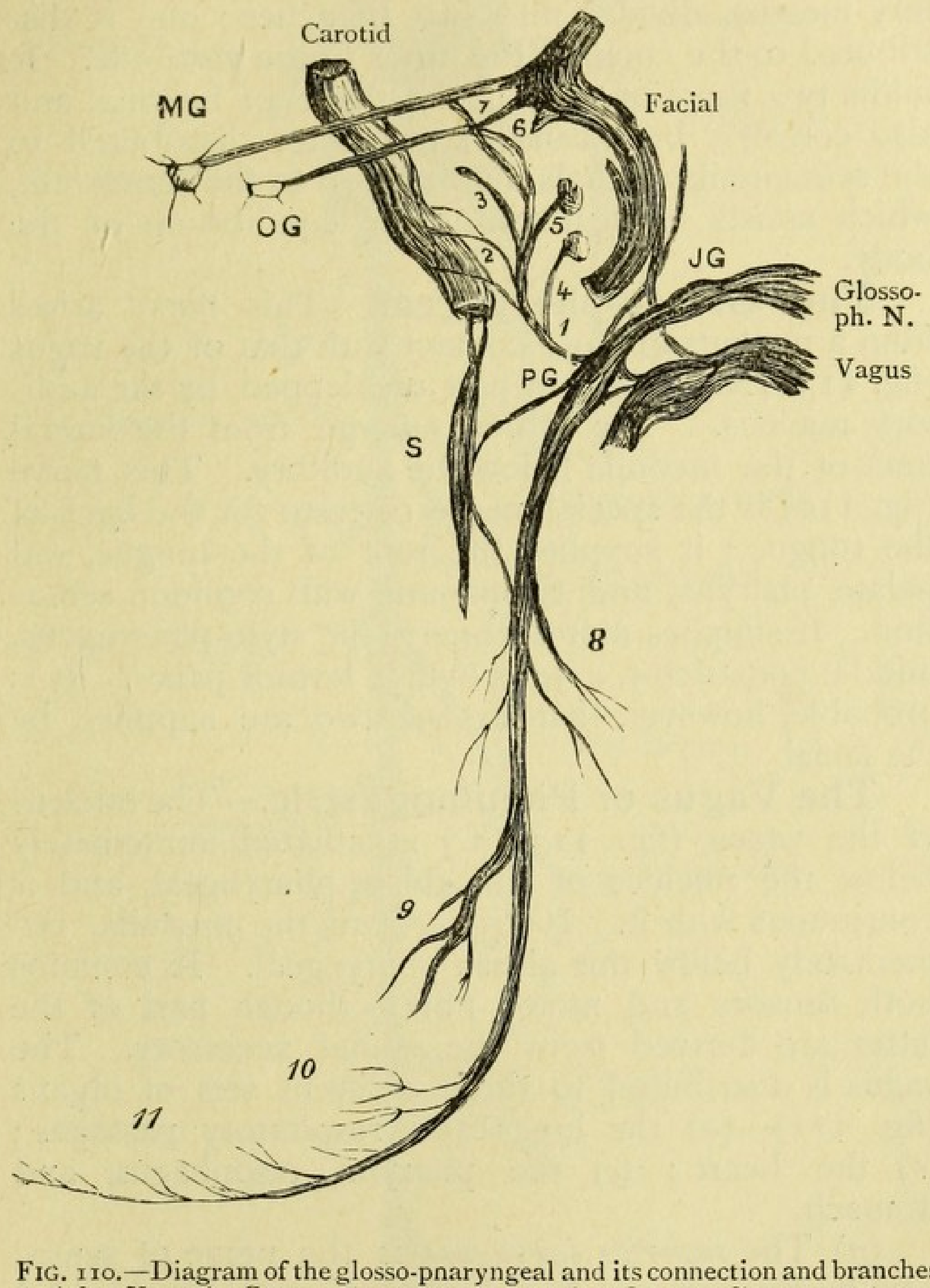

FIG. 110.—Diagram of the glosso-pnaryngeal and its connection and branches (after Young). GLOSSO-PHARYNGEAL ; JG, *jugular ganglion* ; PG, *petrosal ganglion* : 1, tympanic branch ; 2, filaments to the carotid ; 3, to Eustachian tube ; 4, to fenestra rotunda ; 5, to fenestra ovalis ; 6 and 7, to small and great superficial petrosal ; 8, pharyngeal branches ; 9, to stylo-pharyngeal and constrictors ; 10 and 11, tonsillitic and terminal. VAGUS branches from ganglion of root : *s*, superior cervical ganglion.

The *auditory* nerve passes into the internal auditory meatus, divides into two branches; one is distributed to the cochlea, the other to the vestibule. It fulfils two functions; it is the nerve of hearing, and also conveys, by means of the fibres distributed to the semicircular canals, information to the sensorium, which assists in maintaining the equilibrium of the body.

The Glosso-pharyngeal.—This nerve arises from a nucleus in close contact with that of the vagus (fig. 113, IX.), and is in part overlapped by the auditory nucleus. The fibres emerge from the lateral tract of the medulla below the auditory. This nerve (fig. 110) is the special nerve of taste for the back of the tongue; it supplies the root of the tongue, soft palate, pharynx, and tympanum, with common sensation. It supplies motor fibres to the stylo-pharyngeus, middle constrictor, azygos uvulæ, levator palati. It is probable, however, that the last two are supplied by the facial.

The Vagus or Pneumogastric.—The nucleus of the vagus (fig. 113, X.) is situated immediately below the nucleus of the glosso-pharyngeal, and is continuous with it. It arises from the medulla, immediately below the glosso-pharyngeal. It contains both sensory and motor fibres, though part of the latter are derived from the spinal accessory. The vagus is distributed to three different sets of organs (fig. 111)—(*a*) the lungs and respiratory passages; (*b*) the heart; (*c*) the pharynx, œsophagus, and stomach.

(*a*) The *superior laryngeal* is the nerve of sensation to the mucous membrane of the larynx, and supplies one muscle—the crico-thyroid. Paralysis of this nerve causes loss of sensation in the larynx, and interferes with the utterance of high notes from paralysis of the crico-thyroid. The *inferior laryngeal*

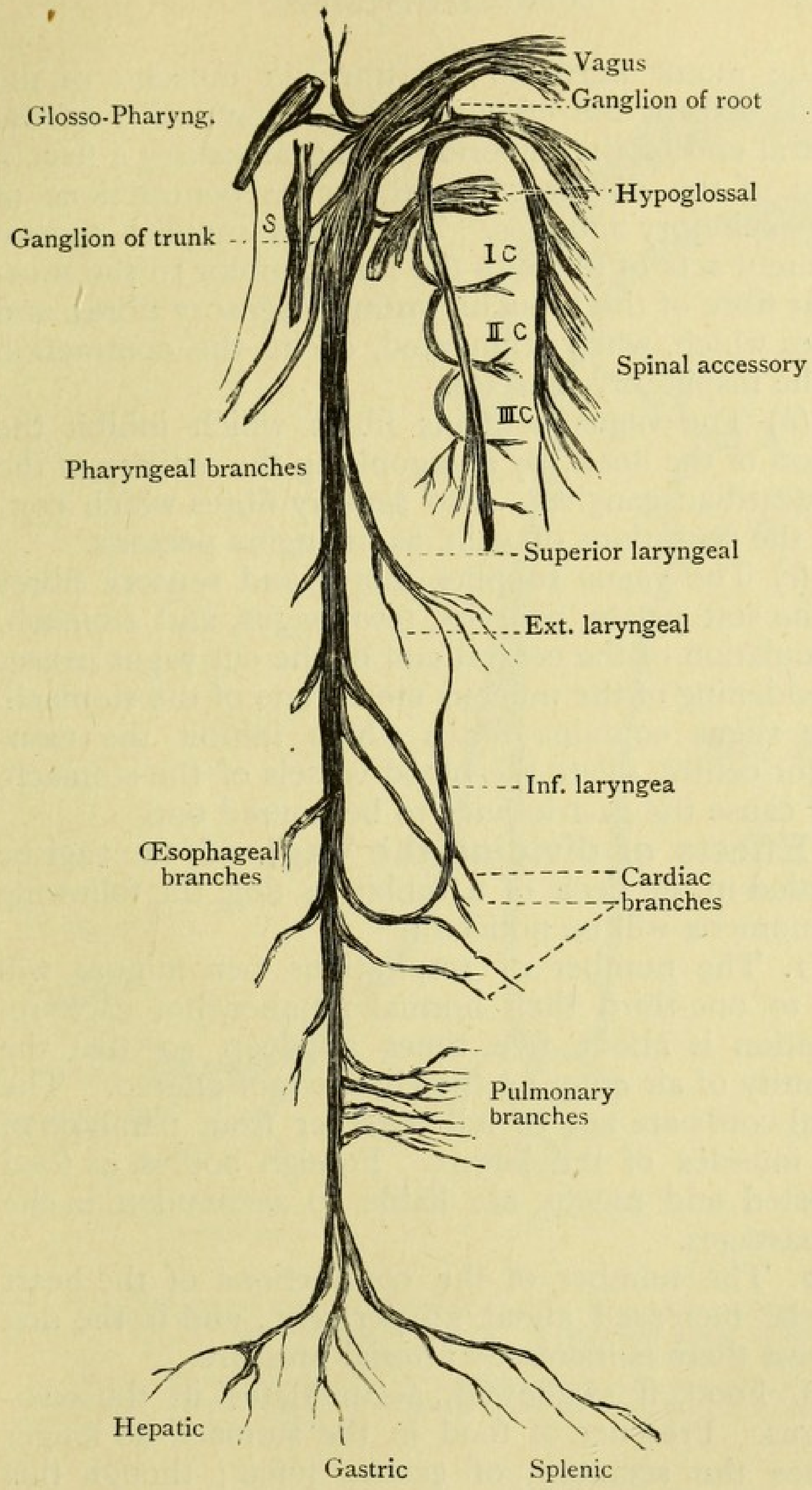

FIG. 111.—Diagram of vagus, its branches and connections.

is the motor nerve to the intrinsic muscles of the larynx, except the crico-thyroid. Stimulation of the central end of the superior laryngeal causes a flaccid state of the diaphragm, and excites contractions of the expiratory muscles. The vagus supplies several different sets of fibres to the lungs, motor to the muscular fibre of the bronchi, ordinary sensory fibres, and fibres which, when stimulated, excite the contraction of the inspiratory muscles.

(*b*) The vagus contains fibres which inhibit the action of the heart, by antagonising the activity of the intracardiac ganglia. Also sensory fibres which convey the sensations of pain, as in angina pectoris.

(*c*) The vagus supplies motor and sensory fibres to the soft palate, pharynx, œsophagus, and stomach. Stimulation of the central end of the cut vagus causes a reddening of the mucous membrane of the stomach. The vagus contains fibres which inhibit the vaso-motor centre, dilate the blood-vessels of the stomach, and cause the gastric juice to be poured out.

Effects of dividing the Vagi.—If the vagi be divided in the neck of a rabbit or dog, the following phenomena will be noticed :—

1. The number of respirations per minute will fall to one-third their normal number, but each respiration is about five times as deep, so that the quantity of air entering the chest is not altered. The vocal cords are apt to fall together from paralysis of the muscles of the larynx. Foreign bodies, as food ingested and mucus, are liable to accumulate in the air-passages.

2. The number of the contractions of the heart will be increased about 20 per cent., and in the dog at least there is increased arterial pressure.

3. Food, if swallowed, accumulates in the œsophagus. Presence of food in the stomach no longer excites the secretion of gastric juice ; though this latter effect is denied by some.

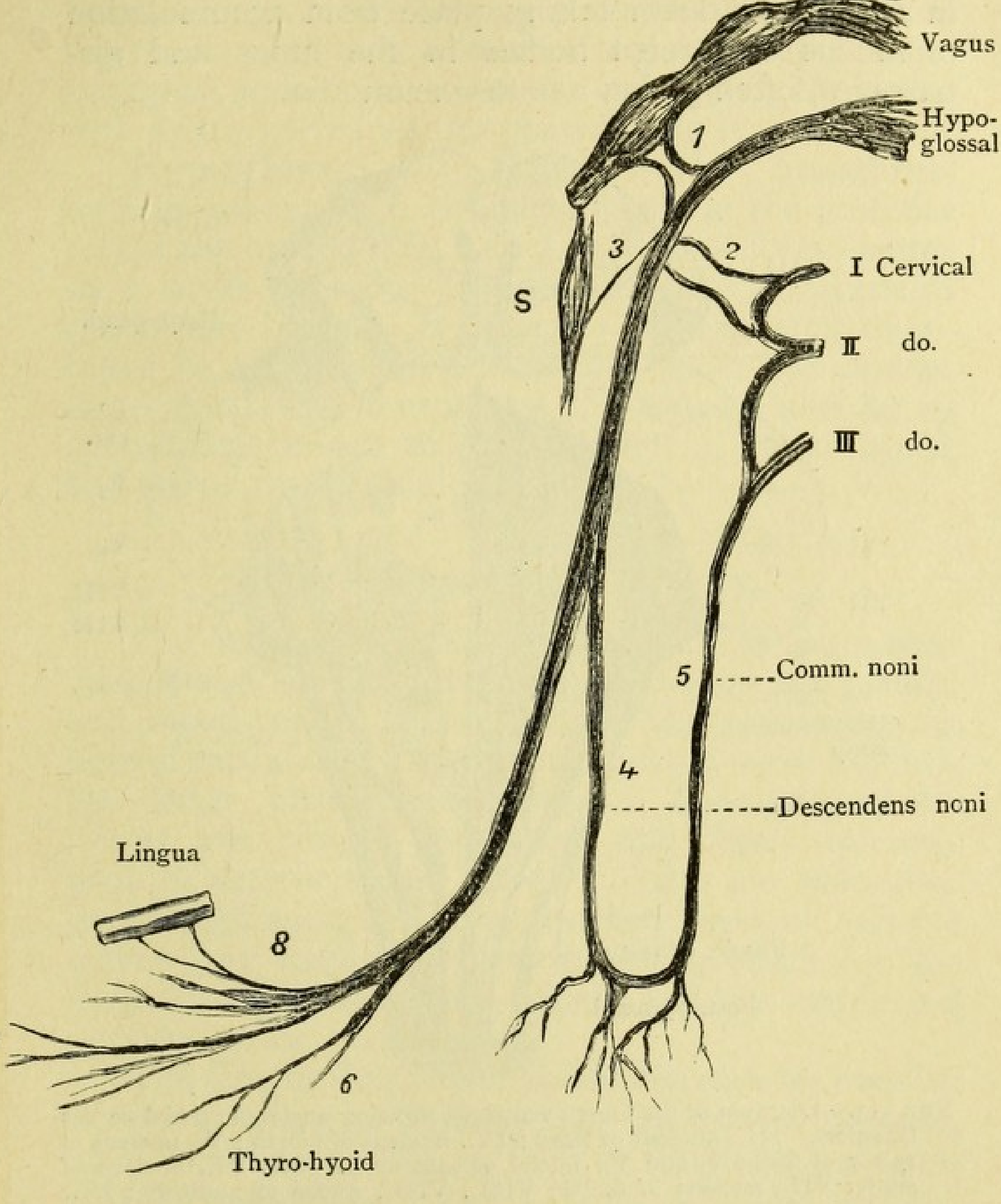

FIG. 112.—Diagram of the hypoglossal nerve, its connection, and branches (after Young). HYPOGLOSSAL NERVE: 1, communicating branch to ganglion of trunk; 2, filaments to loop of first and second cervical; 3, filament to sympathetic; 4, descendens noni; 5, communicans noni; 6, branch to thyro-hyoid; 7, terminal muscular branches; 8, communicating with lingual of fifth.

ganglion; it accompanies the internal carotid into the skull, and divides into an outer and inner branch. The *outer* branch forms the *carotid plexus*, which lies on the outer side of the internal carotid, and communicates with the Gasserian and Meckel's ganglia and the sixth nerve. The *inner branch* also accompanies the internal carotid, and forms the *cavernous plexus*; it communicates through the plexus with the third, fourth, fifth, and sixth nerves, and with the ophthalmic ganglion. Terminal filaments from these two plexuses accompany the branches of the internal carotid. The superior cervical ganglion also gives an *inferior* branch to the middle ganglion, *external* branches to cranial and spinal nerves, *internal* branches to pharynx, larynx, and heart (the latter being called the superior cardiac nerve), and *anterior* branches to the external carotid. The *middle cervical ganglion* communicates with the ganglia above and below, and gives spinal, thyroid, and cardiac branches. The *inferior cervical ganglion* communicates with the middle ganglion, gives branches which travel with the vertebral artery and form a plexus around it, also the inferior cardiac nerve.

Cardiac Nerves.—The superior, middle, and inferior cardiac nerves come from the cervical ganglia; the middle is the largest. The *deep cardiac plexus* lies on the bifurcation of the trachea and behind the arch of the aorta, and is formed by the cardiac branches of the sympathetic and vagi. The *superficial cardiac* plexus lies below the arch of the aorta and in front of the right pulmonary artery; it helps to form the *anterior coronary* plexus, the *posterior coronary plexus* being formed by the deep cardiac plexus.

The **Thoracic Sympathetic** consists of a series of ganglia, placed on each side of the spine, resting against the heads of the ribs. The *external* branches of the ganglia communicate with the dorsal spinal nerves. The *internal* branches of the upper six supply the aorta and pulmonary plexus ; the internal branches of the lower six unite to form the three splanchnic nerves. The *great splanchnic* is formed by branches from the sixth to the tenth, it perforates the diaphragm, and terminates in the semi-lunar ganglion and renal plexus. The lesser splanchnic is formed by the tenth and eleventh ganglia, pierces the diaphragm, and enters the cœliac plexus. The smallest splanchnic comes from the last ganglion and passes to the renal plexus. The solar, or epigastric plexus, surrounds the cœliac axis, and sends branches forming plexuses, which surround the phrenic, gastric, hepatic, splenic, renal, superior and inferior mesenteric and spermatic arteries. The semi-lunar ganglia, which are situated on each side of the cœliac axis, are the largest ganglia of the body.

The **Lumbar portion** of the sympathetic consists of four ganglia connected by nerves.

The **Pelvic Sympathetic** consists of four or five ganglia on each side. The *hypogastric plexus* is situate between the common iliacs, and supplies branches through the inferior hypogastric plexus to the rectum, bladder, prostate, vagina, and uterus. Branches accompany the external iliacs to the lower extremities.

