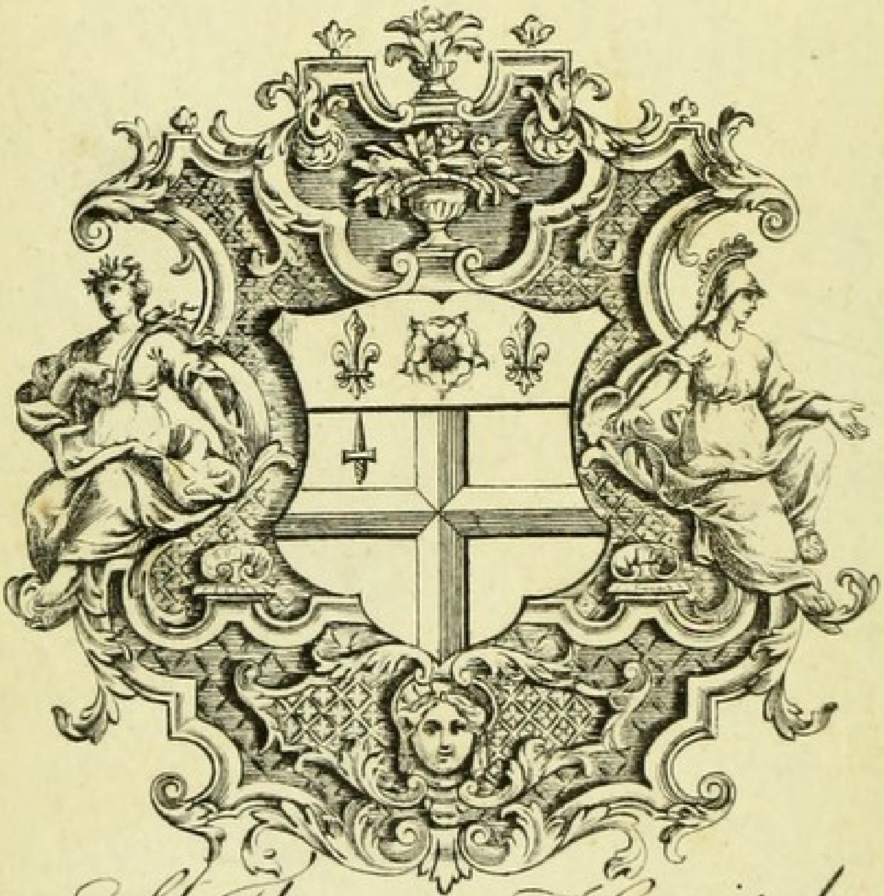

18.6.13.

MANUAL

OF

HUMAN PHYSIOLOGY.

Wilson and Ogilvy, 57, Skinner Street, Snowhill, London.

MANUAL

OF

HUMAN PHYSIOLOGY

FOR STUDENTS;

BEING

A CONDENSATION OF THE SUBJECT,
A CONSERVATION OF THE MATTER, AND A RECORD OF
FACTS AND PRINCIPLES UP TO THE PRESENT DAY.

TO EACH SUBJECT ARE APPENDED, IN NOTES,

Summaries, in Rhyme,

OF THE

COMPOSITION OF THE FLUIDS AND SOLIDS, &c.

BY

JOHN MORFORD COTTLE,

LICENTIATE OF THE ROYAL COLLEGE OF PHYSICIANS, LONDON;
MEMBER OF THE ROYAL COLLEGE OF SURGEONS, ENGLAND;
MEMBER OF THE ROYAL PHYSICAL SOCIETY, EDINBURGH; AND
FORMERLY SURGEON TO THE LEAMINGTON HOSPITAL.

"Such knowledge is too wonderful and excellent for me; I cannot attain unto it."—PSALM CXXXIX. V. 5.

LONDON:

HIGHLEY AND SON, 32, FLEET STREET,

Booksellers, by Appointment, to the Royal College of Surgeons of England.

1851.

Dedication.

TO

ROBERT B. TODD, M.D. OXON., F.R.S.,

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS, LONDON, PROFESSOR OF PHYSIOLOGY AND OF GENERAL AND MORBID ANATOMY IN KING'S COLLEGE, LONDON, AND PHYSICIAN TO KING'S COLLEGE HOSPITAL.

MY DEAR SIR,

WHEN I obtained your permission to dedicate this little register of the facts and the matters of human physiology to yourself, I thought it in keeping with the plan of its contents to place one of those facts prominently in the dedication,—the important fact, that you are truly and in every sense the leader of a list of authors who, from the various schools of Europe, have made England common ground, and have been content to co-operate with you in advancing the page of Anatomy and Physiology, and to signalise themselves in the annals of these sciences: I am, however, convinced that any attempt of mine to record this fact is unneeded: for when I consider the magnificent and enduring structure which you have raised to your own memory in the pages of the Cyclopædia of Anatomy and Physiology, you have need of no memorial of mine: in borrowed language I would say—"si requiris monumentum ejus, circumspice." Not, indeed, that you have touched with your own hand the materials or workmanship of others, for then might you have stamped the whole with the mannerism of a single mind; but, like a good master builder, while you have assigned to yourself a full portion of the labour, you have been careful to secure for the several parts the freshness of originality.

I remain, my dear sir,

Yours faithfully,

J. M. COTTLE.

Leamington, Sept. 3, 1851.

PREFACE.

The publication of a work on the principles of physiology may at first sight appear unnecessary, when there are such works extant as Dr. Carpenter's and Dr. Kirkes's on the same subject. It was, however, undertaken under the conviction that the foregoing books are not all that is required by the student who is pursuing the study of physiology as a qualification for the medical examinations. It is necessary for those examinations that he should possess a knowledge of the facts and principles of physiology, and the obvious grounds on which such facts are based. More than this is not required, and more than this cannot be obtained from a medical student without detriment to the other sciences with which he must be familiar. A recitation of such principles, with their necessary contingent matter, carefully sifted from less important minutiæ, it has been the object of the author to furnish,—necessary alike for the medical student, and as a stepping-stone to him who is purely a student of physiology. Among the sciences that form the handmaidens to the practice of medicine, there are none more rich in facts than physiology, or that more require, and can so easily bear, that the same should be brought before the student in a condensed form.

The introduction of rhymes in the notes the author is well aware ill accords with the tenor of a book of science. He well knows that the two in very nature are opposed to each other, and how much learned professors will writhe when they see some of the valuable facts of animal physics, and those, perhaps, the very glory and triumphs of the science, tortured into doggerel rhyme. If, however, they will serve to fix these facts upon the memory of the student, it will be a sufficient apology for their introduction: the gold will not be polluted by the dross, and

"————————— ridentem dicere verum
Quid vetat?"

The following are subjects in which the author has propounded some original propositions: they are here pointed out, that they may be held in that reservation and that estimation that is due to all matters that have not undergone general adoption:—On the origin of the oily base of the chyle, page 92; refutation of Kölliker's proposition that the colouring matter of splenic blood becomes the colouring matter of the bile, p. 115; defence of the spleen as a lymphatic gland against Kölliker's doctrine, p. 114; periodical acidity of perspiration, p. 131; explanation why the tongue is sometimes not paralysed by the section of one hypoglossal nerve, p. 197; new arrangement of alimentary principles, p. 49; suggestions on the modes of combination of organic and inorganic bodies, p. 4; on the difference in the effect of dividing and crushing the spinal cord, p. 154; on the operation of contractility of arteries in aiding the circulation of the blood, p. 266, 267; on a difference in the vital phenomena of cilia and spermatozoa, p. 282; an explanation why vegetable food increases the free acid of the urine, p. 120; on the use of the sebaceous glands, p. 130; on the formation of uric acid in the blood, and a dietary founded thereon, pp. 124, 125; proposition for simplifying the theory of diastaltic or reflex action, p. 167; Dr. J. Reid's experiments not conclusive in settling the question whether irritability is dependent on nerves, p. 205; on the pathology of the fascicular glands of the stomach, p. 70; proximate cause of perforation of the intestines, p. 68; explanation of the absence of coagulation of the menstrual discharge, p. 295; effects upon the mind of the study of physics or metaphysics respectively, 186.