Functions of the Sympathetic.—The centre of the sympathetic system is in the medulla. Section of the cord below the medulla causes a general dilatation of blood-vessels throughout the body. The ganglia take part in the reflex and automatic acts of the body ; such are the ganglia of the intestines and the ganglia situated in the heart. The non-striated muscles of the body, as the muscular fibres surrounding the blood-vessels, are supplied by the sympathetic.

The **Cervical Sympathetic** contains—

1. Vaso-motor fibres for the corresponding side of the head.
2. Fibres which supply the dilating muscular fibres of the iris.
3. Accelerating fibres for the heart.
4. Fibres for the salivary and lachrymal glands.
5. Fibres proceeding to the medulla which excite the inhibitory fibres of the vagus.
6. Fibres to medulla, which stimulate the vaso-motor centre.

The **Thoracic Sympathetic** gives off through the splanchnics—

1. Vaso-motor fibres for the vessels of the viscera.
2. Inhibitory fibres for intestine.
3. Fibres inhibiting renal secretion.
4. Fibres which inhibit the heart reflexly.

The **Abdominal** and **Pelvic Sympathetic** contain fibres which are distributed to the vessels of this part, but little is known of them experimentally.

CHAPTER XIX.

THE SENSES.

Smell.

THE mucous membrane of the nose is supplied with branches of the olfactory nerve in the upper third of the nasal cavity ; branches of the second division of the fifth are distributed over the whole surface. The surface is increased by the turbinated bones, which are highly developed in some of the lower animals. The mucous membrane of the upper or olfactory region is provided with modified columnar cells, with which the terminations of the olfactory nerves are connected (*see* p. 275).

Odoriferous substances give off minute particles, which, when inhaled, come in contact with the epithelium of the olfactory tract, and excite the terminations of the olfactory nerve, giving rise to the sensations of smell. Oxygen seems necessary to the development of the sense of smell; if the nostrils be filled with rose water, or other odoriferous fluid, no sensation of smell is produced.

Pungent and irritating odours, as of ammonia, are perceived by the fifth.

Taste.

The tongue is the organ of taste, though in reality we perceive many odoriferous substances taken as food and drink rather by the sense of smell. The mucous membrane of the tongue receives the impressions made upon it by the food, and these impressions are carried to the brain by special nerves. The papillæ lodge the terminations of the nerves and the *taste-buds* with which the nerves are connected. The nerves which, directly or indirectly, administer to the sense of taste are (1) the glosso-pharyngeal, supplied to the circumvallate papillæ; (2) the lingual, to the front and sides of the tongue; and (3) the chorda tympani.

Special Functions.—1. *Glosso-pharyngeal*, bitter tastes; savoury tastes. 2. *Lingual*, pungent tastes, acids, pepper, &c.; sweet tastes; common sensation; 3. *Chorda tympani* stimulates secretion of saliva.

It is necessary for the development of taste that the substance should be in solution, one of the offices of the saliva being to dissolve sapid substances and so render them more evident to the taste. A temperature of 40° C. is the most favourable one for tasting.

Feeling and Tactile Impressions generally.

The afferent spinal nerves are distributed to all parts of the body and convey to the brain various sensations arising in the different organs. These may be divided into—

(*a*) Sensations of touch or simple contact.
(*b*) Sensations of pain.
(*c*) Sensations of temperature.
(*d*) Sensations of pressure.
(*e*) Muscular sensations or muscular sense.

(*a*) **Sensations of Touch.**—The skin with its papillæ and tactile corpuscles and nerve-terminations is the organ of touch. By its means we are enabled to recognise the shape, the size, the hardness, the roughness or softness of the various bodies with which we come in contact, though aided in an important manner by the muscular sense. The presence of special end organs in the skin is as necessary for the sensation of touch as the rods and cones of the retina are necessary for the sense of sight. In the cavity of the mouth, more especially in the mucous membrane of the tongue, there are also sensory end-organs, and the tongue is very sensitive to impressions of contact. On the other hand, the mucous membranes of the œsophagus, stomach, and intestine are insensitive to simple contact, and we have only vague feelings of pain or discomfort when they are injured or inflamed. When any foreign substance comes in contact with any part of the skin, the sensation is referred by the brain to that particular spot. This power of localising sensations of touch differs in different parts of the body. If the two points of a pair of compasses be made to touch the tongue, they are distinctly felt as two when 1·1 mm. apart, whereas on any other part of the body they would be felt as only one. On the tips of the fingers they are felt as two points when 2·2 mm. apart, but when applied to the back they have to be separated 66 mm. before being felt to be double. The impairment or loss of tactile sensibility is called *anæsthesia*; there is generally also insensibility to pain and variations of temperature as well. Occasionally, in morbid conditions, there is insensibility to pain, with but little impairment of touch; this condition is termed *analgesia*.

(*b*) **Sensations of Pain.**—Injury to, or excessive stimulation of, any sensory nerve gives rise to the sensation of pain. The stimulus may be mechanical, thermal, or electrical. In inflammation the parts become highly sensitive, and a slight stimulus, even the least touch, may give rise to severe pain. Pain may vary from a feeling of discomfort or irritation to the acutest agony.

(*c*) **Sensations of Temperature.**—The raising or lowering of the temperature of the skin by the approach of, or contact with, hot or cold bodies gives rise to thermal sensations which may be pleasurable or highly painful. Bodies of the same temperature as the body, as lukewarm water, give rise to no thermal sensations. We are able roughly to judge of the temperature of a body, but we are especially liable to be deceived, inasmuch as good conductors of heat appear respectively hotter or colder than bad conductors, and the sensations also depend largely on the temperature of our skin. When our hands are cold, we judge bodies with which they come in contact to be warmer than they really are, and *vice versâ*.

(*d*) **Sensations of Pressure.**—The acuteness of the skin for estimating pressure sensations may be estimated by placing weights on the skin of different parts of the body. Thus it is estimated that a weight of ·002 gramme can be perceived when laid on the skin of the forehead ; on the palmar surface of the index finger ·005 gramme.

(*e*) **Muscular Sense.**—It is generally believed that there are special sensory nerves supplied to the muscles, which conduct to the sensorium sensations connected with the action of the muscles. By means of these afferent impressions we are made aware of the condition of the muscles, whether at rest or in active contraction, and also get information as to the amount of exertion they are putting forth. Aided by the sensations of pressure, we are enabled to judge of the weight of a body held in the hand. In locomotor ataxia, where there is disease of the posterior roots and posterior columns of the cord, there is more or less loss both of the sense of touch in the soles of the feet and also of muscular sense. Under these circumstances, while the patient retains full motor power in the muscles, his gait is difficult and awkward, as he does not know accurately the position of his feet or how much muscular power to put forth ; such are, therefore, guided largely by sight, and are unable to walk or balance themselves with their eyes shut.

The fact that in some forms of paralysis there may be insensibility to pain, and yet the sensations of touch, temperature, pressure, &c., may be present, makes it probable that the different forms of sensation travel to the brain by different routes.

Sight.

THE EYE.

Structure.—The eye has three tunics, or layers :—

(1) Sclerotic, and cornea.
(2) Choroid, iris, and ciliary processes.
(3) Retina.

And three refracting media :—

(4) Aqueous humour.
(5) Crystalline lens.
(6) Vitreous humour.

(1) The **Sclerotic** is a firm, dense, fibrous membrane, forming $\frac{5}{6}$ths of the external coat of the eyeball. It is composed of white fibrous tissue, and fine elastic fibres, with numerous connective-tissue corpuscles. It is continuous in front with the cornea, and is pierced behind by the optic nerve. It contains blood-vessels and nerves. The loose tissue next to the sclerotic contains in dark eyes numerous pigment corpuscles, and is called the *lamina fusca*.

The **Cornea** is transparent, and forms $\frac{1}{6}$th part of the external tunic. It has five layers (fig. 115) :—

(1) Epithelial cells of conjunctiva.
(2) Anterior elastic lamina.
(3) Cornea proper.
(4) Posterior elastic lamina.
(5) Layer of flattened cells lining anterior chamber.

The cornea proper is continuous with the sclerotic, and consists of about sixty lamellæ of transparent fibrous tissue, and numerous corpuscles contained in the cell spaces. The fibres comprising the lamellæ run parallel to the surface of the cornea ; they cross one another at right angles in the alternate layers. The fibres are held together by a semi-fluid cement of the nature of globulin. The cell-spaces and corpuscles are situated between the lamellæ, and appear fusiform in vertical section, being seen sideways. When stained with chloride of gold, and seen in section made parallel to the surface, they appear as granular nucleated corpuscles, with anastomosing branches, and only partially filling their cell-spaces ; the room left being a lymph space. It is evascular, but contains nerves.

(2) The **Choroid** is a dark membrane lining

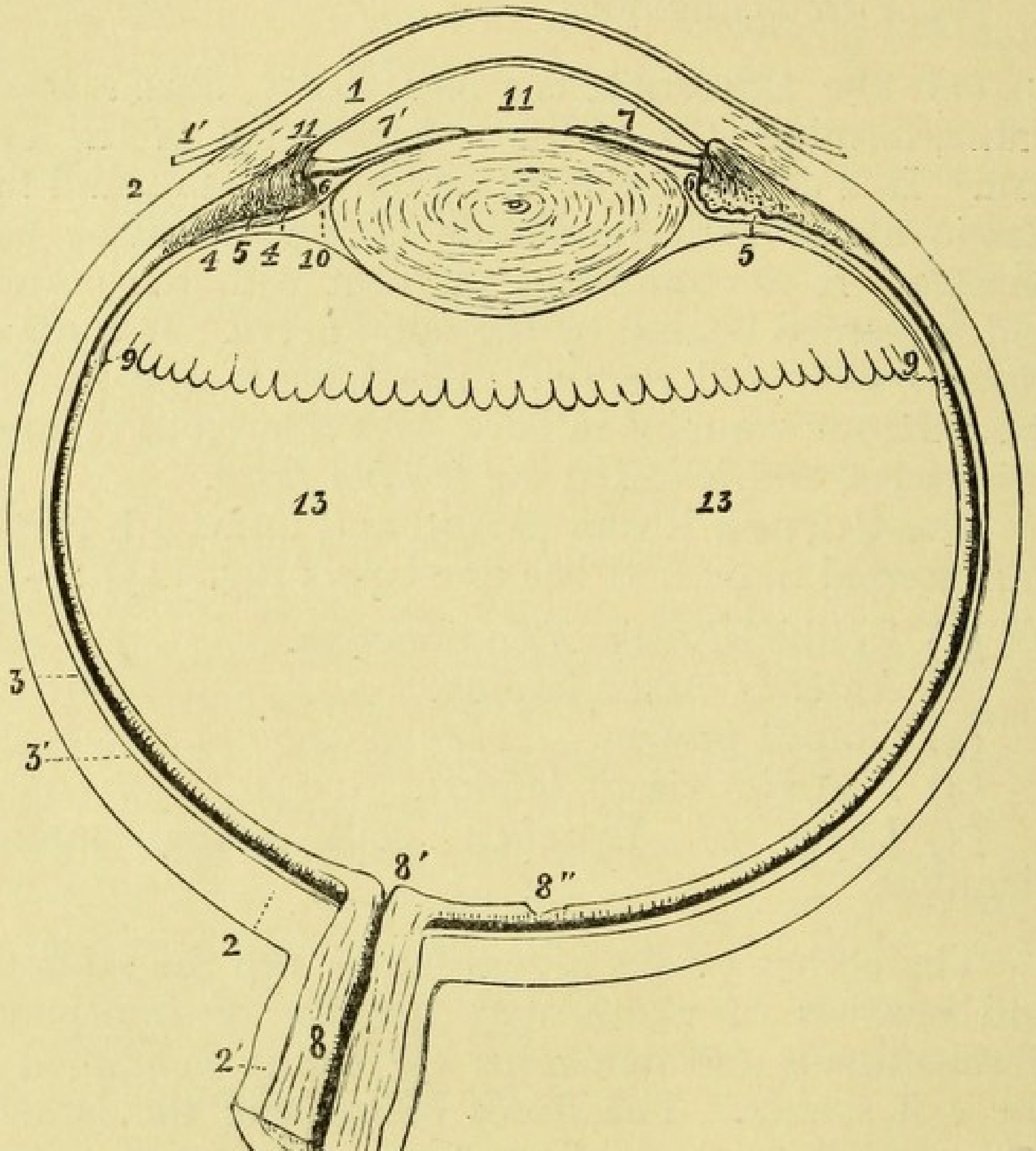

FIG. 114.—General view of the parts of the human eye, horizontal section (Quain's Anatomy). 1, cornea; 1′, conjunctiva; 2, sclerotic; 2′, sheath of optic nerve; 3, 3′, choroid; 4, 4′, ciliary muscle; 5, ciliary processes; 6, posterior division of the aqueous chamber in front of the suspensory ligament of the lens; 7, 7′, the iris; 8, central artery of the retina; 8′, its entrance in the centre of the optic disc; 8″, fovea centralis; 9, ora serrata; 10, canal of Petit; 11, aqueous chamber; 12, lens; 13, vitreous humour.

$\frac{5}{6}$ths of the eyeball, internal to the sclerotic. Its external layer consists of veins—the *venæ vorticosæ*

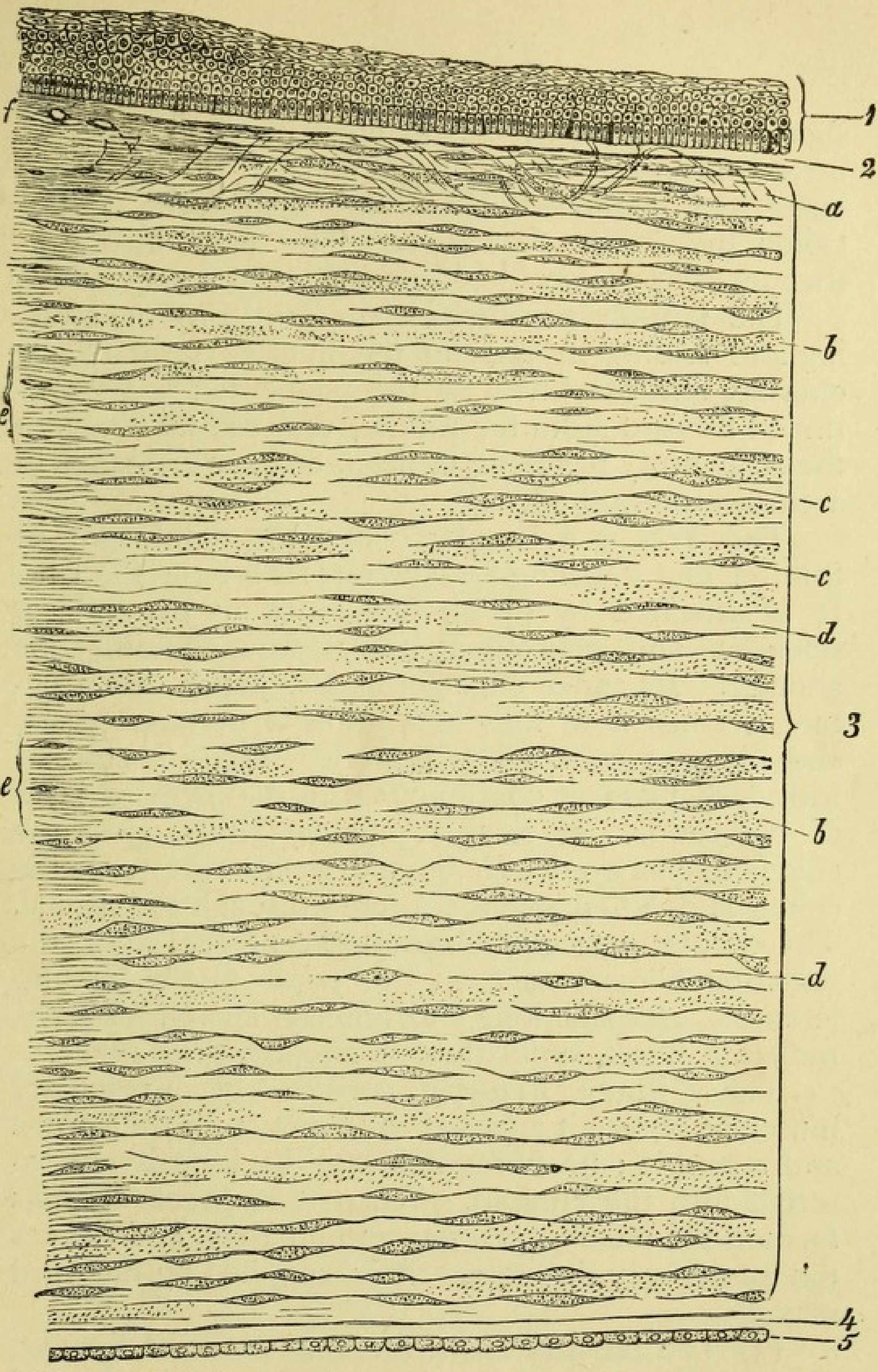

FIG. 115.—Vertical section of human cornea from near the margin (Quain's Anatomy). 1, epithelium ; 2, anterior homogeneous lamina ; 3, substantia propria of the cornea ; 4, posterior elastic lamina ; 5, epithelium of the anterior chamber ; *a*, oblique fibres ; *b*, lamellæ of the fibres cut across, producing a dotted appearance ; *c*, corneal corpuscles appearing fusiform in section ; *d*, lamellæ the fibres of which are cut longitudinally ; *e*, transition to the sclerotic ; *f*, blood-vessels.

short ciliary arteries, elastic fibres, and stellate pigment cells. Its internal layer consists of fine capillaries and pigmented connective-tissue cells, and is called the *tunica Ruychiana.* The pigmented epithelium layer is considered part of the retina.

The **Ciliary processes** are formed by the plaiting and folding inwards of the internal layer of the choroid, and are lined by the pigmented layer continued forward from the retina ; they are attached to the suspensory ligament in front, and are arranged in a circle around the lens.

The **Iris** is a circular contractile diaphragm in front of and touching the anterior surface of the lens. It is attached by its circumference to the cornea, sclerotic, and choroid at their junction with one another. Its inner edge forms the pupil. In structure it consists of muscular fibres, a fibrous stroma, and pigment cells. The posterior surface is covered with dark pigment continuous with the pigment layer of the retina. It is this pigment which gives the colour to *blue* eyes. In *black*, *brown*, or *grey* eyes the colour is due to pigment scattered through the stroma. The circular muscular fibres surround the pupil, the radiating fibres pass from the pupil to the circumference. *Arteries*, long and anterior ciliary. *Nerves*, radiating fibres, sympathetic ; circular, third nerve.