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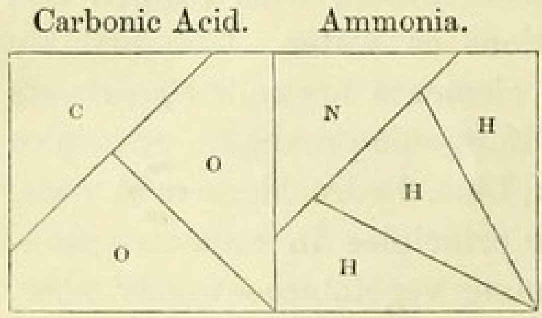
A

MANUAL OF PHYSIOLOGY.

CONSTITUTION OF THE HUMAN BODY.

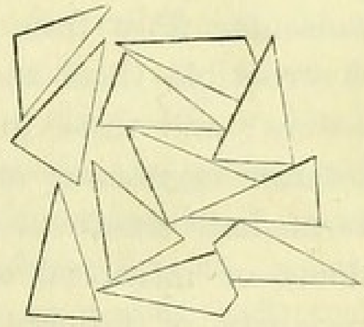
THE proximate elements are 20 in number—oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, chlorine, fluorine, iodine, bromine, silicon, potassium, sodium, calcium, magnesium, iron, albuminum, manganese, copper, and lead. The first four in this list are named *essential* elements: these exist in organic bodies in a much larger proportion than the others; and two out of the four at least are found in every organic substance, but more generally three or four. Of the other elements, which have been named *incidental*, phosphorus and sulphur exceed the rest in the importance of the combinations which they contribute to form. Sulphur, in union with proteine, forms caseine; and the two with proteine form albumine. The sulphur is easily detected in these substances by treating them, first, with hot solution of potash, which forms sulphuret of potash, and then precipitating the black sulphuret of lead by adding the acetate of that metal. Phosphorus and sulphur enter into the composition of the brain, the muscles, and most animal tissues, the blood, chyle, and other organic fluids; they are set free by disintegration or waste with the other elements of the tissues, and form in the blood two powerful acids by union with oxygen, and make their appearance in the phosphates and sulphates of the blood. There is no sulphur, and consequently no sulphates, in gastric juice or in bone. The other elements come more or less prominently into the formation of other textures to be noticed in their respective places. Iron forms an important particle in hæmatine, but does not give colour to the blood. Lime, in union with phosphoric, carbonic, or fluoric acids, forms the principal earthy material of bone. Soda gives alkalinity to the organic fluids. Chlorine figures prominently in the gastric juice and in other states, taking its share in the formation of hydrochloric acid. The fact of the presence of manganese as a component of hair and bone, and aluminum in the enamel of teeth and in bone, rests solely on the authority of Fourcroy, Vauquelin, and Morrichini; but that the teeth are protected by the fluoric acid in the enamel from the reaction of the saliva, is generally admitted. The presence of copper and lead is supported by the testimony of M. Barse, of Riom, who produced copper in a metallic state, and lead to its re-agents from the human body; and more recently the same has been substantiated by the researches of Orfila. M. Rossignon, in his experiments on gelatine, obtained for the use of the Hospital St. Louis in Paris, found that its ashes contained the extraordinary amount of 3 per cent. of pure copper, and various proportions of the same metal in the fecule of sorrel, chocolate, coffee, chicory, sugar, barley-sugar, bread, and corn. And in his analyses of the human tissues he found it in the muscles, the organs, the blood, and the semen. M. Sarzeau confirms these reports by his researches, and calculates that no less than 3,650 kilogrammes of copper are consumed annually by the people of France. Physiologists generally are not yet, however, prepared to accept the proposition that either lead, copper, or manganese, exist normally in the tissues of man. But though this may be doubted, the possibility of their presence in the body should be borne in mind in medico-legal inquiries. Although the incidental elements exist in much smaller quantities in organic substances than the essential, and also generally in the number of only one, two, or three, they are very important in imparting to aliments their respective values. Gelatine, though richer in nitrogen than albumen, contains no phosphorus; and this is one of the reasons for the low station which it occupies amongst aliments. There is an essential difference between pure proteine and those bodies that are called proteine compounds, inasmuch as the latter contain incidental elements, while they are absent in proteine; and it has not yet been proved whether pure proteine is an efficient aliment. Caseine contains only sulphur; and this may be the reason why bean-flour, with all its extra nitrogen, does not equal wheat in its powers of nutrition, though both rank as proteine compounds.

Modes of combination of organic and inorganic bodies.—While these bodies resemble each other generally in their component elements, they differ widely in three particulars—1st, in their durability; 2d, in the number of atoms that form the individual or compound atom of each body; and 3d, in the mode of their combination. Organic bodies are peculiar to the animal and vegetable kingdoms. The formation of an organic body cannot be artificially imitated; its synthesis cannot be accomplished. Animals are principally nourished by organic matters, although inorganic are essential, such as water and chloride of sodium. "Although," observes Professor Brande, "carbon, hydrogen, oxygen, and nitrogen, are the ultimate elements of our food, we should soon starve upon charcoal, water, or atmospheric air, or any of their compounds which had not already gone through the process of organization." The essential and incidental elements exist in vegetables in nearly the same number as in animals, yet generally three only of the essential elements are found in vegetables—carbon, with oxygen and hydrogen in the same proportions as water. The primary combinations of the proximate elements are called *proximate principles.* The most abundant inorganic proximate principles are—atmospheric air, water, clay, lime, hydrochloric acid, soda, &c.: those of organic proximate principles in animals—albumen, fibrine, and gelatine. Among vegetables—woody fibre, sugar, gum, starch, &c. Animal proximate principles are mostly composed of the four essential, with one or more of the incidental elements. It is a principle in physiology that vegetation effects the transformation of proximate elements into organic compounds. It does not, however, seem to act on these elements in their crude and separate state, but seizes them as it were in the act of changing from proximate principles to proximate elements; they also have the power of effecting this change and ultimate reduction, and thus it is that decaying vegetable and animal matters are serviceable to the support of vegetation, their components being in a state of change from the organic to simple chemical or inorganic forms. The consequent action of vegetation is to build up ultimate elements thus obtained into organic substances ; and it is from the latter chiefly that animal life derives its support. The difference in the modes of combination of the atoms of organic and inorganic bodies may be better understood, if for the time being we name the compound atoms of which the bodies themselves are formed, *bricks*. Under such license of speech, then, we will call the compound atom of the chief of all animal proximate principles, albumine, an *organic brick*, and sesquicarbonate of ammonia, which is an inorganic salt, composed of the same proximate elements as albumine, an *inorganic brick*. We will suppose this latter brick to be composed of seven elementary angular bodies, which shall represent the seven elemental atoms of the compound atom of sesquicarbonate of ammonia, each having so many flat surfaces, or rhombic planes, that when one of the seven (carbon) is united to two others (oxygen), their planes so join as to form a perfect rhomb or cube (carbonic acid). When another of the angular bodies (nitrogen) is joined to the remaining three (hydrogen), another quadrangular body or cube (ammonia) is produced, and by joining the two cubes together, you have an oblong substance of the shape of a brick (the sesquicarbonate of ammonia). For obvious mechanical reasons, when this body is knocked in pieces, or into its elements, it will first divide through the middle (into carbonic acid and ammonia), and then into its ultimate elements, the seven angular bodies. And so it is with the combination of the elements of inorganic substances ; although they have in reality no palpable planes and angles, they appear first to fit together in pairs (hence they are called *binary*), and then in double pairs ; the primary pairs being held in closer union than the secondary. The ultimate elements of inorganic bodies are few in number as compared with the organic, and when this number is increased, as is the case in the peroxides of metals, their stability is weakened, and they are more easily decom-