The **Ciliary Muscle** consists of involuntary muscular fibres ; it arises at the junction of the cornea and sclerotic ; its fibres radiating backwards are inserted into the choroid. When it contracts it pulls forward the ciliary processes and choroid, and relaxes the suspensory ligament. It is supplied by the third nerve.

(3) The **Retina** forms the inner tunic of the eye, and contains the terminations of the optic nerve and certain minute bodies, the *rods* and *cones*, with which the optic nerve is connected. Its thickness varies

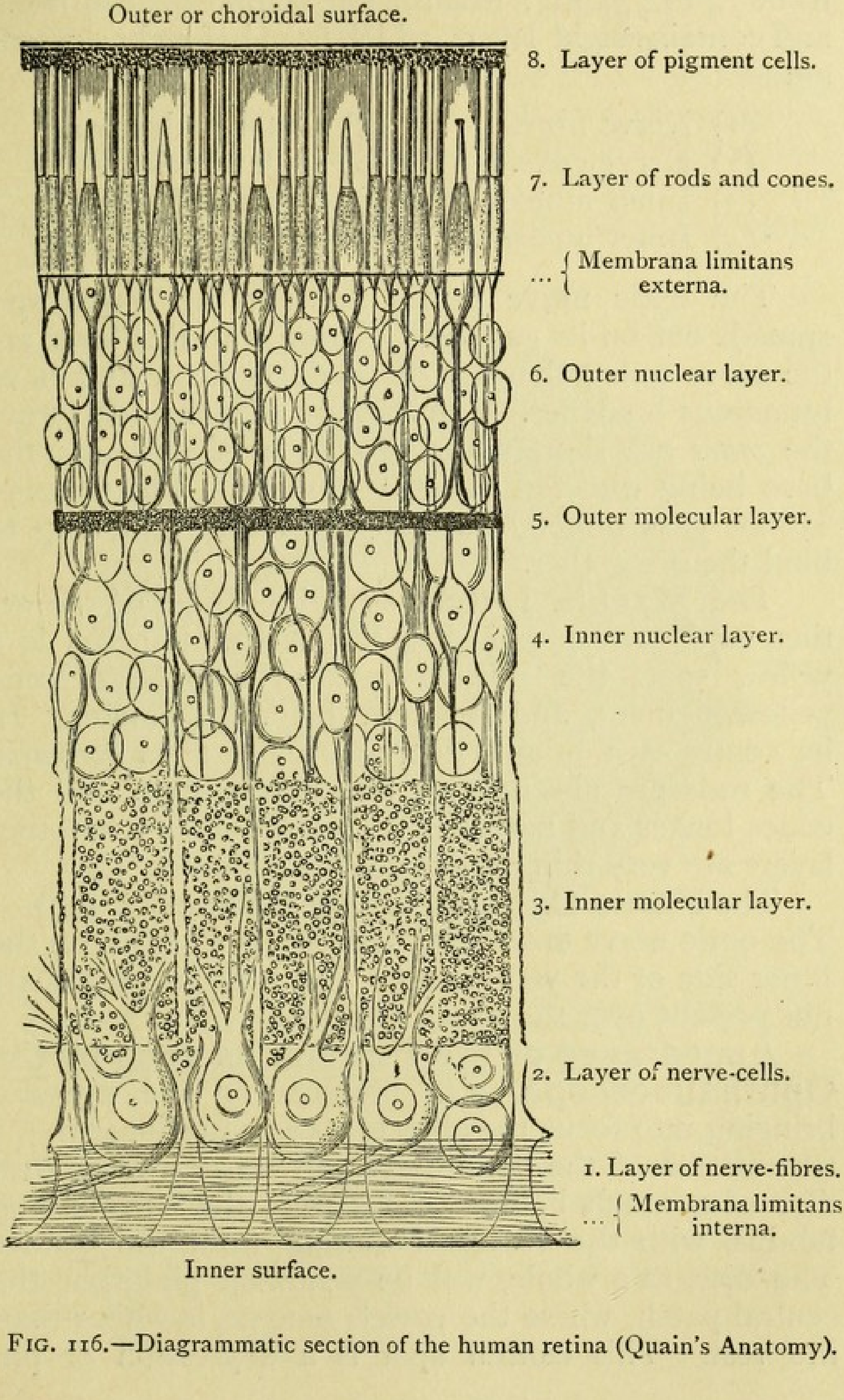

FIG. 116.—Diagrammatic section of the human retina (Quain's Anatomy).

from $\frac{1}{50}$ to $\frac{1}{200}$ in.; it is thicker behind than in front, and contains eight layers, which from before backwards are—

(1) Nerve fibres.	(5) Outer molecular.
(2) Nerve cells.	(6) Outer nuclear.
(3) Inner molecular.	(7) Rods and cones.
(4) Inner nuclear.	(8) Pigment cells.

The optic nerve passes through the retina and spreads out on its surface. External to this layer are the nerve-cells; they are of pyriform shape and have numerous branches. The *rods* are of elongated form; the *cones* are shorter and thicker at their bases, the base being directed towards the lens. The fibres of Müller pass directly through the layers and help to bind them together.

The **Macula Lutea.**—In the centre of the retina, and corresponding to the axis of the eye, is a yellow spot—the macula lutea; it contains some yellow pigment, and is about $\frac{1}{20}$ in. in diameter. In its centre is a minute depression, the *fovea centralis.* The rods are absent over the yellow spot, and the cones longer and narrower than elsewhere. The other layers are very thin over the fovea centralis.

The **Porus Opticus, or Optic Disc** (fig. 117).—The optic nerve enters the retina about $\frac{1}{10}$ in. on the inner side of the yellow spot. The rods and cones are not present over the porus opticus.

Appearance of the Fundus as seen by the Ophthalmoscope.—On illuminating the eye and bringing into focus the objects at the posterior part, the termination of the optic nerve will be seen as an oval disc of a much lighter colour than the surrounding fundus, with the vessels radiating from the centre. The disc, as a whole, will be yellowish pink, but the central patch, where the vessels emerge, is whiter than the rest. This central spot is a depression or pit, with irregular markings, caused by the holes in the *lamina cribrosa*, through which the nerve-fibres pass. In many discs a white ring may be seen surrounding the disc, which represents the border of the sclerotic, and outside this is a deposit of pigment. The retinal vessels branch from the centre of the disc, the arteries being smaller and lighter in colour than the veins.

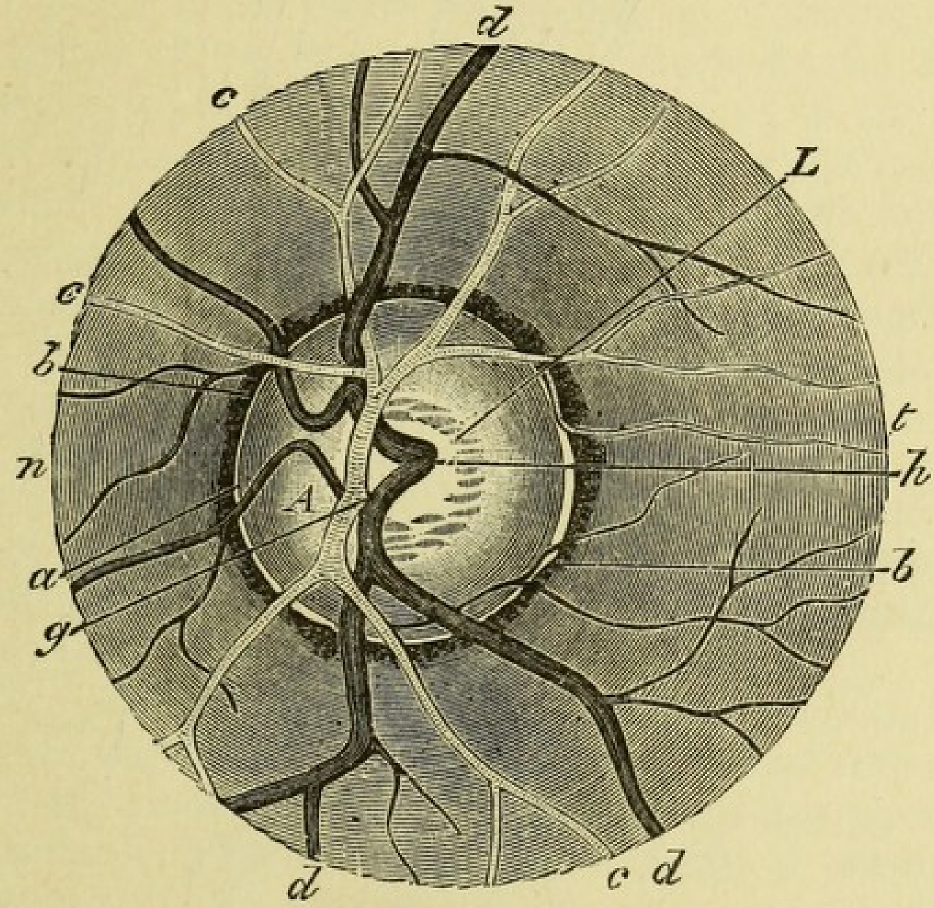

FIG. 117.—The retina with the point of entrance of the optic nerve (Quain's Anatomy). A, optic nerve; L, lamina cribrosa; *a*, ring of connective tissue; *b*, choroidal ring; *c*, branches of the central artery of the retina; *d*, branches of the central vein *h*; *n*, inner or nasal side; *t*, outer or temporal side.

The disc is surrounded by the bright red reflection from the choroid, which is generally uniform, at other times mottled by the choroid vessels being visible. In some cases the yellow spot and fovea centralis may be readily seen.

(4) The **Aqueous Humour.**—The aqueous

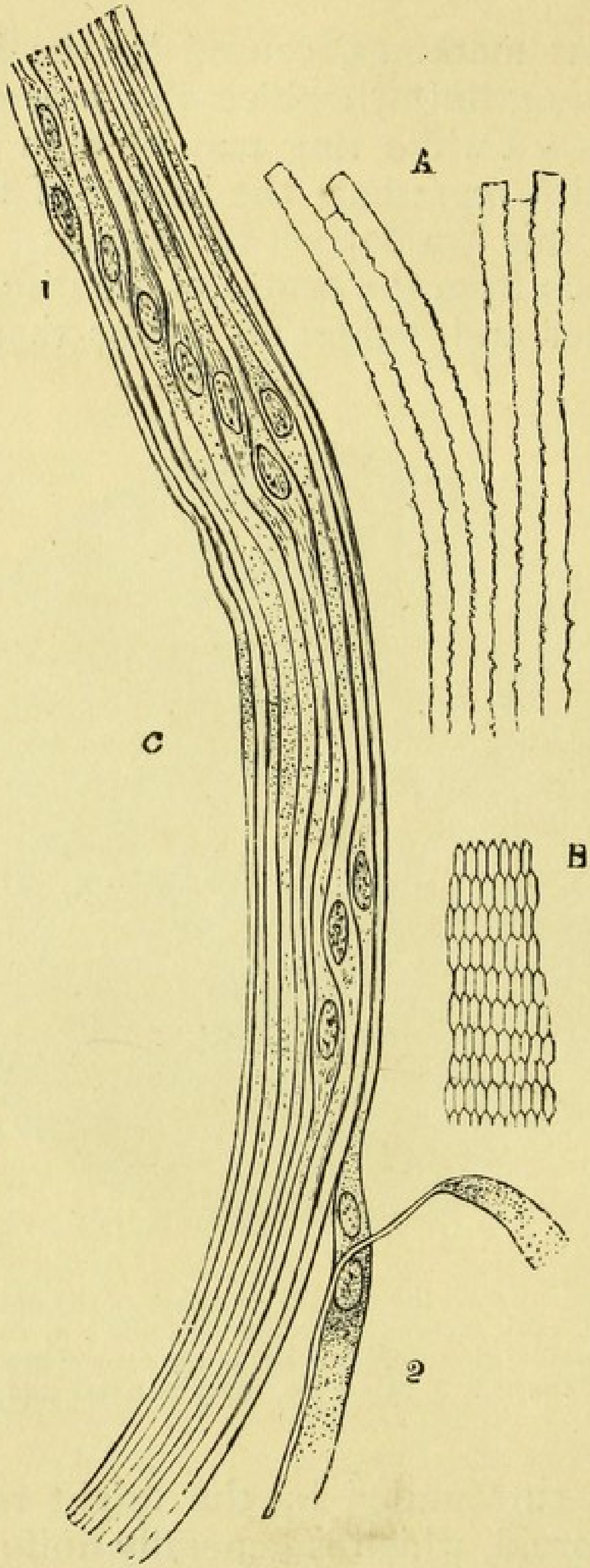

FIG. 118.—Fibres of crystalline lens × 350 (Quain's Anatomy). A, longitudinal view of the fibres of the lens of the ox, showing the serrated edges; B, transverse section of the fibres of the lens from the human eye; C, longitudinal view of a few fibres from the equatorial region of the lens. Most of the fibres in C are seen edgeways; and, at 1, present the swelling and nuclei of the nuclear zone, and, at 2, the flattened sides of two fibres are seen.

fluid fills the space between the lens and cornea. It closely resembles water, but contains a small quantity of salts dissolved in it.

(5) The **Lens** is about $\frac{1}{3}$ in. in diameter, biconvex, being more convex behind than in front, and is surrounded by a capsule. The outer portion of the lens is soft and easily detached, the succeeding layers are firmer, and the central part or nucleus is harder still. Faint white lines may be seen radiating from the centre to the circumference, which in the fœtus are three in number and well-marked. In the hardened lens a succession of concentric laminæ may be detached, like the coats of an onion. The laminæ are composed of fibres, their edges are finely serrated and fit into each other (fig. 118). The fibres are six-sided prisms, and are in reality elongated cells, and in the young state contain nuclei.

Changes in the Lens by Age.—In the *fœtus* the lens is nearly spherical. In the *adult* the anterior surface becomes more flattened than the posterior. In *old age* it becomes more flattened at both surfaces, and its transparency is impaired.

(6) The **Vitreous Humour.**—The vitreous body occupies the chamber between the lens and retina. It is of a gelatinous consistence, and forms a support for the retina. When hardened it exhibits a laminated structure and numerous corpuscles scattered through it.

Accommodation.

If a convex lens be made to throw the image of an object upon a screen, and then the object move farther away or nearer to the lens, the image on the screen will be indistinct, being out of focus, and the lens must be moved to get a distinct image. In a similar manner, the crystalline lens must be moved, or its convexity altered, when viewing objects at different distances, in order to obtain distinct images on the retina. If distant objects are being looked at, objects at a foot distant will be indistinct, and *vice versâ*, unless some accommodating mechanism exists. This is accomplished, not by moving the lens as in a telescope, but by altering its convexity. The lens is more or less elastic, and its anterior surface is kept flattened by the tension of the elastic suspensory ligament. If the suspensory ligament is relaxed the lens becomes more convex, and when the suspensory ligament tightens it flattens the lens again. The contraction of the ciliary muscle, by drawing forward the ciliary processes, relaxes the suspensory ligament, and therefore the lens becomes more convex.

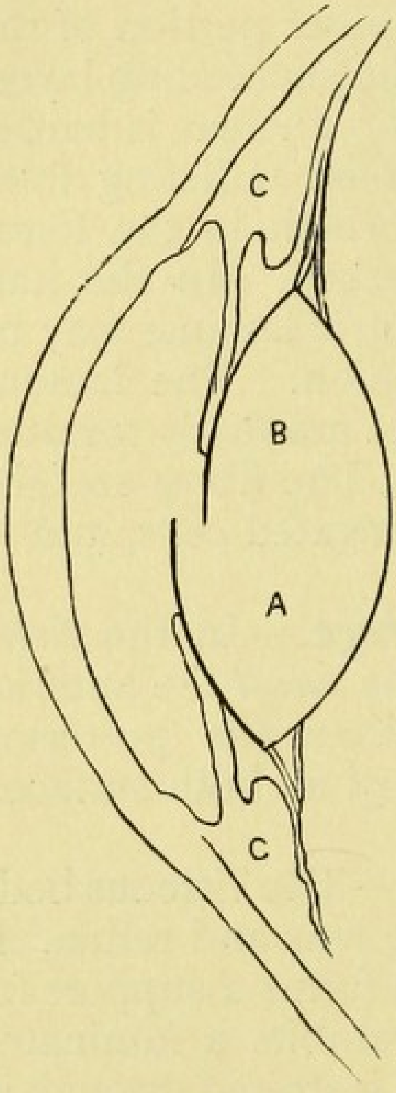

Fig. 119.—Mechanism of accommodation. A, the lens during accommodation for near objects; B, for distant objects; C, position of ciliary muscle.

The accommodation of the eye for near objects is a muscular act, being effected by the contraction of the ciliary muscle, the lens becoming more convex; accommodation for distant objects is simply effected by the elasticity of the suspensory ligament, the ciliary muscle relaxing, and the lens becoming flatter. Images of distant objects are thrown upon the retina when the ciliary muscle is not contracting, images of near objects are thrown behind, and the lens must be rendered more convex in order to bring them to a focus on the retina (fig. 119).

Hypermetropia.—In the hypermetropic eye the horizontal axis of the eye is shortened, so that the retina is nearer the lens than in the normal eye. The images of objects are formed behind the retina; those of distant objects can be brought to focus on the retina by contraction of the ciliary muscle, but the images of near objects are formed so far behind that no effort of the ciliary muscle will focus them on the retina. Convex spectacles are used especially for near objects.

Myopia.—In the myopic eye the horizontal axis is elongated, so that the retina is farther away from the lens than in the normal eye. The image of objects will fall in front of the retina, especially the images of distant objects. The lens cannot be rendered sufficiently flat to bring them into focus, and concave glasses must be used.

Presbyopia, or the long sight of old people, consists in a defective condition of the accommodation apparatus, so that, while seeing distant objects distinctly, near ones are indistinct.

Astigmatism.—It sometimes happens that the surfaces of the cornea are not equally convex, the cornea being more convex in the vertical meridian than in the horizontal, or *vice versâ*. This will interfere with the distinctness of vision ; most eyes are slightly astigmatic, with the greater curvature in the vertical meridian.

Movements of the Pupils.

The contraction of the pupil when light falls on the eye is a reflex act. The dilating fibres are supplied by the sympathetic, and the circular by the third. The sympathetic is constantly in action, so that when the stimulus of light is removed the pupil dilates.