posed; and this would be the case in our analogy, by multiplying the number of the angular bodies; for it is easy to imagine, that by crowding more of the angular bodies together than are sufficient to form the cube, they will not be held so firmly; and when their components are put in motion, they are likely to reunite in pairs, and form the cube. A peroxide, therefore, is more easily decomposed, and on such being the case, it takes the form of a protoxide, or our imaginary cube. To continue the analogy, all organic bricks are composed of the angular bodies just described; the principal difference between them is the number and arrangement of the angular components. That of albumine, or rather proteine, according to Scherer, contains 114 of these bodies; they are neither fitted together in cubes, nor the double cubes, after the manner of inorganic bodies, but come together, we will suppose, with their angles projecting against each other, like the particles of broken stone in concrete; not accidentally jumbled together, but definitely arranged, and in such exact and proportionate precision that if one angular component is disturbed, the symmetry of the whole brick (compound atom) is disarranged, and its structure loosens and crumbles to pieces (decays). There are several circumstances which operate to bring about the dissolution of the organic brick: 12 out of the 114 angular bodies (the nitrogen) of which it is composed, have weak adhering powers for holding the matter, by which they are cemented together; and it is so in whatever structure they enter, whether organic or inorganic. A reference to the chemical history of nitrogen will show its low affinities for oxygen and hydrogen, and how slightly it is held in union with oxygen in nitrate of potass, and with hydrogen in ammoniacal salts. Moisture is also well known to produce the decay of organic compounds, or, in other words, to loosen the angular components; and the soft animal tissues are composed of at least two-thirds of water; and, lastly, the contact of atmospheric air. These physical conditions, especially when

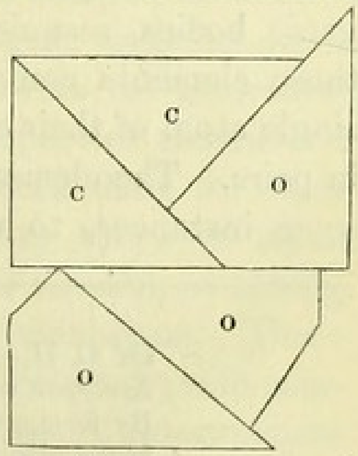
The fourth part of an atom of Albumine.



aided by another predisposing agent, a favourable temperature, will set the angular bodies in motion, and thus the organic brick, representing the compound atom of albumine, with which atom the whole animal fabric is constructed, is shook to its foundation; and as the angular bodies are moving, they fall first into several intermediate organic shapes, no longer of that complicated and perfect construction that characterises the higher orders of organic atoms, but are, as it is called, of a low and degenerate, or more simple order of organization. The angular bodies, we may suppose, though fewer in number, and still joined with angles and edges to planes in the organic fashion, instead of plane to plane as in the inorganic method, are in a degree more firmly held together than they were in the atom of albumine: for it is a principle in organic chemistry, that intermediate products, as they arise in their wonted gradations, in descending from the high organic to the low inorganic forms, as gradually assume firmer forms of composition: thus fat or adipocere is less destructible than the muscular fibre from which it may be formed; starch is less destructible than the vegetables into whose composition it enters; and thus, in the course of these changes, a host of inferior organisms are produced, or the pabulum for such intermediate creations is furnished, and thence come the kingdoms of infusorial organisms, contagion, and infection, the products of fermentation, and the generation of sickening odours from putrefactive decomposition. The existence of these organic forms is of short duration, being the temporary products and shapes that the angular bodies, or the elementary atoms of animal organics, assume when once set in motion before they unite plane to plane, or fall into the three notable chemical cubes—*ammonia*, *carbonic acid*, and *water;* notable because they form the last stage in the destination of all animal organics. Urea, pus, some organic acids and their ammoniacal salts, alcohol, ether, are some of the intermediate products just referred to; the fats also, and their acids, may be reckoned among them, for fat may be artificially formed by the action of bile upon sugar.

There are some among these substances, especially the organic acids and some of their salts, that come near in their constitution to inorganic bodies; they resemble them in their binary composition and the paucity of their elementary atoms; for instance, urea or cyanate of ammonia. But, though they have a binary arrangement and few component atoms, still, if we look to the number of their atoms, we find too many for the simplicity of an inorganic substance: in other words, for forming the inorganic cube; and for the purpose of still addressing the tangible sense, we will continue the simile, and suppose that the angular bodies, though too many to form cubes, yet are better fitted together than in the animal organic atom. It is more important to distinguish between these substances and the inorganic, because the former are decomposed by the action of digestion, while the inorganic are not. Digestion accordingly has no power to decompose the inorganic cubes of sulphuric, nitric, carbonic, and other like inorganic acids, but modify only a little the composition by adding slightly to the number of their elements (such as admit of it) —say carbonic acid; which, if we look to its cube, consists of one of carbon and two of oxygen—by adding one more of carbon and one of oxygen, becomes oxalic acid—a much stronger acid than the carbonic; but, though the planes will fit together much closer than animal organics generally, there are in it too many elements to form the cube; it is an organic body. It belongs to the class of organics last described as coming nearest to the inorganic; but, not being united, as it were, in cubes, it is assimilated in digestion, as is well known to be the case with oxalic acid. The salts formed from the inorganic acids are also not generally assimilated, such as the sulphates and nitrates: their imaginary double cubes are not displaced, or their matter-of-fact chemical affinities are not disturbed. Such salts are introduced into the blood unchanged, by absorption by the veins of the stomach. The tartrates, citrates, acetates, &c., on the other hand, are decom-

An atom of Oxalic Acid.



posed before they are introduced. The class of organic substances that we have described as resembling the organic are mostly ternary, or consist of three elements. The lines attached in the notes give concisely the components of five of these substances, which are important to be borne in mind by the medical practitioner, inasmuch as they daily come before him in his dietary prescriptions. Like the other rhymes in this book, they are not written for the use of the chemist or for the physiologist, but for causing valuable facts, in which physiology and chemistry go hand in hand, to be *at hand* in the memory, and more readily available in therapeutics. And if, by the aid of six lines of rhyme, five prominent articles in dietetics may be called up in the memory, it is hoped that the homeliness of the language will not be despised.

The word *binary* has been applied to inorganic bodies, and *ternary* to organic; but such a restriction of their meaning will lead to confusion. The leading distinguishing marks by which inorganic bodies are known from organic are, that the atoms of their different elements consist of the smallest proportion of which they are capable of uniting with each other, by the union of their elements in pairs, and by the durability of the new product. Two atoms of oxygen and one of carbon we call a pair of elements—carbonic acid, although it consists of three atoms. One atom of nitrogen and three of hydrogen is another pair—ammonia. By uniting this pair of inorganic bodies, sesquicarbonate of ammonia is produced; but these elements could not be made to unite if you abstract a single atom of their elements, and thus break the order of union in pairs. The elements of inorganic bodies may be made, in some instances, to unite in still smaller proportions without

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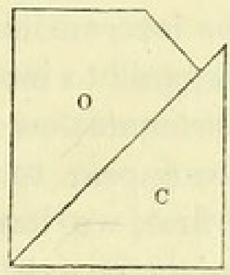
Of C, H, and O,* six equivalents take,
And you've sugar, which also will alcohol make;
By fermenting some acid carbonic away,
Make alcohol acid acetic you may
By oxygenation; and sugar's the sum
Of starch's components, and also of gum.

* The chemical symbols of carbon, hydrogen, and oxygen.

altering the inorganic character of the new compound. There is another compound of oxygen and carbon besides carbonic acid, consisting of one atom of carbon and one of oxygen; and we can imagine that the angular bodies supposed to form the cube of carbonic acid may be made to part with one of the oxygen without altering the character of the new combination for durability, which is seen in the annexed representation of two of the angular bodies of carbonic acid united to form carbonic oxide. In harmony with our simile of the cube-like union of inorganic bodies are the various combinations of carbon and hydrogen; and they also form instances of inorganic and organic substances being alike composed of only two elements, as well as showing the multiplicity of the substances that result from the union of the element in numbers too great to form the cube. Carburetted hydrogen is the inorganic product; and a list of substances of the nature of camphor, turpentine, and essential oils, the organic. An atom of the gas is composed of two atoms of hydrogen, and one atom of carbon—3. An atom of turpentine, and others of its class, is composed of 8 of hydrogen, 10 of carbon = 18. The compound atom has, therefore, six times the number of component atoms; is six times larger than the atom of the gas; and, like other organic substances, has no comparative powers of endurance. M. Raspail and M. Dumas have their respective theories on this subject, under the head of "Différences dans les êtres vivants et les corps inertes;" but neither they, or other writers, have adopted the homely allegory of rhombs, or oblong bodies, to typify the differences of their combinations. There is seen during life a constant tendency in animal organic compounds to pass into simpler forms of combination, intermediate to the organic or chemical; and the weaker the formative powers become in the tissues, from the diminution of the powers of life, and the nearer the close of life, the more energetic is the tendency to chemical combinations. The diarrhœa

An atom of Carbonic Oxide.



that is common in the last stage of many diseases is thought to arise from the large amount of carbon, and other excrement, with which the blood becomes loaded, from the increased absorption that takes place, occasioned by the rapid waste of the tissues. Thus it is that chemistry and vitality hold each other in perpetual variance: they are, it has been said, continually destroying the works of each other. Vitality has the power of checking chemical decomposition. We may say that organic chemistry holds inorganic chemistry at bay in animal life; and thus is the common tendency to fermentation and decay resisted in living animals.

The intermediate formations that ensue from the passage of the organic to inorganic matters constitute the prolific progeny of fermentation and decay. Three great and mysterious armies appear to hover around the corpses of defunct organic life: first, we have animalcules in every form of microscopic organism, or, at any rate, the most favourable condition for their development; then comes the pestilence, in its dark forms and varieties; and, lastly, every shade of effluvium that, speaking with anatomical precision, the first pair of nerves can recognise, with the aid of the fifth, to discriminate the pungent substances and ammoniacal combinations.

Albumine is identical in chemical composition with the following substances:—vegetable albumine, or that obtained from kitchen-garden vegetables; with the gluten of corn; with animal fibrine, that abounds in muscular tissue; with the organic

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Fermentation and Decay.

All fermentations and decay, depend on't,
Are nothing more than chemistry ascendant.
Complex organic atoms in a panic
To change to simple pairs, joined inorganic;
While in this stage of change a mighty host
Of intermediate products they can boast;
Of animalcules in various region,
Contagion and infection in a legion;
With each effluvium from the exhalation
Of sickening putrefactive fermentation.
Vis vitæ all organic life enables
At once on chemistry to turn the tables;
Stays, in each form of life, the prone decay.
Thus vital force holds chemistry at bay.

constituents of the blood, excepting the hæmatine; and with caseine, whether obtained from leguminous seeds or milk, excepting that caseine has no phosphrous. Albumine is the source from which the whole of the animal tissues are generated; it is present in a soluble form in the serum of the blood, in the lymph, the chyle, and some of the secretions, and forms a considerable portion of the brain, ganglia, and nerves. Albumine is remarkable for the two forms in which it presents itself,—in solution, as it exists naturally in the animal fluids referred to, and in its coagulated state. It coagulates at about 160° Fahrenheit, and also by the action of the following substances:—the acids, except when much diluted, and except, also, the acetic. In union with acids it acts as a base. It combines and coagulates with the alkalies, with which, also, it performs the part of an acid. With some metallic substances it forms, also, insoluble albuminates: hence its power as an antidote to the salts of mercury and lead. By treating such coagulum with an excess of albumine they are re-dissolved, and the coagulum obtained by an acid is redissolved again by the same acid in excess. In like manner strong hydrochloric acid re-dissolves its own precipitates; and this acid forms a test for albumen by imparting to the solution a purple colour. When coagulated albumine is digested in very dilute sulphuric acid, the mixture becomes of a deep crimson colour. Albumine is precipitated also by alcohol and ether. It possesses the power of dissolving metallic oxides; and it is in this way that they, and especially the protoxides, are taken into and held in solution in the blood. The compounds thus formed with albumine are in close chemical union with it, and not easily decomposed. Besides the four essential elements, it contains phosphorus and sulphur. Boiling is not a sure test for albumine, for a weak solution is not precipitated by boiling.

The paramount station that albumen holds in the animal economy no less demands our attention than the remarkable affinities just enumerated, and the variety of habitudes that it is capable of assuming,—to wit, the proteine compounds, and others isomeric in composition. It is said to contain a little free soda, and to this is attributed the cause of its solution; but no good explanation has as yet been given of its remarkable property of coagulating, either by heat or other agents. The relative amount of its essential elements should be remembered; for great and important questions in therapeutics are resolved by such knowledge: many of the tissues and secretions especially draw upon its nitrogen, others upon its phosphorus, — such as milk and nervous matter, of which more will be said. M. Becquerel, in a memoir to the Academy of Sciences of Paris, on the subject of the relative amount of albumine in diseased fluids, reports that the amount of albumine contained in any solution may be accurately determined by the deviation of polarized light in passing through the liquids; that they throw the polarized plane of rays of light to the left, and thus the intensity of the deviation is in proportion to the albumine. In plethora, the amount of albumine in the serum of the blood is rather diminished than increased. In disease of the heart, the albumen in the serum decreases in a great degree so soon as dropsy appears; but not before. The last observation applies to Bright's disease of the kidney. Of the numerous analyses that have been made of albumine, the following is here given as being the most recent. The authorities that will more or less confirm the facts advanced on this subject are, Dumas, Mulder, M. Baudumont, Wœlher, Gmelin,

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The Physiology and Analysis of Albumine.

This fruitful dame, from whom does issue
The pabulum for every tissue,
Has for the alkalies a balm:
She also can the acids calm.
These and metallic salts involve
With her a tie that won't dissolve,
Save in excess, when she'd be fain
To re-dissolve the same again.
In like excess you may confide
That she'll take up a protoxide.
Weak acids, and acetic, proof
Will give from her they stand aloof.
Heat throws her down; but ah! how strange!
When *weak* she'll not by boiling change!
Seven from hydrogen 's but few,
Since oxygen gives twenty-two;
Sixteen from nitrogen; and see,
From carbon she has fifty-three.
From phosphorus thirty fractions come;
From sulphur full four times that sum.

Henle :—The centage composition of albumine, C53·4, H7·1, O22·3, N15·6, P0·3, S1·3.