The circular fibres contract and overcome the contraction of the radiating when stimulated by light or during sleep. Division of the sympathetic in the neck of the rabbit causes contraction of the pupil.

The pupil *contracts*—

(1) *When stimulated by light.*
(2) *When we accommodate for near objects.*
(3) *When the eyeball is turned inwards.*
(4) *Through the action of certain drugs—opium, calabar bean.*

The pupil *dilates*—

(1) *When the stimulus of light is removed.*
(2) *When the eye accommodates for distant objects.*
(3) *Through the action of certain drugs, as atropine.*
(4) *In dyspnœa.*

Functions of the Retina.

The retina receives the images of objects, and through its agency they are perceived by the mind. The exact use of the different layers of the retina is unknown, but the perception of light is probably due to the rods and cones. The power of distinguishing colour is said to be due to the cones.

The *optic nerve* enters the retina $\frac{1}{10}$ in. to the inner side of the yellow spot, and when viewed from the front by means of an ophthalmoscope it appears like a round white spot, termed the optic disc. The optic disc is insensible to light. This can be demonstrated by fixing the right eye (the left being closed) on a dark spot on a sheet of paper held 10 in. from the eye. If a black point, like the tip of a pen, be made to move from right to left towards this spot, it becomes invisible when it reaches a point $2\frac{1}{2}$ in. from it, but will reappear again on moving nearer. The image of the spot is projected on to the macula lutea in the centre of the retina, and the image of the moving point falls on the optic disc ($\frac{1}{10}$ in. from yellow spot) when $2\frac{1}{2}$ in. from the fixed black spot. This shows that the optic disc is insensible to light.

The *macula lutea* occupies the centre of the retina, and is the most sensitive part of it. Small objects appear most distinct when their images fall in the centre of the retina, as when we look straight at an object. Points which appear separate when their images fall on the yellow spot appear as only one when their image falls elsewhere, as when they are moved out of the centre of the field.

Purkinje's Figures.—If a strong ray of light be concentrated on the edge of the sclerotic near the cornea, the light will pass through the sclerotic and throw the shadow of the retinal vessels on the retina, a dark branching figure being seen. Or, if on entering a dark room a candle is moved up and down by the side of the eye, the same appearance will be seen. As the vessels lie in front of the rods and cones, it is probable that it is through them that light is perceived.

Hearing.

THE EAR.

The organ of hearing is divided into—

(1) The external ear.
(2) The middle ear or tympanum.
(3) The internal ear or labyrinth.

(1) The **External** ear consists of the pinna and the external auditory canal. The pinna consists of an irregularly concave piece of yellow elastic cartilage, which receives the sound and conducts it to the

meatus. The external auditory canal is $1\frac{1}{4}$ in. in length, partly cartilaginous and partly bony, and conveys the vibrations of sound to the membrana tympani, which closes its inner end. In its inward course it is inclined somewhat *forwards*, then slightly upwards, and after turning over a convexity in the floor it passes slightly downwards to the membrana.

(2) The **Tympanum** is a small cavity hollowed out of the temporal bone, which communicates with the pharynx through the Eustachian tube, and contains a chain of bones which convey vibrations received by the membrana tympani to the fluids surrounding the nervous mechanism of the internal ear (figs. 121 and 122). Its *roof* is formed by a thin plate of bone which separates it from the cranial cavity. The *floor* is narrow, and corresponds to the jugular fossa beneath. Its *anterior wall* corresponds with the carotid canal, and presents the canal for the tensor tympani and the opening of the Eustachian tube. The *posterior wall* presents the openings of the mastoid cells. The *outer wall* is occupied by the membrana tympani, and near its margin are three small apertures, the *iter chordæ posterius* and *iter chordæ anterius* for the entrance and exit of chorda tympani, and the *Glasserian fissure* for the handle of the malleus, laxator tympani, and some tympanic vessels. The *membrana tympani* is a thin transparent membrane which forms the outer wall of the tympanic cavity; it is of oval form, and placed obliquely, so that its outer surface looks downwards and somewhat forwards. The handle of the malleus is attached to its inner surface, and draws the membrane inwards, so that its outer surface is concave.

On viewing the outer surface of the membrane after removal of superficial layers the handle of the malleus is distinctly seen through the membrane, the long process of the incus appears faintly, running

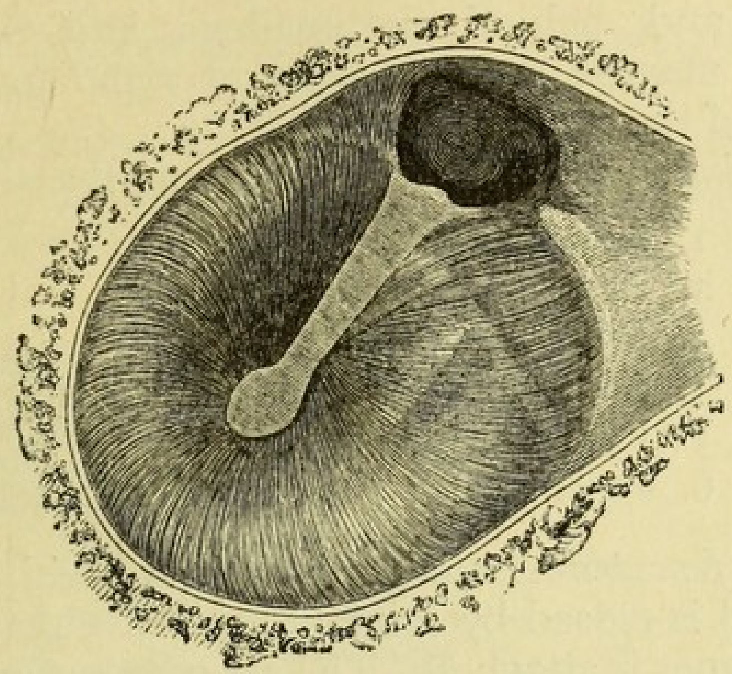

FIG. 120.—View of the outer surface of the left membrana tympani, after the removal of the cutaneous layer × 4 (Quain's Anatomy). See p. 310.

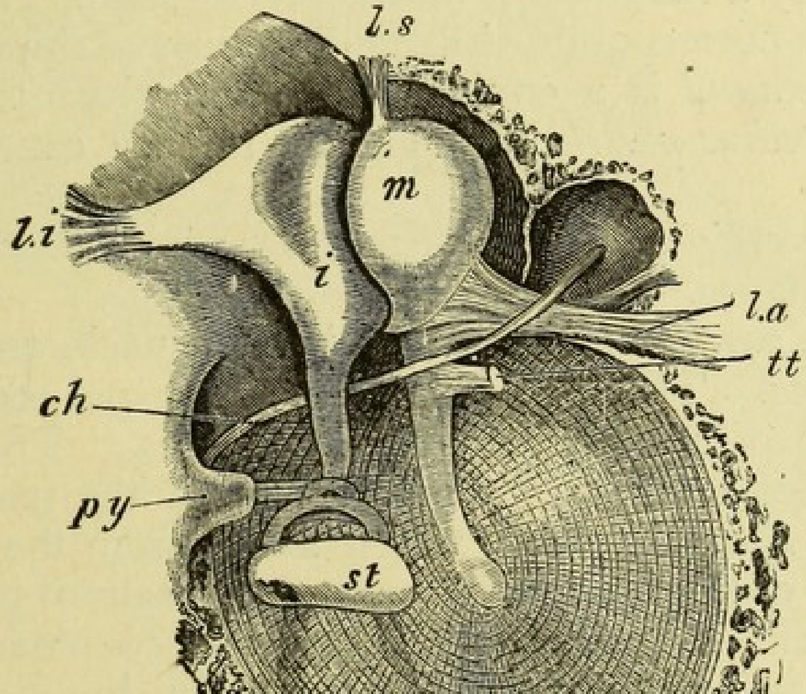

FIG. 121.—View of the left membrana tympani and auditory ossicles from the inner side × 4 (Quain's Anatomy). *m*, malleus ; *i*, incus ; *st*, stapes ; *py*, pyramid from which the tendon of the stapedius muscle is seen emerging ; *tt*, tendon of the tensor tympani cut short ; *la*, anterior ligament of the malleus ; *ls*, superior ligament of the malleus ; *li*, ligament of the incus ; *ch*, chorda tympani.

parallel and behind the malleus, and the chorda tympani may be seen crossing at right angles to the process of the incus (fig. 120).

The *inner wall* (fig. 122) presents the—

1. Fenestra ovalis (*fo*).
2. Fenestra rotunda (*fr*).
3. Promontory (*p*).
4. Ridge of the aqueductus Fallopii (*aF*).
5. Pyramid (*py*).
6. Opening for the Stapedius muscle.

The *fenestra ovalis* communicates with the vestibule, and is closed by a membrane to which the base of the stapes is attached. The *fenestra rotunda*, placed below and behind, opens into the cochlea, but is closed by a membrane in the recent state. The *promontory* corresponds with the first turn of the cochlea. The *pyramid* is a conical projection which transmits the *stapedius muscle* through the minute canal in its centre.

The *ossicles of the tympanum* consist of the malleus, incus, stapes.

The *malleus* consists of a head, a neck, and three processes. The *incus* resembles a bicuspid tooth, and consists of a body and two processes. The *stapes* resembles a stirrup. The muscles of the tympanum are the *tensor tympani*, which arises from the petrous portion of the temporal bone and the walls of its canal; it is reflected round the processus cochleariformis, and is inserted into the root of the handle of the malleus. The *laxator tympani* arises from the spine of the sphenoid, passes through the Glasserian fissure, and is inserted into the neck of the malleus. This muscle is considered by some to be a ligament. The *stapedius* arises from the walls of its canal, and is inserted into the neck of the stapes.

The Eustachian tube is a canal, partly cartilaginous, partly bony, which leads from the pharynx to the tympanum.

The mucous membrane of the tympanum is continuous with the mucous membrane of the pharynx through the Eustachian tube.

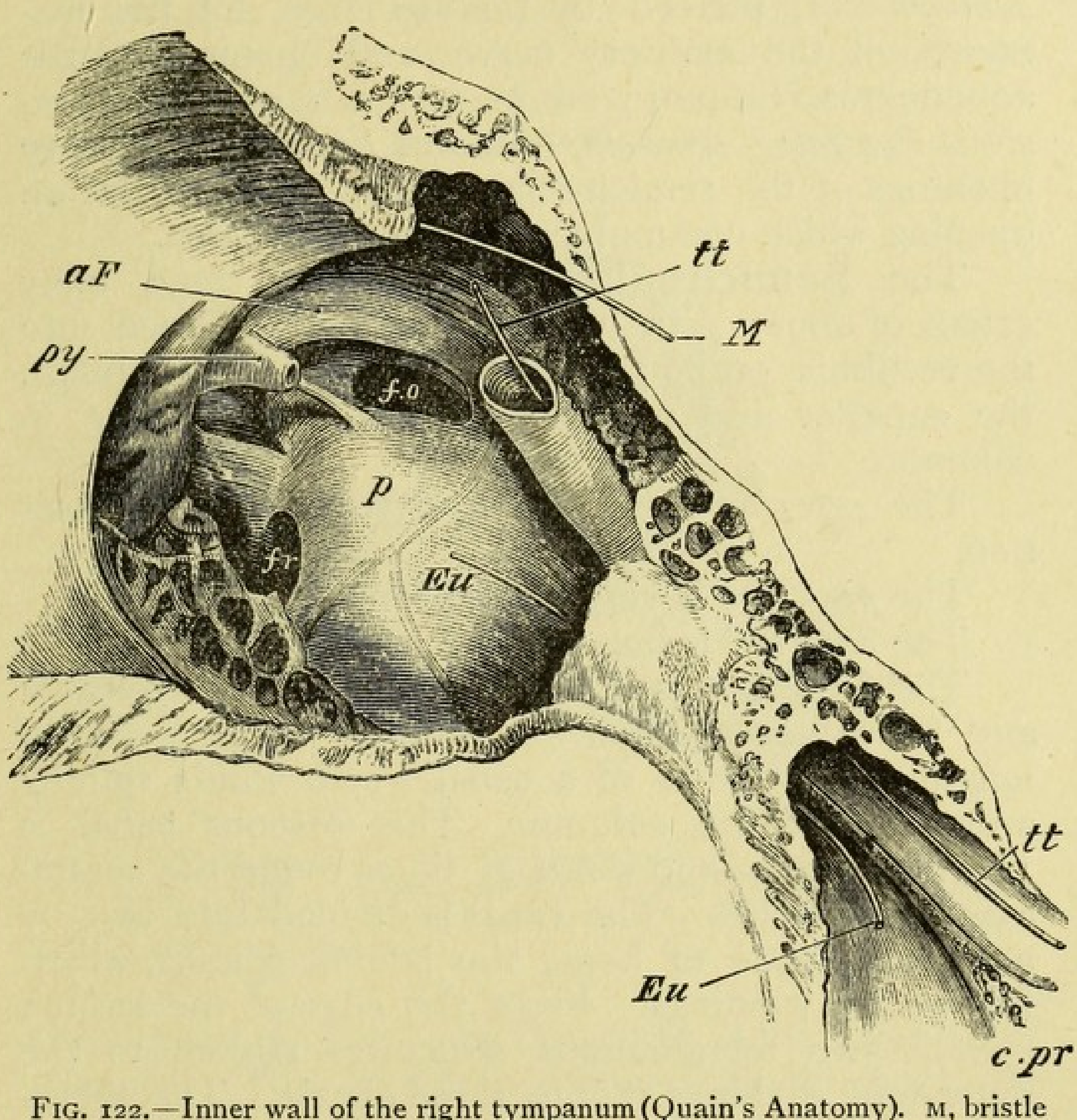

FIG. 122.—Inner wall of the right tympanum (Quain's Anatomy). M, bristle passing into mastoid cells ; *fo*, fenestra ovalis ; *fr*, fenestra rotunda ; *p*, promontory ; *a* F, aqueduct of Fallopius ; *c pr*, processus cochleariformis ; *tt*, bristle passed through the canal for the tensor tympani ; *E u*, bristle in the Eustachian tube.

(3) The **Internal Ear** or **Labyrinth** consists of the vestibule, semicircular canals, and cochlea.

The **Vestibule** is situated on the inner side of the tympanum, behind the cochlea, and in front of the semicircular canals. It is somewhat ovoid in shape, and measures about $\frac{1}{5}$ in. in length. On its *outer* wall is the fenestra ovalis, closed by the base of the stapes and membrane ; on its *inner* wall is the *fovea hemispherica*, pierced by minute holes, for the filaments of the auditory nerve and opening of the aqueductus vestibuli ; on its *roof* is a small depression, the *fovea semi-elliptica*, and *behind* are the five openings of the semicircular canals, and in *front* an opening which communicates with the cochlea.

The **Semicircular Canals** are three bony canals of about $\frac{1}{20}$th in. in breadth, which open into the vestibule, on its posterior aspect, by five openings, the superior and posterior having one opening in common.

The *superior* is vertical and transverse in position.

The *posterior* is vertical and longitudinal.

The *external* is horizontal.

The **Cochlea** is situated in front of the vestibule and resembles a small snail-shell. It is $\frac{1}{4}$ in. in length, and consists of a canal which winds spirally around a central column. This osseous canal is $1\frac{1}{2}$ in. in length, and winds $2\frac{1}{2}$ times round the central axis or modiolus. The canal is divided into two by a delicate plate of bone, the lamina spiralis, which follows its windings. From the edge of the lamina spiralis two membranous structures stretch to the outer wall, dividing it into three canals. The membranes are called the *m. of Reissner* and the *m. of Corti*, or *membrana basilaris.* The canals are the *scala vestibuli*, *scala tympani*, and *scala media* or *canal of Corti*, the latter interposed between the other two. The scala media contains the organ of Corti. The scala tympani communicates with the tympanum by means of the foramen rotundum, the scala vestibuli with the vestibule, though both openings are closed by a membrane in the recent state.

The *membranous labyrinth* is a closed membranous sac containing fluid. It corresponds in shape to the vestibule and semicircular canals, and is continuous with the canal of Corti ; it contains the terminations of the auditory nerve, is filled with the endolymph and surrounded by the perilymph. The vestibular portion consists of two sacs, the *utricle*, lodged in the

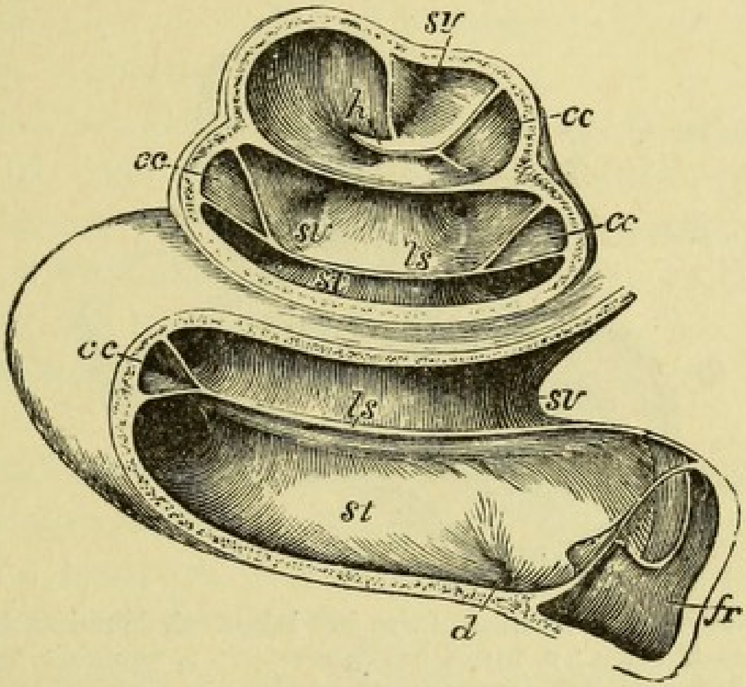

FIG. 123.—Left cochlea of a child (Quain's Anatomy). *fr*, fenestra rotunda *st*, scala tympani ; *sv*, scala vestibuli ; *ls*, lamina spiralis ; *h*, hamulus ; *cc*, canalis cochleæ ; *d*, opening of the aqueductus cochleæ. The organ of Corti is not represented.

fovea hemi-elliptica, and the *saccule* in the fovea hemispherica. The membranous semicircular canals are about $\frac{1}{3}$rd the diameter of the osseous canals ; they are hollow, and open into the utricle. In the endolymph of the utricle, saccule, and ampullæ of the semicircular canals there are hair-like processes attached to the epithelial cells, and numerous crystals of carbonate of lime called *ooliths*.