Fibrine, like albumine, is distinguished by remarkable peculiarities, the bare facts of which must suffice us, without explanation. It exists naturally in a liquid state *only* in the blood, the lymph, and the chyle, and only so long as these fluids retain their positions in their respective spheres of vital action; for, on separation from the body, it coagulates without the aid of reagents. It is best obtained by tying one end of an open tube (a few inches in length) over with linen, placing a clot of blood in it with some shots, and shaking the tube while water is poured through it. It is an elastic, opaque, grey, fibrous substance in combination with a little fat, which may be removed from it by either. Fibrine, by the action of either nitric or sulphuric acid, becomes a jelly, which does not dissolve in water. In phosphoric acid, or acetic, a jelly is also formed, which is soluble in water: this product, though gelatinous, is not gelatine. These effects are not produced upon albumine coagulated by acids. Another difference between the two substances is, according to Henle, that hydrochloric acid gives a violet tint to albumine, and a purple tint to fibrine. Chemists are generally agreed that in composition these substances do not differ, and physiologists are equally agreed that fibrine is albumine partially organised, and that fibrine occupies a midway station between albumen and solid animal tissue. For the discovery of this latter fact relative to fibrine, and for elucidating the source of its formation, physiology is indebted to Dr. Carpenter, whose views have been confirmed by the experiments and researches of Mr. Addison and Dr. Williams, which will be again referred to. An important feature in the physiology of fibrine has been pointed out by M. P. S. Denis, that a warm solution of nitrate of potash dissolves the fibrine of venous blood, but has no effect upon that of arterial blood, or even upon venous blood, if exposed to the action of the oxygen of the atmosphere,—a fact that may be important in medical jurisprudence, and also in therapeutics. With the foregoing exceptions, fibrine exhibits the same changes under reagents, and forms the same compounds with acids and alkalies as albumine.

Proteine is a substance obtained by the action of hot solution of potash upon albumine, fibrine, or caseine. From this solution acetic acid throws down a grey precipitate. In composition it is the same as the substances from which it is obtained, with the exception that while they are the same in their essential elements, the proteine is without the incidental, without the phosphorus and sulphur. The discovery of this substance (by Mulder) is chiefly valuable by simplifying and connecting the three *proteine compounds* from which it is furnished. The word proteine is from πρωτευω, to stand first. It stands first as the foundation of albuminous substances; but it is in the second rank as an aliment, from its deficiency in the incidental components. It does not exist, however, as a separate aliment. Liebig has added to our little stock of facts one of those scarce donations, more prized in their simplicity than the highly-wrought productions called theories, the fact that the proteine compounds in some shape or proportion are universally present in vegetable aliments.

Mulder's formula for proteine is—carbon 36; hydrogen 50; nitrogen 8; oxygen 10. Several of the tissues are called *gelatinous*, in consequence of the large amount of gelatine of which they are composed. It does not, however, exist in these tissues as gelatine, but is altered by organization in the same manner as fibrine is organised albumine. These tissues are the tendons, ligaments, the white fibrous element in areolar tissue, and it exists in the same principle, probably, in the dermis, in periosteum, synovial, and serous membranes, fibro-cartilages, and it forms the organic portion in the substance of bone. From these tissues it is obtained by boiling. Gelatine is remarkable for forming a compound with tannin more durable in its organization than gelatine itself; this is, a dense precipitate obtained by tannic acid (tannate of gelatine) from its solution. When a solution of tannic acid is made to endosmosize hides, they become leather. It has been recently ascertained that gelatine contains as much as 0·56 of sulphur. The following is the composition given by Scherer, which will be seen to contain sulphur—carbon 50·557; hydrogen 6·903; nitrogen 18·790; S, and O, 23·750; and oxygen 23·750. The formula is, carbon

48; hydrogen 41; nitrogen 7½; oxygen 18. A remarkable feature in gelatine also is, that it is dissolved by boiling water, and becomes solid on cooling, in which state it becomes a jelly, unless much concentrated. By repeated melting and cooling it enters into combination with a portion of water, becoming a hydrate which will no longer dissolve. Having all the components of albumine and nitrogen more abundant, proteine cannot be formed from it, although nothing seems easier in the tables of chemists. Pepsine, with the help of an acid, cannot bring it to that one form to which it reduces all the albuminous compounds. It is, therefore, introduced into the blood in its own shape and form, and as such is supposed to nourish no other than the gelatinous tissues. The reports of chemists to the Academy of Medicine in Paris are unfavourable of it as an aliment unless mixed with albuminous food, and under all circumstances it stands second to the albuminous class. But in its due proportion as a part of daily food it may be better than the proteine compounds; for in persons of weak assimliating powers the presentation to the stomach of the necessary amount of gelatine, ready prepared for the support of the gelatinous tissues, may so far spare the vital energies, the work of elaborating the same from albuminous matter, which must otherwise be the case. The acids do not precipitate gelatine or decompose it (except the sulphuric), but aid in its solution, especially the acetic; and, except as solvents, the alkalies have scarcely any effect upon it, which in this forms a striking contrast to the proteine compounds. It is insoluble in alcohol; but neither this, corrosive sublimate, or other metallic salts, form good tests for gelatine. One part of gelatine gelatinizes 100 parts of water, but it is dissolved in 150 parts. One part is detected in 5000 parts of water by infusion of galls. Professor Brande considers sulphate of platinum a very delicate test for gelatine, giving a brown precipitate, and one not affected by albumine, which is not the case with tannin.

Chondrine is the substance obtained from simple cellular cartilage, but not from the fibrous. In its physiology it so nearly resembles gelatine that it is ranked as a variety of that substance. It becomes a jelly, and a glue, like gelatine, with this difference, that it requires longer boiling. In chemistry it is totally distinct from gelatine, though, having the same number of elements, they differ more in their proportions than the proteine compounds differ from each other; in proof of which, chondrine is not precipitated by tannic acid, but, on the contrary, it is so by the acetic and the salts of metals which have no effect upon gelatine. Its formula is—Carbon 48; Hydrogen 40; Nitrogen 6; Oxygen 20. Simple cellular cartilage contains much more inorganic matters than the gelatinous tissues, amounting to from 4 to 6 per cent. of ashes.

The *horny tissues*, like chondrine, are nearly allied to gelatine in external relations; they are the same gelatinous gluey substances, but in chemistry they differ essentially. They comprise hair, horns, or nails, the epithelium and epidermis. The formula is C^{48}, H^{39}, N^{7}, O^{17}. They are more insoluble than either gelatine or chondrine. From these substances proteine may be obtained in the usual way by potash and acetic acid; but it is worthy of remark, that it does not appear that any such transformation can take place by the reactive power of the gastric juice, or by the other forces of digestion. Like

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Gelatine.

When demonstrating gelatine,
Proportions relative we mean.
Let albumine the basis be;
Then taking from it carbon three,
Give three to azote, also then
Add three more to the oxygen.

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Per-centage analysis of albumine by Mulder . . .	53·4	7·1	15·6	22·3
Deduct	3		Add 3	Add 3
Numbers obtained for gelatine by following the directions of the rhyme.	50·4	7·1	18·6	25·3

gelatine, therefore, it cannot be brought to that one form of albuminous composition to which it is the province of gastric juice to reduce all albuminous compounds.

BLOOD.

The specific gravity of healthy venous human blood varies between 1050 to 1060. When either above or below these numbers, it may be considered in an unhealthy condition. Its temperature is from 98° to 100° Fah. The gross amount of blood in the body averages about 28 lbs., or $\frac{1}{5}$th the weight of the body. The components of 1000 parts of blood, as given below, are taken from Becquerel and Rhodier's extensive tables: they correspond in the main points with most other computators, except that they are considered low in their estimate of fibrine, in confirmation of which a sort of tradition seems to prevail, which settles the fibrine at 3. Attention is drawn to this circumstance, because the Table of Diseased Blood fixes the healthy average of fibrine at 3.