The *membranous cochlea* consists of the S. vestibuli and S. tympani, containing perilymph, and the canal of Corti, containing the endolymph and organ of Corti.

The *organ of Corti* is situated on the membrana basilaris, and consists of the rods of Corti, and numerous hair-cells. The rods of Corti are arranged in rows, their upper ends in contact with one another, and their lower ends resting on the membrana basilaris. The hair-cells are supported on the rods, and

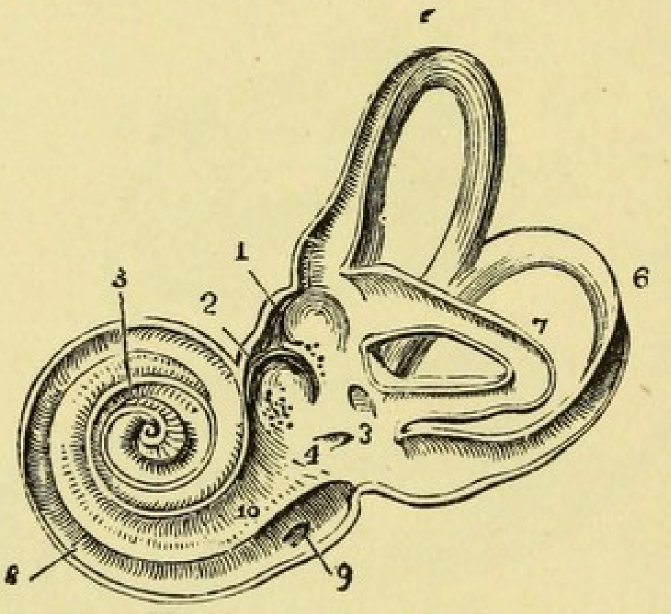

FIG. 124. -View of the interior of the left labyrinth (Quain's Anatomy). 1, fovea hemi-elliptica ; 2, fovea hemispherica ; 3, common opening of the superior and posterior semicircular canals ; 4, opening of the aqueduct of the vestibule ; 5, the superior, 6, the posterior, 7, the external, semicircular canals ; 8, spiral tubes of the cochlea ; 9, opening of the aqueduct of the cochlea ; 10, the lamina spiralis in the scala vestibuli.

consist of columnar epithelium provided with hair-like processes.

The **Auditory Nerve** is distributed to the vestibule and cochlea. The vestibular division divides into five branches, which are distributed to the utricle, the saccule, and the three ampullæ of the semicircular canals. The terminations of the nerves are connected with the hair-cells, and float in the endolymph. The cochlear division passes into a small bony canal, which runs up the modiolus, and then is distributed to the rods of Corti, and hair-cells passing between the layers of the lamina spiralis.

Functions of the External and Internal Ear.—The *external ear* collects the waves of sound, and the auditory canal conveys them to the membrana tympani.

The *membrana tympani* receives the waves, and is thrown into vibrations accordingly.

The *tensor tympani* renders tense the membrana tympani. When the membrane is tense it readily responds to high sounds, and when relaxed it is best adapted for receiving low sounds.

The *auditory ossicles.*—The malleus is attached by its handle to the membr. tymp., and any movement of the latter is communicated to the malleus. The incus and stapes transmit the vibrations to the membrane covering the fenestra ovalis, and the vibrating membrane sets in motion the perilymph of the vestibule.

The *stapedius* regulates the action of the stapes.

The *Eustachian* tube forms a communication between the tympanum and external air, and is opened during the act of swallowing.

The *labyrinth.*—The vibrations communicated by the ossicles to the perilymph of the vestibule pass through the cochlea, ascending by the scala vestibuli, and descending by the scala tympani to the fenestra rotunda ; and also passing along the perilymph of the semicircular canals. The vibrations of the perilymph are communicated to the endolymph of the scala media, and the terminations of the auditory nerve by means of the rods of Corti and hair-cells. The endolymph contained in the membranous labyrinth of the vestibule and semicircular canals in like manner communicates the vibrations to the auditory nerve through the medium of the hair-cells.

The vibrations travel along the following channels to reach the auditory nerve :—

Concha.
External auditory meatus.
Membrana tympani.
Ossicles.

Perilymph of vestibule—utricle and saccule.

Perilymph of S. vestibuli	Perilymph of semicircular canals
,, S. tympani	Endolymph of ampullæ
Endolymph of C. of Corti	Ooliths and hair-cells
Basilar membrane	
Rods of Corti	Auditory nerve
Hair-cells	
Auditory nerve	

Auditory perceptions.—Musical tones and noises are distinguished from one another by the normal ear. *Tones* are produced when a musical instrument or some vibrating body executes regular movements, as, for instance, the string of a violin when struck with the finger. A *noise* is produced when some sounding body makes irregular or unequal movements.

In tones three distinct factors may be recognised :—

1. **Intensity.**—This depends upon the size or amplitude of the vibrations. The smaller the vibrations of the string of a violin, the feebler is the sound.

2. **Pitch.**—This depends upon the number of vibrations occurring in a given time. The greater the number of vibrations per second, the higher is the pitch. It is stated by Preyer that the lowest audible tone lies between 18 and 23 vibrations per second, the highest audible tone being 40,960 vibrations per second.

3. **Quality** or **timbre.**—This depends upon the form of the vibrations. The same note struck on a piano or violin differs in quality or timbre.

CHAPTER XX.

MECHANISM OF SPEECH.

SPEECH constitutes one of the great differences between man and the lower animals, and is of great importance as a means of communication between man and his fellows. It depends—

1. Upon a suitable mechanical apparatus for the production of sounds.
2. Other mechanical arrangements in the oral cavity for modifying those sounds.
3. Nervous centres for co-ordinating the muscular movements, and intellectual powers of a high order to express ideas in language.

I. The Larynx.

The larynx consists of cartilages, various muscles, and ligaments.

1. The **Cricoid** resembles a signet ring, being deep behind and narrow in front. It gives attachment at its front and sides to the crico-thyroid, and behind this to the inferior constrictor. Posteriorly it gives attachment to the œsophagus and crico-arytenoideus posticus. Its upper border gives attachment to the crico-thyroid membrane and crico-arytenoideus lateralis. It has articular surfaces, for the thyroid behind, and arytenoids superiorly.

2. The **Thyroid** cartilage consists of two lateral halves, of a quadrilateral shape, joining at an acute

angle in front, and forming at their upper angle the *pomum Adami.* The outer surface gives attachment to the thyro-hyoid, sterno-thyroid, and inferior constrictor. At the posterior inferior angle there are two cornua for articulation with the cricoid. Its posterior border gives attachment to the stylo-pharyngeus. At the angle formed by the alæ on the inner aspect it gives attachment to the epiglottis, the false and true vocal cords, and thyro-arytenoidei. Its inferior border gives attachment to the crico-thyroid.

3. The **Arytenoid** cartilages resemble pyramids, having three surfaces, a base, and apex. The base is seated on the cricoid, its anterior angle giving attachment to the true vocal cords, and its external angle to the crico-arytenoid, posticus, and lateralis. The posterior surface gives attachment to the arytenoids, and the anterior to the false vocal cords, and thyro-arytenoids.

4. The **Epiglottis** is shaped like an obovate leaf, being round at its free extremity, and pointed inferiorly where it is attached to the angle formed by the alæ of the thyroid.

It is composed of yellow elastic cartilage, and covers the superior opening of the larynx, and is covered by mucous membrane, which is reflected by the neighbouring parts.

5. The **Cornicula Laryngis,** or **Cartilages** of **Santorini,** are two small nodules of yellow fibro-cartilage, which are placed at the summit of the arytenoids.

6. The **Cuneiform Cartilages,** or **Cartilages of Wrisberg,** are two yellowish cartilaginous bodies situated in the aryteno-epiglottidean folds.

Structure of the cartilages.—The epiglottis, cornicula laryngis, and cuneiform cartilages consist of yellow fibro-cartilage. The other cartilages are hyaline, resembling the costal and are prone to ossify.

The **Vocal Cords**—so called from their being concerned in the production of the voice—are two bands of yellow elastic tissue covered with mucous membrane, attached in front to the angle between the

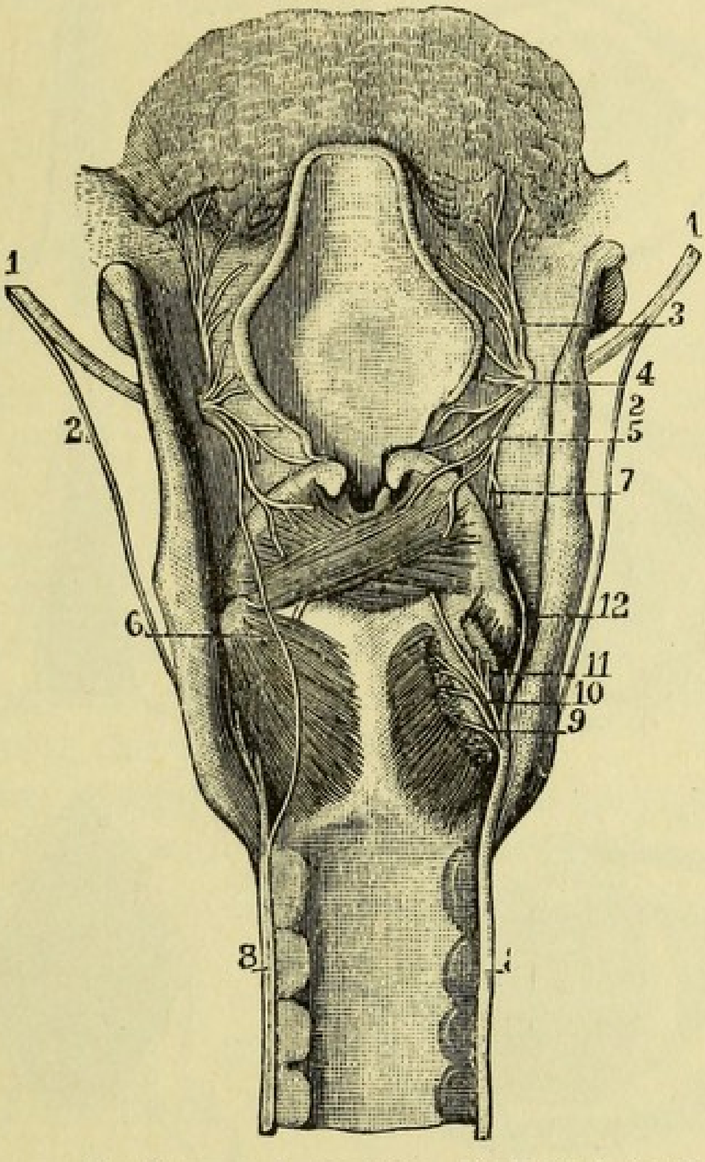

FIG. 125.—1, superior laryngeal nerve; 2, its branch to the crico-thyroid muscle; 3 4, 5, branches to the mucous membrane of the larynx; 6, filaments uniting the left superior and inferior laryngeal nerves; 7, the same on the right side, cut; 8, 8, inferior laryngeal nerves; 9, branch to the posterior crico-arytenoid muscles; 10, branch to the arytenoid; 11, 12, branches to the lateral crico-arytenoid and the thyro-arytenoid muscles.

alæ of the thyroid, and behind to the anterior angle of the base of the arytenoid. They are continuous below with the crico-thyroid membrane, and their free edges are directed upwards.

The **False Vocal Cords** are two folds of mucous membrane, enclosing fibrous tissue, situated above the true vocal cords.

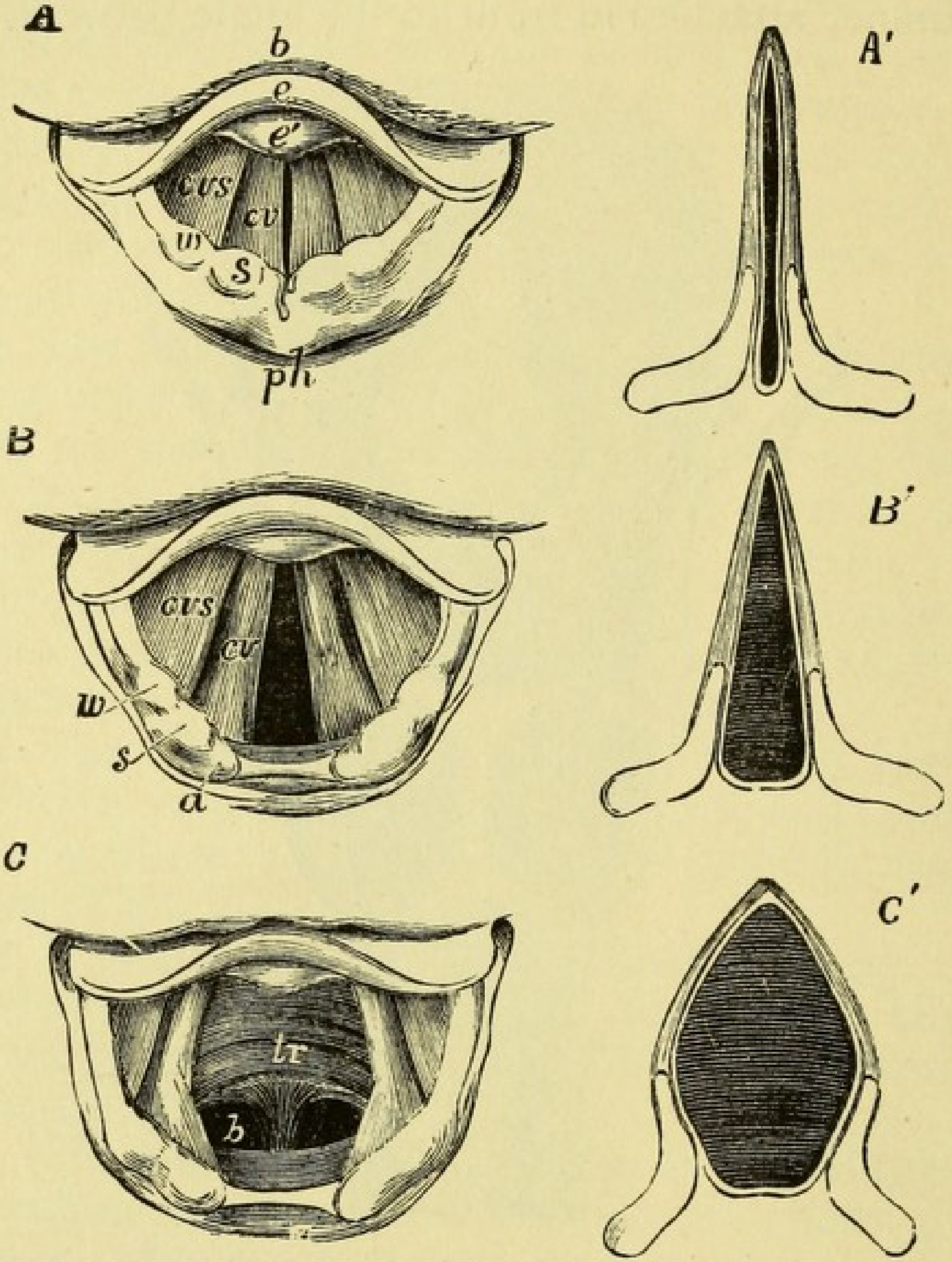

FIG. 126.—Three laryngoscopic views of the superior aperture of the larynx and surrounding parts in different states of the glottis during life (Czermak). A, the glottis during the emission of a high note in singing; B. in easy inhalation; C, in taking a deep breath; *b*, base of tongue; *e*, the upper free part of the glottis; *e'*, the tubercle or cushion of the epiglottis; *ph*, part of the anterior wall of the pharynx behind the larynx; in the margin of the aryteno-epiglottidean fold *w*, the swelling of the membrane caused by the cuneiform cartilage; *s*, corniculum: *a*, tip of arytenoid; *cv*, true vocal cords; *cvs*, false vocal cords; *tr*, trachea; *b*, bronchi.

The **Ventricle of the Larynx** is a fossa between the true and false vocal cords: it communicates with the sacculus laryngis, and forms a pouch between the superior or false vocal cords and the thyroid cartilage.

The **Rima Glottidis** is the narrow fissure between the inferior or true vocal cords. In the male it measures eleven lines, and its breadth is from three lines to half an inch. In the female and in the male below puberty it is eight lines in length, and two lines in breadth. When a sound is produced its edges are approximated.

Action of the Muscles.—The *crico-thyroids* tighten the vocal cords by pulling the anterior part of the thyroid downwards. The *thyro-arytenoids* have an opposite effect. The *crico-arytenoid laterales*, by pulling forward the outer angle of the arytenoid cartilages, will approximate the vocal cords. The *posterior crico-arytenoids* pull back the outer angle of the arytenoid cartilages, and separate the vocal cords. The *arytenoids*, by pulling the arytenoid cartilages nearer together, approximate the vocal cords.

Nerve supply.—The superior laryngeal supplies the mucous membrane with common sensation, and one muscle, the crico-thyroid, which makes tense the vocal cords. The recurrent laryngeal supplies the rest (fig. 125).

Different Characters of Voice.

1. **Loudness** or **Intensity** depends upon the amplitude of the movements of the cords, and hence upon the force of the expiratory blast.

2. **Pitch** depends upon the rate of the vibrations, the number of vibrations being dependent upon the tension and length of the cords. The tenser the cords the higher the pitch, the shorter the cords the higher the pitch. When a high note is being made the cords are approximated, when a low note they are

separated. It is said that no sound is elicited if they are separated more than one-tenth or one-twelfth of an inch. Males have longer cords than females and children, and hence have a lower range of notes. But every voice has a certain range, in consequence of the power possessed by each individual to vary the tension of the cords. The following table exhibits the action of the muscles in altering the pitch :—

Muscles governing Pitch of Voice.

Raise pitch	crico-thyroids sterno-thyroids	depress front of thyroid and stretch vocal cords
	crico-arytenoid lat. arytenoidei	approximate vocal cords
Lower pitch	thyro-arytenoids thyro-hyoids	elevate thyroid and relax vocal cords
	crico-ary. post.	open glottis

3. The **Quality** or **Timbre** of the voice depends chiefly upon individual peculiarities, depending upon the shape of the various cavities.