	Mean in 11 men.	Mean in 8 women.
Specific gravity of blood, defibrinated	1060·2	1057·5
Ditto of serum	1028·0	1027·4
Water	779·0	791·1
Corpuscles	141·1	127·2
Albumine	69·4	70·5
Fibrine	2·2	2·2
Extractive matters and free salts	6·8	7·4
Fatty matters	1·600	1·620
Serolin	.020	·020
Phosphorized fat	·488	·464
Cholesterine	·088	·090
Saponified fat	1·004	1·046

Inorganic matters from 1000 parts of blood after calcination.

Chloride of sodium	3·100	3·900
Other soluble salts	2·500	2·909
Phosphates	·334	·354
Iron	·565	·541

It must be observed, that the free salts in the first analysis do not include some inorganic substances, the incidental elements of the organic compounds, viz. the iron in the hæmatine, and the sulphur and phosphorus in the albuminous compounds; they do, however, contain the compounds of iron in the serum, which consist of a phosphate and a peroxide, the latter of which is held in solution by albumine. A considerable range must be allowed between the maximum and minimum for fixing the limits of healthy blood as a standard, when making a quantitative analysis for clinical purposes; otherwise reference must be had to the original memoir, or to Dr. Ranking's Half-yearly Abstract of Medical Science (Vol. i. p. 310), which contains also the results of the researches of most other writers on the subject. Attention should not be solely confined to the constituents of the blood, for disease and remedial measures may possibly affect more the volume of the blood than the component parts. The blood is crimson, approaching to scarlet in the arteries, having in the veins that darker tint that the mixture of carbonaceous matters confers upon it. It is alkalescent, having a peculiar odour. In the space of five to ten minutes after removal from the body it becomes a coagulated mass, from which the serum gradually separates in the course of 24 hours afterwards, the coagulum becoming gradually smaller. The proportion which the serum should bear to the coagulum is said to be as 10 to 17, or about 2 of serum to 3 of coagulum.

This estimate is mentioned as giving data on which to judge of the relative proportions by the bed-side. If more than this is required, the blood should be analysed. The coagulation of the blood is not perhaps so wonderful as its fluidity, coagulation being caused by the fibrine resuming its natural state on being freed from the inexplicable influence that the living fluids exercised upon it, and causing its solution. On the whole mass of blood in the basin first becoming coagulated, the fibrine spreads through the whole in a fine net-work; and on contracting, entangles the whole of the corpuscles, intermixed with some serum, leaving in the remainder of the serum the albumine, the fatty matters, and salts. Owing to the quantity of albumine contained in the serum, it becomes a gelatinous mass at about 150°. The red corpuscles being heavier than the other components, have a tendency to sink in the fluid. This is perceptible in blood drawn in inflammation; a layer of fibrine is seen on the surface, which constitutes the *buffy coat:* the reason of which is, that blood in inflammation retains its vitality, and consequently its fluidity, longer than ordinary blood, and thus time is given for the red corpuscles to sink: added to this, the red corpuscles have a mutual attraction for each other. The high specific weight of the blood depends on excess in the red corpuscles, this being the heaviest portion. Coagulation of blood may be regarded as a vital operation, which certain shocks received by the nervous system greatly retards, but does not, according to Polli, altogether prevent. This is the case in deaths from lightning, some poisons, some fevers, and blows on the cœliac plexus; in such cases, irritability has totally forsaken, or is much diminished in the muscles. The nitrate of potass will be seen (see Fibrine) to have a specific effect in dissolving a certain form of fibrine—venous, in which plasticity is lower than in arterial: hence its advantages as a remedy in over-fibrinated states of blood, inflammations, &c. The coagulation of fibrine is suspended by freezing, and retarded by a low temperature: the latter fact may account for the good effect of cold in phlegmasiæ. The slower blood is drawn from a vein, the quicker is its coagulation: the contact of air is thought to be the cause of this effect. The tendency which fibrine has to contract being resisted below the layer of buffy coat, by the mass of corpuscles in that situation, and being free on the upper surface, a tendency to curve inwards is given to the upper edges, which creates the cupped appearance of blood, as seen in the basin. It is the *contraction of coagulation* that causes the gradual condensation of the clot. The contraction of fibrine, and also the reticulated net-work of fibres that extends through it, are important facts in the physiology of that material; and it is important to observe, that fibrine, whether as it exists in the blood, or in first-formed simple membrane, or in formative blastema, holds in its meshes either the white corpuscle, granular matter, or free nuclei. Fibrine, according to Dr. Carpenter, is albumine in a stage of organization progressive to its introduction into the tissues. We are indebted to this gentleman for the discovery that certain membranous tissues are produced by layers of these plastic elements. Dr. Addison adopts the same view, and denominates the same material the *protoplasma* of the blood: he demonstrates the interesting fact that this substance in incipient formations, whether of repair or original growth, is the forerunner of the vascular system, and, as it were, the herald of the red corpuscle. A delicate investment of this plasma surrounds and precedes the red corpuscle in its penetration into new structures, as it organizes and renders them vascular, and, in the words of Dr. Addison, "as growth advances, the coats of the vessels become recognisable as a distinct form of tissue, interspersed between the blood current and the more solid portions of the structure." In this procedure the solids of the serum thus take precedence of the corpuscles. It is moreover observed, that, in physical properties and microscopical appearances, the protoplasma and the coats of the fine capillaries and basement membrane are identical. The researches of Professor Paget add a great weight of testimony to the doctrine that active formative powers reside in the plasmatic portion of the blood. This is especially made apparent in the matters effused from the blood in the process of repair and reproduction after injuries, and in development of the embryo. Phlegmasiæ and acute rheumatism are states in which the formative powers of the blood are in an exalted state, and in such cases there is a sudden growth both of fibrine and the white corpuscle. By a subsequent table it will appear that such increase of fibrine is upwards of three times the normal amount. The white corpuscles not being separable from the fibrine, cannot be estimated correctly. It is also well known that there is a large assemblage of the white corpuscle in the part inflamed, and that even so slight a matter as a boil, or an inflamed finger, will not only attract those corpuscles to the spot, but cause so great an increase of them in the general mass of blood, as to produce the appearance of the buffy coat. Mechanical irritation applied to a vessel causes the white corpuscle to accumulate around the spot.

The red corpuscle is composed of two organic substances—*globuline* and *hæmatine:* the first is a proteine compound; the cell-walls are composed of it, and another portion, in the shape of albuminous matter, is in union with the hæmatine. Hæmatine constitutes the colouring matter of the corpuscle. When separated from the albuminous matter by coagulating the latter by heat, the hæmatine becomes of a dark brown colour, and is precipitated. The acids and alkalies dissolve it, restoring in some degree the red colour; but with nitric acid the solution remains brown. These are negative proofs that the colouring matter is not dependent on the iron which is in combination with hæmatine; for such treatment, by altering the form or habitude of the iron, would destroy the colour. Mulder's form for hæmatine is, $C^{65·84}$; $H^{5·37}$; $N^{10·4}$; $O^{11·75}$; $Iron^{6·64}$.

A large quantity of iron, in the shape of an incidental element, is seen to form part of this analysis: like all other components of substances that bear the name of incidental, it is not held in combination in the form of a dissolved oxide or salt mixed into an organic compound, but is in such close and mysterious chemical union that the re-agents which usually act readily upon it in its ordinary state do not do so in this. Thus diluted sulphuric acid cannot be brought to act upon this combination of iron under three or four days. Hæmatine, after its removal, and before it forms the brown precipitate, is thought to exist in organic union with the albumine. Neutral salts of most kinds have a striking effect in rendering florid the red corpuscle of venous blood. Alkalies and acids, particularly the carbonic, have the effect of darkening arterial blood. No satisfactory account can be given of the change that takes place in the colour of the blood under the influence of respiration. Chemistry has altogether failed in supplying an explanation, either in regard to an oxide of iron, as suggested by Liebig, or in the ingenious idea of Mulder of an oxide of proteine formed by the influx of oxygen, which being insoluble, gives an additional coating to the corpuscle, causing it, by its contraction, to assume more of its concave shape, and producing an optical effect by reflection of light. A similar effect never having, however, been produced by like causes, and as the shape of the corpuscle may be altered indefinitely by other means without producing an alteration of colour, the subject seems again to relapse into its previous mysterious state.

In shape, the red blood-corpuscle, as seen by the microscope, is usually described as a flattened cell or disc, the flattened surfaces being a little concave, and having rounded edges; in shape like a lens being indented a little on each surface to represent the slight concavity which is observed on the two surfaces of the corpuscle. The measure of the corpuscle is from $\frac{1}{3000}$ to $\frac{1}{4000}$ of an inch in diameter, and about $\frac{1}{10000}$ of an inch in thickness: so that if the lens measured $3\frac{1}{2}$ inches in diameter, in thickness it should be $1\frac{1}{6}$ of an inch. The cell wall is transparent, and of the same delicate construction as that of myolemma or basement membrane. Like these membranes, it is permeable to fluids by the physical law of endosmose and exosmose, and is moreover as readily permeated by gases. But though so delicate, the cell-wall is of ample strength, as may be seen by the elongations and the compressions it appears to undergo occasionally in penetrating the capillaries in the web of a frog's foot. The exosmosic transmission of their fluid contents is produced by placing them in a saline solution, which, by diminishing their size, flattens and corrugates their walls, and gives them a granulated appearance. By dilution of the fluid in which they float, they swell out, and either burst or become so pale that they are not recognised. A peculiar characteristic in this corpuscle is its tendency to cluster or form into irregular columns, the flattened surfaces coming together; but this is seen only in blood drawn in inflammation, whose plasticity is augmented. It gives the idea that they are so congregated in readiness to form tubes by the absorption of that part of their walls that are in apposition. The red corpuscle has no nucleus on its walls, though its concavity causes at times this appearance by the non-refraction of light from the concave spot. Sugar in solution causes an exosmosic current and a flattening of the cell. A fluid of the exact consistence of healthy blood preserves their right shape. They keep to the centre of the current in the capillary vessels, and consequently move quicker than the white corpuscles. The walls of the red are less firm than the white, which favours their tendency to part with and add to their contents, and the admission of oxygen, for which they have so strong an affinity; their principal office being to receive oxygen in the pulmonary tissue, and convey it to the systemic tissues, to receive carbonic acid in the systemic tissues, and convey it to the capillaries of the lungs.

Several substances exercise a solvent power upon the red corpuscle: amongst these are the alkalies, carbonic acid, bile, and urea; for which see an excellent account in the lectures of Dr. Day on animal chemistry. A weak solution of an alkali added to blood is sufficient to cause the total disappearance of the red corpuscle. Ammonia and the bicarbonates, which are but little alkaline, have this effect. Urea is slow in its solvent operation upon them; and before they disappear they assume a variety of shapes, which is observable in Bright's disease. It must not be supposed, as observed by Dr. Day, that the great diminution of the corpuscles characteristic of this complaint arises entirely from the presence of urea in the blood; for it must be recollected that the altered state of the density of the blood is sufficient to burst and destroy the corpuscle by endosmosis. As regards the effect of bile upon them, Mr. Simon ascertained that on a little pure choleine being added to blood it became almost gelatinous, and capable of being drawn out in threads in which no corpuscles could be seen, and on the addition of fresh bile to blood, the corpuscles disappeared: when the choleine was diluted, they resisted for some time its solvent power, altering also in shape, and becoming twisted and elongated. The effect of carbonic acid on the red corpuscle has been demonstrated by Harless. The corpuscle first swells and becomes transparent, and then undergoes complete solution.

Arterial blood contains as much as 20 per cent. in volume of carbonic acid; venous blood, 25 per cent. Arterial blood contains 10 per cent. of oxygen, and venous 5 per cent. The additional 5 per cent. of carbon which characterises venous blood produces a swelling out of the corpuscle. The effect of oxgen is to diminish the size of the corpuscle, and produce the corrugation, which alters its colour. Nitrogen gas has no effect upon the red corpuscle.

The *white corpuscle*, except the unevenness given it by a tuberculated surface, is spherical. Its measurement is more stationary than that of the red corpuscle—its diameter about $\frac{1}{2600}$th of an inch. It therefore probably doubles in bulk the red corpuscle. They have a greyish, opaque appearance, and so constantly filled with a granular contents, that Mr. Wharton Jones, who first brought them into notice, named them "granule cells." When their cell-wall is filled to its fullest extent by endosmosic percolation, the granular mass holds together, and does not appear to mix with the water: this appearance is seen best when, by dilution in water, or weak acetic acid which is better, the walls give way, at the same time adhering by their internal surface to the globular contents.

There appears to be a very near relationship between the fibrine of the blood and the white corpuscle. Since Dr. Carpenter first drew attention to the subject, the physiology of the blood corpuscle and the development of fibrine has been exposed to the test of experimental research. His doctrine, that blood plasma is generated by the operation of the white corpuscle, seems likely to withstand the investigation that has upset much other doctrine. It is remarkable that, in the analysis of the blood, the white corpuscle cannot be separated from the fibrine. M. Horn, a writer on the subject, asserts that the fibrine is united to the corpuscle. He found by the microscope that the fibrine from the blood of a frog is derived from the granules that are met with in the blood,—the same nuclei that are so abundant in the chyle,—and that, when the fibrine is removed from the frog's blood, these granules are no longer to be found. M. Horn believes that an aggregation of the granules produces the lymph corpuscle. We know that the white corpuscle is virtually a collection of granules which are held together in a ball when the walls of the cell are separated from it; but whether the fibrine produces the globuline, or the globuline the fibrine, is not certain. The red corpuscle developed in the embryo of mammals, before and after the addition of those sources already referred to, from which blood is formed in the more perfect animal, is different. The first formed corpuscle derives its origin from, or is identical with, the formative or vitelline cells. They are at first colourless and transparent, and, besides having a nucleus in the centre, contain a number of minute granules: many of the cells have two nuclei, and are probably double from the commencement, for they divide into two corpuscles. They differ also from the red corpuscle of after-life in being spherical and larger. The first change in them is the disappearance of the granules and the acquirement of the blood colour. Mr. Paget states that he has inspected the blood of a human fœtus so early as the end of the fourth week, and found the red corpuscles spherical, very distinctly nucleated, of a deeper colour than even adult blood, and observed many of the corpuscles dividing into two. They were about one-third larger in diameter, and, being circular, we may suppose them to be at least two-thirds of the size of the adult red corpuscle.