Movements during Respiration.—During inspiration the rima glottidis opens widely, and is in a semi-contracted state during expiration. It is closed entirely prior to a cough or sneeze.

The Larynx as a Musical Instrument.—The different kinds of musical instruments are strings, flutes, and reeds. In certain instruments, as the harp, the musical sounds are produced by vibrating *strings*, but no strings, as short as the vocal cords, could give a tone comparable to the human voice. In the *flute-pipes* the sound is produced by the vibration of an elastic column of air. Possibly, this is the case with the notes of birds, but it would require a column of six feet to produce the ordinary bass voice. In the *reed* the sound is produced by the vibrations of certain tongues, as in the accordion, harmonium, &c. With this kind of instrument the human larynx agrees, the notes being produced by the vibrations of the vocal cords, the pitch depending on their length and tension.

II. Articulate Sounds.

The larynx produces tones only, but speech consists in the modification of the laryngeal tones, so as to produce articulate sounds.

Vocal Sounds.—The only true vocal sounds are the *vowels* : the *consonants* are sounds produced, not by the vocal cords, but by the expiratory blast being modified in the mouth and throat.

The vowel sounds are produced in the larynx, but are modified in their passage through the pharynx and mouth. Thus in pronouncing the vowel sound *oo* the lips are protruded, and the larynx is depressed, making the column of air as long as possible. With the sound *ee* the lips are retracted, and the larynx raised, making the column of air as short as possible.

Consonants are sounds produced in the buccal cavity. The *labials* are produced by approximation of the lips ; the *dentals* by the approximation of the tongue to the teeth or hard palate ; the *gutturals* by the approximation of the root of the tongue to the soft palate. Other varieties, as *explosives*, *aspirates*, and *resonants*, are formed by a rush of air through the lips or teeth, or causing the nasal chamber to act as a resounding cavity.

CHAPTER XXI.

ORGANS OF GENERATION.

Uterus.

THE uterus is a hollow, muscular, pear-shaped organ, with thick walls, situated in the pelvic cavity. It is flattened from before backwards, about 3 in. long, and 7 to 12 drs. in weight. It consists of a fundus, a body, and cervix. The *fundus* is rounded, and is directed upwards and forwards. The *cervix* projects into the vagina, and opens into it by means of a transverse fissure, the os uteri. The *cavity* is of triangular shape in its upper part, the base being towards the fundus, where the Fallopian tubes enter ; the inferior angle is constricted, and forms the internal os, which opens into the cavity of the cervix. The cavity of the cervix is somewhat spindle-shaped, being constricted at the internal and external orifices.

Structure.—The uterus consists of serous, muscular, and mucous coats. The *serous* layer passes from the rectum on to the upper part of the vagina, then upwards, covering the whole of the posterior wall of the uterus ; it is reflected over the fundus and covers only three-fourths of the anterior surface and passes on to the bladder. Two folds, which connect the sides of the uterus with the walls of the pelvis, form the broad ligaments, and contain the Fallopian tubes and ovaries.

The *muscular* coat consists of external, middle, and internal layers, of which the latter is the thickest : it forms concentric rings round the entrance of the Fallopian tubes and round the cervix.

The *mucous membrane* lining the cavity of the uterus is smooth and soft, and of a dull red colour, and contains numerous tubular glands.

The membrane of the cervix is thrown into numerous rugæ, and in the lower part there are some papillæ. The mucous membrane is lined throughout with ciliated columnar epithelium, except at the cervix, where it is flattened and non-ciliated.

The **Fallopian Tubes** are contained in the broad ligament, and are between 3 and 4 in. in length. At their inner end they communicate with the cavity of the uterus: they enlarge as they proceed outwards, and end in numerous processes termed *fimbriæ*, one of which is attached to the ovary. These fimbriæ are arranged in a radiating manner around the abdominal opening of the tube. The tube itself consists of a serous, muscular, and mucous coat. The muscular contains longitudinal and circular fibres, and the mucous membrane is lined by columnar ciliated epithelium.

Ovaries.

The ovaries are small bodies about $1\frac{1}{2}$ in. in length: they weigh from 1 dr. to $1\frac{1}{2}$ drs. each, and are enclosed between the layers of the broad ligament. They are for the most part enclosed by the posterior, and touch the anterior layer at their anterior border; along this line is the hilus where the vessels enter.

Structure.—The ovary is surrounded by a firm fibrous capsule, which is not so firm or dense as the tunica albuginea of the testis. The substance of the ovary consists of a stroma composed of connective tissue, and a few muscular fibre cells and blood-vessels. In this stroma the Graafian follicles are imbedded (see fig. 127).

The **Graafian Follicles** consist of small vesicles, which are scattered in great numbers through the ovary (fig. 127). The smallest measure about $\frac{1}{100}$ in., and lie in the cortical part. The medium-sized follicles occupy the more central parts, and are about $\frac{1}{50}$ in. diameter, and are few in number. The largest of all, only few in number, lie near the surface, and project from it. The mature follicles are surrounded by a fibrous and a vascular tunic which have been called the *membrana fibrosa* and *membrana vasculosa*. They are lined internally by several layers of columnar or rounded cells which form the *membrana granulosa*, in

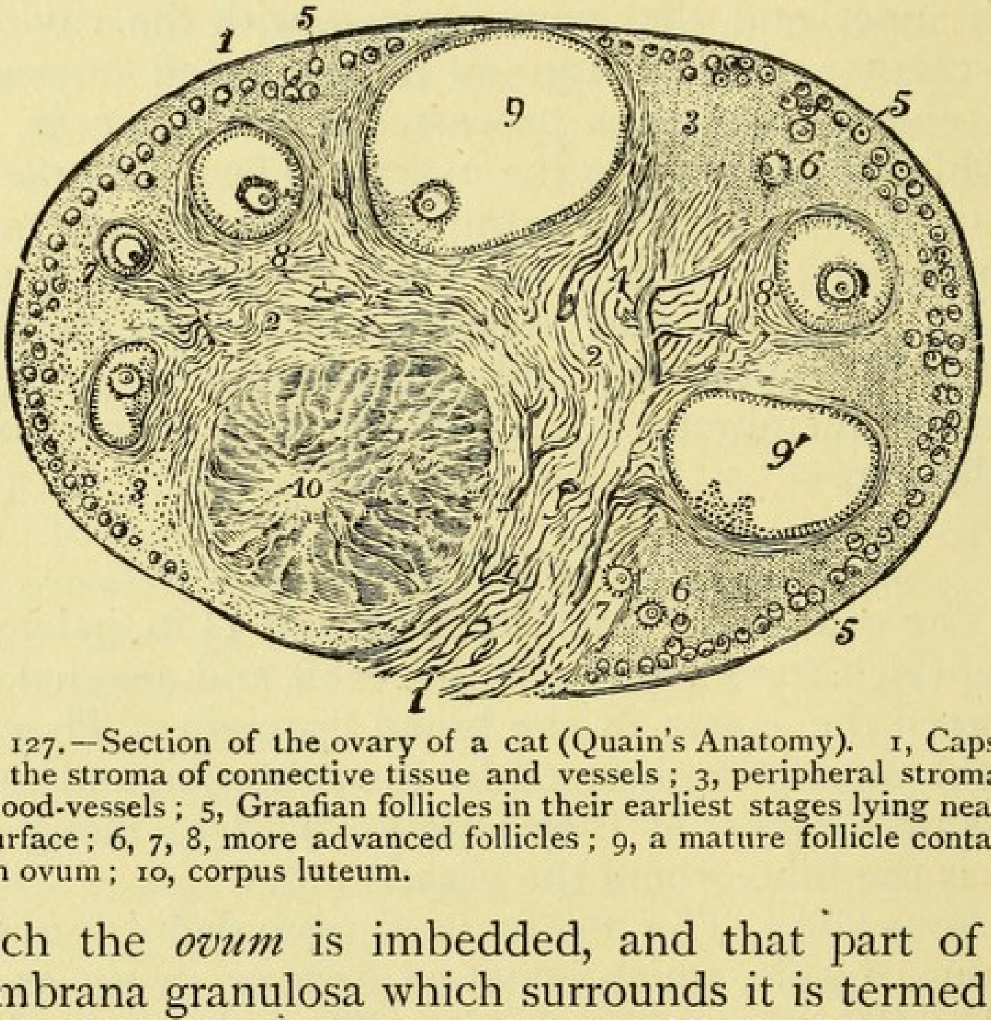

FIG. 127.—Section of the ovary of a cat (Quain's Anatomy). 1, Capsule; 2, the stroma of connective tissue and vessels; 3, peripheral stroma; 4, blood-vessels; 5, Graafian follicles in their earliest stages lying near the surface; 6, 7, 8, more advanced follicles; 9, a mature follicle containing an ovum; 10, corpus luteum.

which the *ovum* is imbedded, and that part of the membrana granulosa which surrounds it is termed the *discus proligerus*. The vesicle is filled with a serous fluid called the *liq. folliculi*.

The **Ovum.**—The ovum is a small round body $\frac{1}{120}$ in. in diameter (fig. 128). It consists externally of

(1) Zona pellucida or vitelline membrane (*zp*).
(2) Yelk or vitellus (*vi*).
(3) Germinal vesicle (*gv*).
(4) Germinal spot (*gs*).

The *zona pellucida* is a fine transparent membrane, often marked with fine radiating lines. The *yolk* is a granular mass containing oil globules. The *germinal vesicle* is a clear spot situated on one side of the yelk, and $\frac{1}{720}$ in. in diameter. The *germinal spot* is a dark granular spot about $\frac{1}{3000}$ in. in diameter.

Menstruation.—In the human female, from the ages of 14 to 45, menstruation takes place every

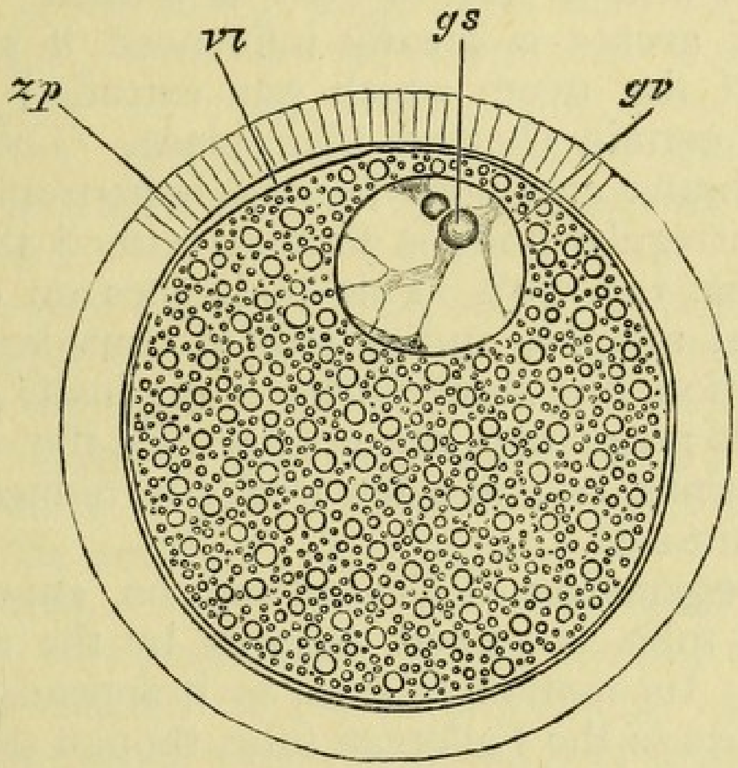

FIG. 128.—Ovum of the cat; highly magnified (Quain's Anatomy). *zp*, zona pellucida, showing radiating lines; *vi*, vitellus; *gv*, germinal vesicle; *gs*, germinal spot.

month. The most important event during this period is the escape of an ovum from the ovary. The uterus, Fallopian tubes, and ovaries are congested, a Graafian follicle bursts, and the ovum is picked up by the fimbriated extremity of the Fallopian tube, and passed along towards the uterus. During this time the mucous membrane of the uterus becomes swollen and congested, and a discharge of blood amounting to several ounces takes place from the uterus. It is probable also, the mucous membrane of the uterus, including the glands, is discharged during this period. During the few days that menstruation is taking place there is a feeling of lassitude, with pains in the back and loins.

Corpus Luteum.—After the discharge of the ovum from the Graafian vesicle there is an effusion of blood into the ruptured follicle, the latter gradually disappears and a sort of scar is formed. But the course of events is greatly influenced if pregnancy occur. If the ovum which was extruded becomes fertilised, certain changes take place. The cells of the membrana granulosa become hypertrophied, and a yellow irregular body is formed, termed the corpus luteum (fig. 127, 10). This body goes on enlarging for several months, and is still of considerable size at parturition, but shortly after it gradually dwindles away. If pregnancy do not occur, the ruptured follicle shrinks, and in a few weeks is reduced to an insignificant scar.

Impregnation.—The ovum, on entering the Fallopian tube, is passed onwards by the action of the cilia. Its motion is slow, as it appears to spend several days in the Fallopian tube, though this is uncertain. If it meets with no spermatozoa, it dies and is discharged. But, if it becomes impregnated, certain changes immediately begin.

Segmentation of the Ovum.—In the mammal, the whole of the yolk at once takes part in the formation of the embryo, and its ovum is said to be *holoblastic.* In birds, only a part of the yolk at once takes part in the formation of the chick, the rest provides a store of nutritive material for the embryo, and is termed the food yolk. Such an ovum is *mesoblastic.* The segmentation of the human embryo has never been observed, but it is presumed to resemble that of other mammals, as the rabbit and dog. Shortly after the ovum has escaped from the Graafian follicle the germinal vesicle disappears : this takes place whether the ovum is fertilised or not. The ovum appears generally to meet with the spermatozoa in the Fallopian tube, and immediately after certain changes begin.

The yolk, which consists of a granular mass of protoplasm, splits into two ovoid masses, and there appears in each a clear space, which resembles a nucleus. Then shortly each ovoid mass splits again, making four, each having a nuclear body. This division goes on, eight, sixteen, thirty-two segments making their appearance, until finally the granular yolk has become a mass of cells, each having a nucleus and cell-wall.

In the next change the central parts become fluid, whilst a layer of cells accumulate at the circumference and form the blastoderm or blastodermic membrane. This membrane at first divides into two, the *epiblast* and *hypoblast*, a third making its appearance in an intermediate position, called the *mesoblast*.

Chorion.—Meanwhile the zona pellucida has acquired a new character. It has become beset with numerous villi, giving the ovum a shaggy appearance, and is now termed the *chorion*, and is probably derived from the cells of the epiblast (fig. 129, *dd'*). Shortly after the ovum has entered the uterus it consists of:—

1. Chorion covered with villi.
2. Blastoderm $\begin{cases} \text{Epiblast.} \\ \text{Mesoblast.} \\ \text{Hypoblast.} \end{cases}$
3. Fluid granular contents.

It is from the blastoderm that the fœtal structures are developed : the different layers take the following part in the process :—

1. **Epiblast.**—Epidermis and appendages, great

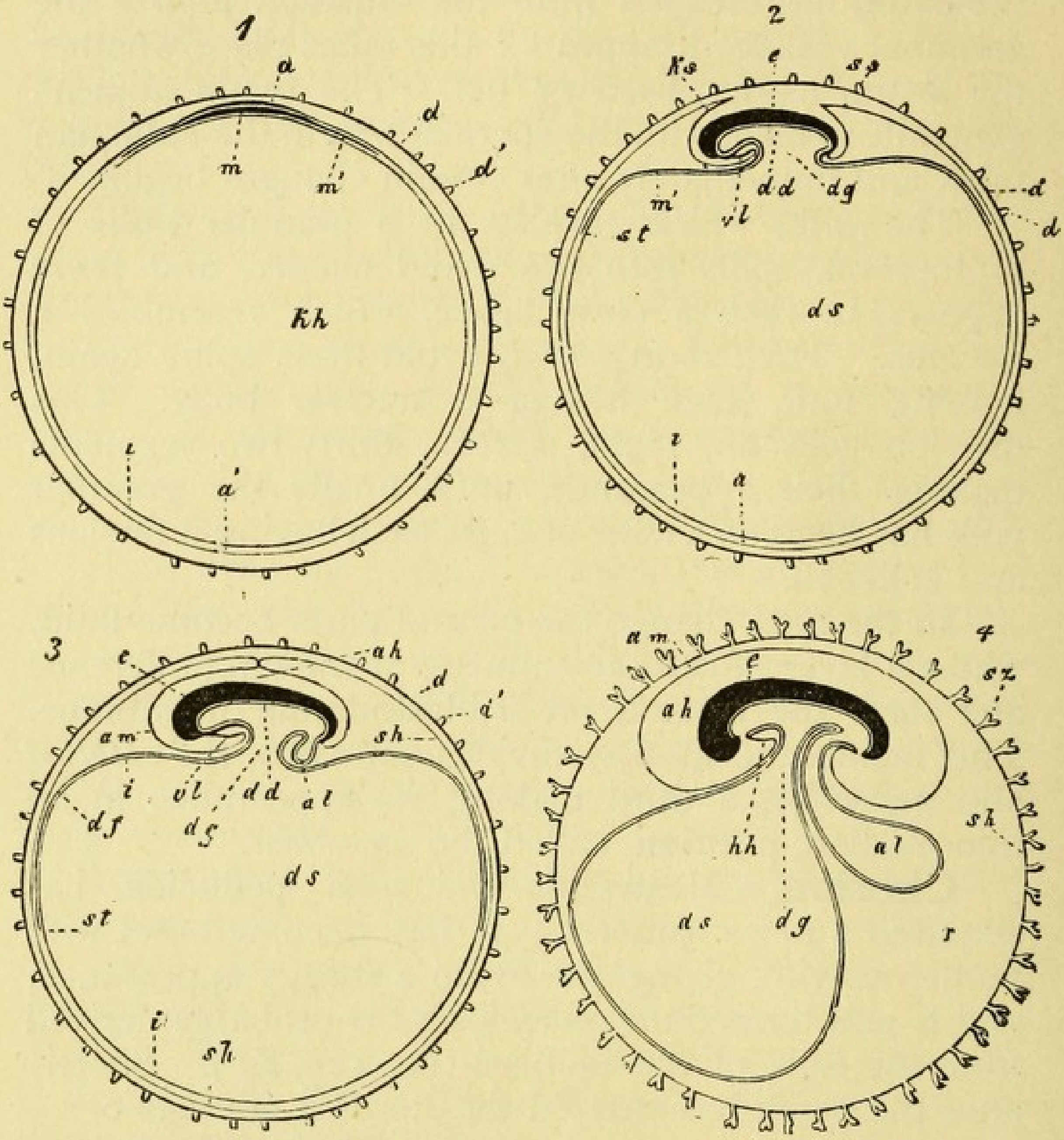

FIG. 129.—Diagrammatic sections of the mammiferous ovum in different stages of development, to show the progress of formation of the membranes (Quain's Anatomy). 1, ovum in which the chorion has begun to be formed, with the blastoderm and rudiment of the embryo within; 2, ovum in which the cephalic and caudal folds have contracted the umbilical aperture towards the yolk-sac, and the amniotic folds are turning towards the dorsal aspect. 3, the amniotic folds, being completed, have met in the dorsal region; the umbilical opening is more contracted, and the allantois has begun to sprout. 4, the true amnion is detached from the reflected or false amnion, which has disappeared or combined with the chorion; the cavity of the amnion is more distended; the allantois projects into the space between the yolk-sac and chorion. *d*, chorion; *d'*, villi of the chorion; *sz*, villi of the chorion more advanced; *am*, amnion; *ds*, hollow of the yolk-sac; *dg*, vitelline duct; *al*, allantois: *ah*, cavity of amnion.

nervous centres, principal parts of eye, ear, nose, and one layer of the amnion.

2. **Hypoblast.**—Epithelial lining of the whole alimentary canal, and of the lungs, and one layer of the allantois.

3. **Mesoblast.**—The bones, muscles, fasciæ, peripheral nerves, vascular system, connective tissue, muscular coat of alimentary canal, outer layer of amnion, and part of allantois.

Membranes of the Ovum.—In reptiles, birds, and mammals four membranes in connection with the ovum are formed—viz. the yolk-sac, the amnion, and allantois, and a fourth, already referred to—the chorion.

The **Yolk-sac** is an organised layer formed from the layers of the blastoderm, which surrounds the yolk. This sac is the seat of the first circulation of blood, and in birds the vessels fulfil the important office of absorbing the yolk and conveying it to the embryo to aid in its development. In mammals the vascular area only in part spreads over the yolk. In man the yolk-sac, or *umbilical vesicle* as it is called, continues to grow till the fifth or sixth week. At that time it is pyriform in shape, and is connected by the vitelline duct with the intestines. At a later period both duct and vesicle have become atrophied.

The **Amnion** is formed at an early stage by the gradual inflection of two layers—the inner of the epiblast, and the outer from the mesoblast (fig. 129, *am ks*). The two layers meet over the dorsum of the embryo and join together. The separated inner division becomes the entire closed sac of the amnion. It is now a serous membrane, having an internal and external layer.

The **Allantois** originates as a diverticulum from the hinder part of the primitive intestine (fig. 129, *al*), and is more highly developed in reptiles and birds than in man. It is the seat of numerous capillary vessels which perform important functions in the aëration of the blood, especially when the allantois is spread out as it is in birds and reptiles, beneath the shell. It is formed from the mesoblast and hypoblast. The allantois soon takes the form of a vesicle, connected to the intestine by a narrow pedicle which pushes to the surface, carrying the blood-vessels with it, and then gradually surrounds the embryo chick. It never attains this size in mammals; the external layer or mesoblastic element spreads over the inner surface of the chorion, while the hypoblastic element atrophies. The bladder is formed from the pedicle of the allantois near the intestine; the urachus is the remains of the allantois, stretching between the bladder and umbilicus.

Changes occurring in the Uterus.

Prior to the entrance of the impregnated ovum into the uterus certain changes occur in the character of its mucous membrane, in order to prepare a suitable bed for the reception of the ovum. These changes correspond to those which take place during the menstrual period. They consist essentially in a proliferation of the subepithelial cells, causing a thickening of the mucous membrane, enlargement, and multiplication of the tubular glands, and hypertrophy of the blood-vessels. This thickened membrane is called the *decidua.* Into this decidual membrane the ovum, on entering the uterus, becomes imbedded, and into the enlarged glands, or specially formed crypts, the villi of the chorion are received. The decidua having enveloped the ovum, it becomes divided into three distinct parts, viz.: *decidua vera*, *decidua reflexa*, and *decidua serotina.* The decidua vera lines the general cavity of the uterus; the decidua reflexa is that part which covers the ovum; the term decidua serotina is applied to that portion of membrane which intervenes between the ovum and the uterine walls, and occupies the site of the future placenta.

The Placenta.

During the first two or three weeks the ovum derives its nourishment through the evascular villi of the chorion, the latter taking up some of the albuminous matter with which it is surrounded. About the third or fourth week the villi contain delicate loops of capillary blood-vessels, received from the allantois, which greatly assist in the absorption of nutrient material. At the end of the sixth to the eighth week (the ovum being about 1½ in. in diameter) the villi which are imbedded in the tissues of the decidua serotina become larger and more complex, and there is a corresponding increase in the decidual membrane, and in the course of another few weeks the placenta is completely developed, while the villi, which correspond to the decidua reflexa, undergo more or less complete atrophy. By the end of the eighth or ninth week the villi can still be separated from the maternal structures, but by the end of the third month, or beginning of the fourth, they are so intimately connected that separation is no longer possible.

The placenta has attained its full development by the end of the fourth month; and when it has attained its full dimensions, towards the end of pregnancy, it is a flat round cake 7 to 8 inches in diameter.

Structure of placenta.—The placenta when fully formed consists of two portions, a fœtal and maternal. The *fœtal* portion consists of highly complex tufts of villi containing numerous loops of capillary blood-vessels. The *maternal* portion consists of numerous spaces or sinuses continuous with the blood-vessels of the mother, and which receive and surround the fœtal villi. The villi dip into spaces filled with maternal blood.

Circulation of Blood.—The fœtal blood is carried to the placenta by the two umbilical arteries: it then circulates through the villi and returns to the fœtus through the umbilical vein. The blood is carried to the maternal portion by the uterine arteries, the blood entering the sinuses through the so-called 'curling arteries,' and is returned by the uterine veins. There are no capillaries in the maternal portion, the blood entering the sinuses and returning by the veins.

There is no direct blood-communication between the mother and fœtus, but the fœtal villi dip into the maternal blood in a way similar to the intestinal villi, which dip into the contents of the intestine.

Changes effected by the Placenta.

The *fœtal blood gains* nutrient material and O, and *loses* effete material (urea, &c.) and CO_2.

The *maternal blood gains* effete material and CO_2, and *loses* nutrient material and O.

Structure of Umbilical Cord.—The umbilical cord when fully developed is from 18 to 20 in. long. Externally it is invested by the amnion, and contains the umbilical vein and two arteries imbedded in a gelatinous material termed Wharton's jelly. Early in fœtal life it contained the omphalo-mesenteric vessels, a second vein, the allantois, and umbilical duct.

Fœtal Circulation.

The arterial blood coming from the placenta to the fœtus travels along the umbilical vein to the liver. After giving off several branches to the left lobe it divides into two streams, the larger joining the portal vein and thus entering the liver, the smaller passing directly into the inferior vena cava through the *ductus venosus*. In the inferior vena cava the blood carried by the hepatic veins and ductus venosus mixes with the blood which has circulated through the lower extremities. On entering the right auricle the blood of the inferior vena cava is directed by the Eustachian valve, through the foramen ovale into the left auricle, and from thence into the left ventricle. The left ventricle forces it into the aorta, and it is then distributed to the head and upper extremities, a small quantity only passing into the descending aorta. The blood which has circulated through the head and upper extremities returns to the heart along the superior vena cava, the blood then passing into the right ventricle and pulmonary artery. A small part of the blood in the pulmonary artery is conveyed to the lungs, but the major part passes through the ductus arteriosus into the aorta at the commencement of the descending portion. This blood is distributed to the lower extremities, a certain portion of it entering the hypogastric arteries and being conveyed to the placenta.

Peculiarities of the Circulation in the Fœtus.—The greater part of the blood of the umbilical vein is submitted to the action of the liver, the liver being of large size during fœtal life. The head receives the purest blood that enters the heart, viz. that of the inferior vena cava, while the blood supplied to the lower extremities is that which has already circulated through the head and upper extremities. The great importance of the cephalic nervous centres makes it necessary for them to receive a large amount of arterial blood. It is probable that in early fœtal life the two streams of blood passing through the right auricle are distinct. At a later period, as the foramen becomes smaller, it is possible that some mixture of the two streams may take place.

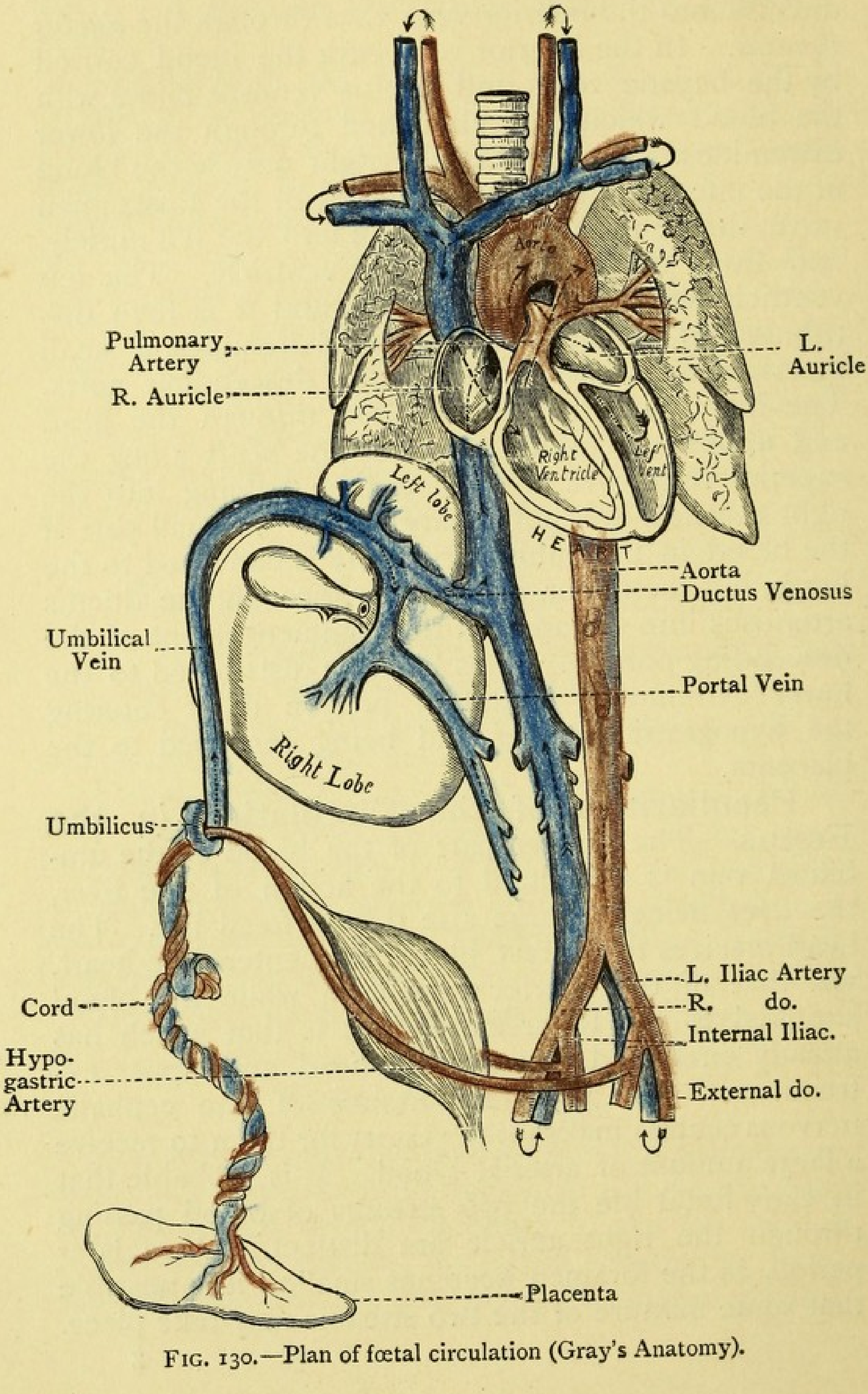

FIG. 130.—Plan of fœtal circulation (Gray's Anatomy).

Changes at Birth.—When the placental circulation ceases, and respiration through the lungs is established, an increased quantity of blood enters the lungs.

The *ductus arteriosus* begins to contract soon after birth, and is completely closed from the fourth to the tenth day.

The *hypogastric arteries* remain patent in their first part, as the superior vesicle, but the portion between the bladder and umbilicus becomes obliterated from two to five days after birth, and remains as the anterior true ligament of the bladder.

The *ductus venosus* and *umbilical vein* become obliterated a few days after birth : the ductus venosus can be traced as a fibrous cord in the fissure of the same name on the under surface of the liver, and the umbilical vein becomes the round ligament.

The *foramen ovale* is closed by the tenth day, and the Eustachian valve is soon reduced to a trace.

The Mammary Glands.

The mammary glands form two rounded eminences, which extend from the third to the sixth ribs. A little below their centre is the nipple, which corresponds in position with the fourth interspace. Around the nipple is the areola, which is of a darker colour than the nipple itself. In the virgin the areolæ are of a pink colour ; during pregnancy their colour becomes darker, the change in colour commencing as early as the third or fourth month.

Structure.—The mammary glands consist of lobes connected together with fat and connective tissue. The lobes consist of lobules, ducts, and blood-vessels. The ducts commence in small clusters of acini, which are lined by short columnar epithelium. The alveoli are larger in size than the ducts with which they are connected, and have a large lumen. During pregnancy the gland undergoes enlargement, the alveoli becoming increased in number and size, and distended with a serous secretion. The epithelial cells also enlarge; oil globules are formed in their interior which are gradually shed into the fluid in the lumen, to form the milk globules. Fresh oil globules make their

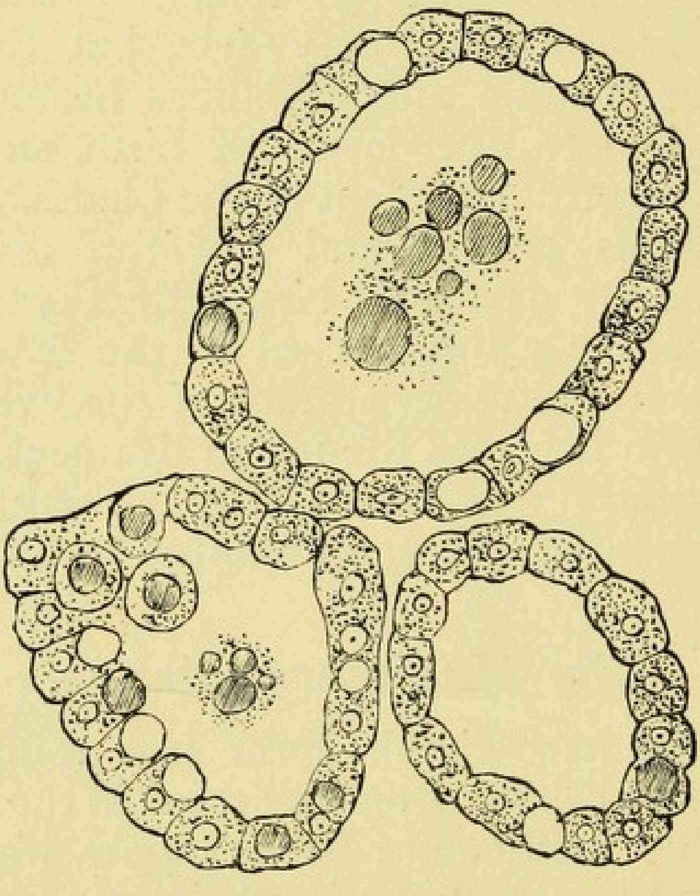

FIG. 131.—Section through the mammary gland of a cat in a late stage of pregnancy (Klein). The epithelial cells lining the alveoli are seen in profile; many cells contain oil-globules.

appearance in the cells, to be again shed into the lumen. Each oil globule receives an albuminous coating. A microscopical examination of milk shows immense numbers of oil globules of different sizes (fig. 132, *a a*) in the field, varying in size from $\frac{1}{5000}$ to $\frac{1}{12000}$ in. in diameter. Milk, during the first two or three days after birth, contains a number of 'colostrum corpuscles,' which consist of cells closely packed with minute fat globules (fig. 132, *b b*). According to Klein these corpuscles are the central epithelial cells of the alveoli, which have undergone fatty degeneration, and are shed, while the peripheral epithelium remains. The ducts empty themselves into some

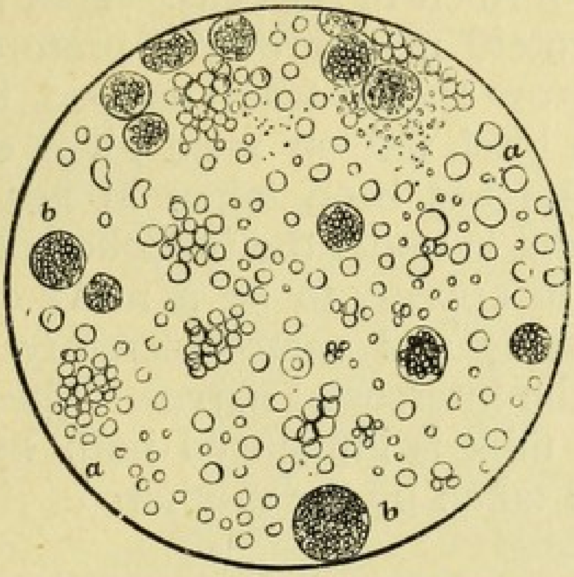

FIG. 132.—Microscopic appearance of human milk, showing 'colostrum corpuscles.' *aa*, milk globules ; *bb*, colostrum corpuscles.

fifteen or twenty excretory ducts termed *galactophorous ducts*, which converge to the areola, where they form dilatations termed the *ampullæ*, $\frac{1}{4}$ to $\frac{1}{6}$th in. in diameter, which serve as reservoirs for the milk. The ducts become again contracted, and finally open on the summit of the nipple. The walls of the ducts consist of elastic tissue and muscular fibres, and are lined by columnar epithelium, except at their orifices, where it becomes squamous.

Composition of Milk.

	Human	Cow
Casein and albumen .	3·35	4·1
Fat	3·34	3·9
Sugar	3·77	5·2
Salts		·8
Water	89·54	86·
	100	100

The colostric milk contains more albumen and fat than when the flow has been fully established.

Secretion of Milk.—The fatty matters in milk are apparently formed at the expense of the protoplasm of the epithelial cells. The casein and milk sugar are also formed in the cells. That fat is formed out of the proteid matter of the protoplasm of the cell, and not from the fat taken as food, is proved by the fact that a bitch fed on meat gives out more fat in her milk than has been taken in her food. The secretion of milk is under the influence of the nervous system. There appears to be a nerve-centre in the cord, the sensory and motor-secretory fibres being contained in the intercostal nerves. The amount and quality of the milk is influenced both by the mental state and food taken by the mother.

The Testes.

The testes occupy the scrotum: they are of an ovoid form, flattened from side to side, are about $1\frac{1}{2}$ in. long, and weigh $\frac{3}{4}$ oz. to an oz. Along the posterior border of the testis is situated the *epididymis*, which is composed of the convolutions of the excretory duct of the testis: the upper part is called the *globus major*, the lower part the *globus minor*.

Structure.—The testes are surrounded by a fibrous capsule, the *tunica albuginea*, the surface of which is covered by the *tunica vaginalis*, except along the posterior border, where the vessels enter. The tunica albuginea passes into the substance of the gland, forming an incomplete vertical septum called the *mediastinum testis*.

Minute Structure.—The testes consist of from 250 to 400 *lobules*: they are conical in shape, their bases being directed towards the circumference of the organ. The lobules are composed almost entirely of minute convoluted tubes, named the *tubuli seminiferi*. Each lobule contains several tubuli, the total number having been calculated at 840, and their length $2\frac{1}{4}$ feet each. The diameter of these spermatic tubules is $\frac{1}{150}$th to $\frac{1}{200}$th in. They consist of a basement membrane, and are lined internally by cubical or flattened cells. In the adult a mass of cells may be

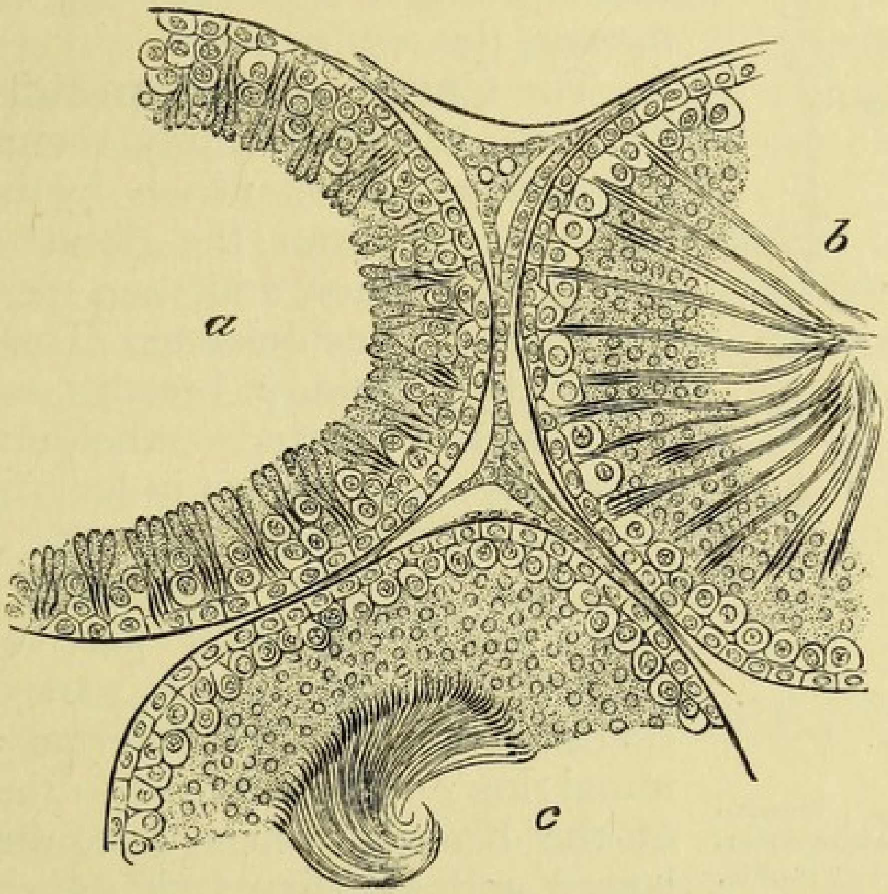

FIG. 133.—Section of three seminiferous tubules in a rat (Quain's Anatomy). *a*, with the spermatozoa least advanced ; *b*, more advanced ; *c*, containing fully developed spermatozoa.

seen, which are spermatozoa in various stages of development (fig. 133).

The **Vasa Recta.**—At the apices of the lobules the tubuli become less convoluted, and unite together to form twenty or thirty larger ducts, about $\frac{1}{50}$th in. in diameter, called the vasa recta.

The **Rete Testis.**—The vasa recta enter the fibrous tissue of the mediastinum and form a network of tubes called the rete testis.

The **Vasa Efferentia** consist of ten to twenty ducts which emerge from the rete testis. They perforate the tunica albuginea. Their course is at first straight, but they become more and more convoluted as they proceed towards the epididymis, and form a series of small conical masses, the *coni vasculosi.*

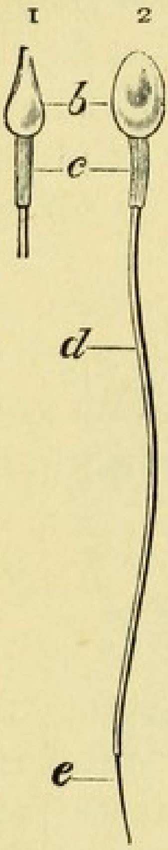

FIG. 134.—Human spermatozoa (Retzius). 1, in profile, tail not represented; 2, viewed on the flat; *b*, head; *c*, middle-piece; *d*, tail; *e*, end-piece of tail.

The **Canal of the Epididymis.** The coni vasculosi empty themselves into a single duct, which by its numerous coils forms the globus major and globus minor, and then turns upwards, as the vas deferens. The canal is $\frac{1}{70}$th to $\frac{1}{90}$th in. in breadth, is lined by columnar ciliated epithelium, and measures about 20 feet in length.

The **Vas Deferens** is the excretory duct of the testis, and, commencing at the lower part of the globus minor, ascends as part of the spermatic cord to the internal abdominal ring: it is continued to the base of the bladder, where, becoming enlarged and sacculated, it unites with the duct of the vesicula seminalis to form the common ejaculatory duct.

It is about two feet in length, with a narrow canal and thick walls.

Structure:—

1. External or connective tissue coat.
2. Muscular, two longitudinal, and intermediate circular layer.
3. Internal or mucous, arranged in longitudinal folds lined with columnar epithelium.

The **Semen** is a thick opalescent fluid discharged from the testes, prostate, and accessory glands. It contains spermatozoa and also highly refracting granules.

Spermatozoa.—The spermatic corpuscles consist of a small oval part or head provided with a long filiform tail. At the junction of the head and tail there is an intermediate portion, called the *middle-piece* (fig. 134, *c*). The *head* is about $\frac{1}{6000}$th in. in length, and the *tail* about $\frac{1}{400}$th in. in length. The tail performs rapid vibratile movements, which enable the spermatozoa to find their way into the Fallopian tube, in spite of the action of the cilia.

The spermatozoa are developed within the cells which line the tubuli seminiferi. The body and coiled-up tail may be seen inside some of these cells from which the spermatozoon makes its escape.

CHAPTER XXII.

THE PHASES OF LIFE.

Infancy.—Infancy commences with birth and extends to the seventh or eighth month, that is to the eruption of the milk teeth. The newly-born infant weighs about 7 lbs., and is about 19 in. in length; for the first two or three days there is a loss of weight amounting to from 4 to 7 oz.; then a regular gain commences, amounting to from 6 oz. to 3 oz. weekly, for the first six months. By the end of six months the weight is doubled, and by the end of the first year trebled (22 lbs.). The cardiac beats are about 130, and respirations 40. The temperature is a degree lower than in adults.

Childhood.—Childhood commences with the eruption of the milk teeth, and extends to the seventh year, or to the commencement of the second dentition. By the end of the seventh year the weight is about 44 lbs., or double the weight attained at the end ot the first year ; the height is about 44 in.

Youth.—Youth extends from the seventh to the fifteenth year, or to puberty. The permanent teeth take the place of the first teeth, and the difference between the sexes becomes marked as the generative organs become developed. Menstruation commences in the female, the voice undergoes a marked change, and in the male hair makes its appearance on the face. By the end of the fifteenth year the average weight is nearly 100 lbs., and the height 60 in.

Adult age.—With the occurrence of menstruation, the girl practically becomes a woman ; the boy becomes a man more gradually. From the twentieth to fortieth year, mentally and physically, the man is at his best, and capable of the greatest exertions.

Old age.—Old age creeps on gradually after the sixtieth year ; it is marked by a general decay of the powers, and by characteristic fatty and calcareous changes in the arteries, cartilages, and other tissues. The mind, however, often retains its powers unimpaired, or may, indeed, become more matured and vigorous.

Death.—Death generally supervenes as the result of some disease, and is generally described as beginning at the brain, the heart, or the lungs. The immediate cause of death is the cessation of the cardiac beats.

APPENDIX.

METRIC SYSTEM.

Capacity.

1 gallon	=	4·543 litres.
1 pint	=	567·93 cubic centimètres.
1 fluid oz.	=	28·39 „ „
1 litre	=	35 fluid ozs.
100 C.C.	=	3·5 „

Lineal Measure.

1 mètre	=	39·3 inches.
25·4 millimètres	=	1 in.
1 centimètre	=	·4 in. (nearly).
1 decimètre	=	4 in. „

Weight.

1 gramme	=	15·43 grains.
1 kilogramme	=	35·27 ozs. (avoirdupois).
·065 gramme	=	1 grain.

QUESTIONS IN PHYSIOLOGY.

1. Describe the mechanism by which the air is moved during ordinary and extraordinary inspiration and expiration; what parts of the nervous system are concerned; and how it can be proved that they are concerned in ordinary respiration.

2. Describe the minute structure of the spleen, the difference between the blood of the splenic artery and that of the splenic vein; what opinions are entertained regarding the functions of the organ, and what are the reasons for these opinions?

3. Give an account of the function of the intracardiac nervous apparatus, and the connections and functions of the extracardiac nerves.

4. Describe the minute structure of the retina. Mention the anatomical and physiological facts that prove the rods and cones to be the peripheral terminal organs of the optic nerve.

5. Give an account of the minute structure of the ovary; the manner in which the Graafian follicle and its contents are developed; the changes in the follicle that precede, and those that follow its rupture.

6. How much of the several groups of essential food-stuffs is needed for the maintenance of health by a man doing severe muscular work, and by a man doing an average amount of muscular work, respectively?

7. Give an account of the minute structure of the several parts of the auditory labyrinth, and of the theories advanced with regard to their functions.

8. What are the functions of the portio-dura nerve? Describe the physical and chemical qualities of chyle, and the changes it undergoes in its course from the intestines to the thoracic duct.

9. Describe the structure of the fibres of a voluntary muscle, and of the heart; and the phenomena of contraction in voluntary and involuntary muscle.

10. Describe the changes which the blood undergoes in passing through the capillaries of the skin and lungs.

11. What is the minute anatomy of adipose tissue? and what purpose does fat serve in the animal economy?

12. What is the action of the arteries in the circulation of the blood? What evidence can you offer of the influence of the nervous system on this action?

13. Describe the structure of the pancreas, and state the effects of the pancreatic juice on the chief constituents of the food.

14. Describe in detail one complete revolution of the heart.

15. Trace the changes by which the temporary are replaced by the permanent teeth, and state the period at which each of the permanent teeth generally appears.

16. Compare the effects of active and prolonged exercise with the ordinary changes which take place in the body during rest.

17. Describe the structure and functions of the true vocal cords. How is speech effected?

18. Describe the structure of the crystalline lens and the changes which occur in it during accommodation.

19. State the average quantity and specific gravity of the urine; enumerate its chief constituents, and the circumstances which affect their proportion.

20. Enumerate the various forms of cartilage, describing the minute character of each, and mention the joints in which inter-articular fibro-cartilage is found.

21. Explain the effect of complete division of the spinal column between the second and third cervical vertebræ in one of the higher animals.

22. Describe as fully as you can the phenomena presented by the circulation of the blood, as may be seen in some transparent part under the microscope.

23. How are the acts of inspiration and expiration accomplished? Describe the changes produced in the air by respiration.

24. Enumerate the functions of the sympathetic system of nerves, and give examples of each function.

25. What are the proofs that the blood is a living fluid? What are the proofs that it circulates? and what is its composition?

26. Describe the arrangement and relation of the several structures which enter into the formation of a lobule of the liver.

27. How is the voice produced and modulated? State by what muscles the rima glottidis is influenced, and how they act in changing its shape.

28. Describe the arrangement of the tubuli uriniferi in the cortical and in the medullary portions of the kidney. State how the capillaries and arteries are distributed in this organ. Give an analysis of the urine.

29. Describe the structure of the duodenum, and the changes the food undergoes in that part of the intestine.

30. Describe the process of growth in a long bone.

31. Describe the mucous membrane of the tongue, and the functions of the nerves which supply it.

32. What is the influence of food, exercise, and season on the organic and inorganic salts of the urine?

33. What is the nature of the arterial pulse? and what are the conditions in ordinary health which have most influence upon its rate and character?

34. Explain physiologically how a tumour in the neck may cause loss of voice, and how a small foreign body in the larynx may cause great dyspnœa.

35. What changes occur in an ovum from the time of impregnation up to and inclusive of the formation of the three embryonal sacs?

36. Describe the effect of dividing the vagi in a mammal.

37. What are the sources of heat in the animal body? In what organs is it principally produced, and by what means is it regulated?

38. Define the terms eupnœa, dyspnœa, asphyxia, apnœa.

39. Describe the phenomena witnessed when the trachea of a rabbit is suddenly occluded.

40. What is the function of the iris with reference to distinct vision? Describe briefly the relations of the iris to the nervous system.

41. Describe the minute structure of the small intestine, and the manner in which the food passes from the intestines into the circulation.

42. State the principal facts which indicate the influence of the nervous system on secretion.

43. What is meant by an inhibitory nerve? Give an instance.

44. Give an account of the formation and structure of the placenta, and the changes which the fœtal blood undergoes in passing through this organ.

45. Describe the effect of dividing the third nerve near its roots.

46. Describe the structure of the mammary gland, and the composition of milk.

47. What is meant by blood-pressure? how may it be estimated? and what circumstances influence it?

48. Describe the special organs in which nerves terminate.

49. Describe the minute anatomy of the scalp.

50. Contrast the tension of the oxygen and carbon dioxide contained in venous and arterial blood, respectively, with the partial pressure of those gases in the pulmonary alveoli. Compare the gas-interchange which takes place normally with that which occurs in suffocation.

51. What is the structure of the muscular fibre of the

heart? By what mechanism is a variation in the rate of the beat of the heart brought about in living mammals? When the heart beats faster, is there necessarily a rise in the blood-pressure?

52. What is known of the origin of mammalian red corpuscles? Explain as accurately as you can the changes they undergo in passing through (*a*) the lungs, (*b*) a contracting muscle.

53. Compare the effect produced by stimulating an efferent nerve going to a muscle with the effect produced by stimulating an efferent nerve going to a gland.

54. What is the structure of the pancreas? Give one method of preparing artificial pancreatic juice. Compare gastric with the pancreatic digestion of proteids.

55. Briefly describe the methods of termination of sensory nerves in the skin. What is meant by muscular sense?

56. State briefly the effects on the organism of a diet of proteids only, and proteids and carbo-hydrates only.

57. Describe the events which take place in a simple reflex action. Give two instances of inhibition of reflex actions. How do you explain this inhibition?

58. What is the Young-Helmholtz theory of colour vision? With reference to this theory, briefly discuss the phenomena of colour-blindness.

59. What are the gases of the blood? What is the average percentage of these gases in arterial and venous blood? In what condition do these gases exist in the blood, and how may this be determined?

60. Describe the principal varieties of epithelium. State where they are found, and the functions they discharge.

61. Describe the structure of a lymphatic gland. How is the movement of lymph maintained?

62. Describe the distribution of the blood-vessels in the kidney. State and explain the effects on renal secretions of an increased arterial supply.

63. State the results of complete intracranial section of the fifth pair of nerves.

64. What is the composition of atmospheric air? What are the changes effected in it by respiration? Give the average amount of oxygen absorbed by a healthy adult in twenty-four hours.

65. Classify food-stuffs in the order of their value as heat-producers; give your reasons for the order in which you place them.

66. Describe the structure of lymphoid tissue, and state where it occurs.

67. Describe the act of deglutition.

68. Describe the process of secretion as it occurs in the submaxillary gland.

69. Describe the structure and functions of the grey matter of the spinal cord.

70. Give an account of the structure, development, and uses of adipose tissue.

71. Describe the action of the oblique muscles of the eye; what is their nerve-supply?

72. Describe the manner in which ossification occurs in membrane; enumerate the bones formed entirely from membrane; in what way does this method of ossification contribute to the formation of other bones?

73. How is carbon dioxide eliminated from the body? What is the average daily quantity excreted? Explain how this may be effected by variations in temperature, quality of food, and amount of work performed.

74. Describe the capillaries and lymphatics, and the methods by which they can be demonstrated. How is the lymph current maintained in man?

75. Describe the structure of the canal of the cochlea. Explain how differences of sound are perceived.

76. Describe the sequences of events in the contraction of the heart's cavities; give the average duration of the different parts of the rhythm. How may both these

points be demonstrated? State the relation borne by the heart's sounds to the various phases of its action.

77. Describe the act of vomiting. By what nervous channels may this act be produced?

78. Describe the structure of the olfactory mucous membrane. Explain the manner in which the sense of smell is exercised.

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96. Describe the development of a milk tooth.

97. Enumerate the chief deep and superficial spinal reflexes, indicating the parts of the cord with which they are related.

98. Describe the minute structure of the thyroid gland, and state the phenomena which are known to occur in dogs, monkeys, and man after its complete removal.

99. What effects follow the application of (*a*) a single maximal induction shock to a frog's muscle, (*b*) of ten similar shocks per second? Describe the mode of distribution and termination of a nerve in striated muscle.

100. State the nature and amount of the gases to be obtained from 100 cc. of (*a*) arterial blood, and (*b*) venous blood. How would you extract and measure the gases? In what condition do the several gases exist in the blood?

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