The *serum* of the blood is a light straw-coloured fluid, with a greenish tint,—is alkaline to tests, with a specific gravity of 1·027 to 1·030 at 50° Fah. It constitutes about one-fourth of the volume of the blood. At about 150° it constitutes about 8 per per cent. of albumine. From this coagulation a little alkaline yellowish liquid exudes, which is termed *serosity*. In the water of the serum are contained the salts of the blood. The colouring matter of the serum is supposed to be the same as that of the bile, the liver separating it and condensing it in that fluid. The alkalinity of the serum is due to the tribasic phosphate of soda. Its density depends much more on the albumine than on the fatty matters or salts. The serum of the blood in gouty patients has been found, by Dr. Garrod and Dr. Bence Jones, to contain urate of soda. The following is the latter gentleman's simple and easy method of demonstrating the presence of lithic acid in the blood, which might readily be put in practice in cases in which the gouty diathesis is questioned:—The clear serum is put into a basin and evaporated to dryness. The mass is to be reduced to the finest possible powder, and then treated with distilled water at 100° F., by which means everything soluble is obtained in solution. The solution is then evaporated to a very small bulk, and strong acetic acid added. Acetate of soda is thus formed, and lithic acid set free; and, in the course of a few or many hours, according to the dilution of the liquid, or the quantity of lithic acid, the crystals of the latter salt are deposited at the sides or bottom of the vessel, like grains of cayenne pepper.

The fatty matters of the blood contain oleine and stearine, or ordinary human fat, cholesterine or bile fat, and cerebrine or brain fat: these substances are doubtless en route to the respective tissues to which they refer, having been previously elaborated by the cell growth of the blood, and are not the worn out and cast off elements of the same tissues. Sereolin is the fat thought to be *proper* to blood. The occasional milky or emulsive state of the blood arises from an undue ingestion of fat, as such, or of starch and sugar, which produces more of the oily base of the chyle than can at once be assimilated and converted to the type of the blood. A portion of fat is found in the *watery* extract of the blood. This is called saponified fat, and proves the existence of a blood-soap, by which it is that cholesterine, which is very insoluble, is held in solution. In a person who has finished growth, the amount of food taken into the body is exactly equal to that of the fæces, urine, perspiration, carbon from the lungs, skin, &c. A small portion of matters from the food passes off undissolved by the intestinal tube, such as colouring matter and woody fibre; but of the two principal classes of food, the azotic, by the aid of a peculiar ferment, the pepsine, is brought under the action of the acid solvents of the gastric juice, which, after being submitted to the complicated agency of choleine, is presented for absorption; the other class, the non-azotic, by the influence of animal diastase and the fermenting principle of the pancreatic fluid, undergoes the process of chemical preparation; and thus both classes of food pass into the blood. All the elements of food taken in excess pass into the excretions, and there make their appearance in more simple combinations. The blood contains surplus elements also that are liberated in the development of the tissues, as when from a complicated organic compound one less complicated is constructed; such as when the gelatinous tissues are generated from the albuminous constituents of the blood, in which case, according to Liebig, certain proportions of all the elements of the proteine compound are eliminated and carried off as useless. The action or function of every organism, and the disintegration or death of a certain portion of the constituents of its structure, are inseparable conditions. The veins gather together the waste and useless elements as they are cast off from the tissues, and deliver them into the general drainage, the main outlets of which are the liver, the lungs, the skin, and the kidneys; though they may be recirculated, and go the cycle of the bile and be again taken into the blood before they are finally excreted. The blood has the office both of furnishing the materials of new growth, and the oxygen that is essential to the chemical change that is identical with the disintegration of the tissues; thus ministering to the purely vital and the purely chemical department of the cycle—the building up and pulling down that is in perpetual progress in the animal fabric. Besides the functions just mentioned as devolving upon the blood, must be added that of preparing and developing materials for its own reproduction, which is a prominent feature in its physiology. The lacteals and lymphatics are properly blood-vessels; the former at least conveying all the constituents of the blood, and especially abounding in cells, and the germs of cells, to be matured with its other contents to the type of blood. Another rich pabulum for nuclei and cell growth is poured in by the blood of the vena porta, taking its origin in the same extensive bed of germs and granules as the chyle, the walls of intestinal tube. Such attributes as the foregoing are sufficient to establish the fact of the vitality of the blood. A quality most remarkable in the blood is the change that must take place in it as the result of certain diseases: for it is impossible to imagine that the freedom that an attack of small-pox gives from future returns of the disease can arise from anything less than a change wrought among the organic arrangement of the atoms of the blood; some modification of them in the size, shape, or contour, in virtue of an admittance of some subtile tenant amongst them, that, with mysterious catalytic power, spreads a change through the whole mass, and which is propagated to the future generations. The same must take place by the virus of hydrophobia and latent infections: what that change is seems to be deeply hidden among the secrets of nature,—nature being another name for Him who constructed the smallest conceivable portion of albumine out of at least 114 portions of other bodies: such design and contrivance is everywhere sufficiently present to humble and prostrate the intellect of man, and warn him of the presence of his God: how much more, then, when we trace his finger and see his commands written upon the face of the blood! The composition of the blood is said to be complicated: the observation applies only to the organic arrangement of most of its atoms, and not to the inorganic or chemical portion. Its pathology is equally complicated, which may be well conceived when we retrace in the mind the many distinct and separate parts that it fulfils in the animal economy, some of which we have just reviewed. How much more complicated, then, must be the abnormal condition, and the numerous aberrations from the standard of health to which each of these functions is liable! The following is the method recommended by Dr. Bence Jones for the analysis of the blood, which, though not the best for the physiologist, is admirably suited for clinical purposes, its great recommendation being the ease with which it is accomplished; and if the drying the residues in vacuo is dispensed with, it may be readily available by every medical man in cases in which a question so often arises as to two opposite states of the blood: such, for instance, as scrofulous tumours in persons in whom the blood is deficient in red corpuscles, and tumours of the same appearance arising from an inactive condition of the lymphatics, in which the blood has more than a right proportion of the red corpuscles.

A light wide-mouthed bottle should be chosen, weighed, and filled with blood from the arm; weigh the bottle and contents; pour off the clear serum into a basin, the weight of which is known. The weight of the serum is ascertained by then either weighing the bottle or the basin, or both. Evaporate the serum to dryness, and place it under the receiver of an air-pump over sulphuric acid till it ceases to lose weight. Weigh the basin with the residue, and strike the balance for the latter.

Place the coagulum on a piece of well washed linen; tie it up securely, but give it space; wash it in distilled water till it is colourless; dry the fibrine first in a water-bath, then in vacuo over sulphuric acid: weigh it. Evaporate the distilled water containing the blood globules, and what serum was held entangled in the clot; evaporate and dry as before; weigh residue, and if the blood thus analysed is found in a healthy state, the result would be (according to Andral, under a similar process), for every 1000 grains of blood—

	Grains.
Fibrine	3·00
Blood-corpuscles . .	127·00
Solids of serum . .	80·00
Water	790·00

The following analyses, selected from Andral's work on the Blood, give the mean result of experiments performed on blood in cases in which the greatest variation occurs in the amount of the constituents (Jan. 26, 1840). The last row of figures on scrofulous blood is from Dr. Glover's work on scrofula.

	Fibrine.	Corpuscles.	Solids of Serum.	Water.
Health	3	127	80	800
Variation in disease	$10\frac{1}{2}$ to 1	185 to 21	114 to 57	915 to 725
Rheumatism . . .	10	101·0	90·0	779·0
Fever	·9	93·1	86·0	820·0
Chlorosis	3·5	38·5	89·0	740·0
Cerebral congestion	2·7	152·3	105·0	740·0
Bright's disease .	3·2	8·2	64·8	850·0
Scrofula	3·18	117·32	81·38	791·95

The effect of bleeding on the constituents of the blood is set forth in the following table, being the mean results of three bleedings on 11 men, by MM. Becquerel and Rodier:—

	1st Bleeding.	2d Bleeding.	3d Bleeding.
Density of the blood defibrinated.	1056·0	1053·0	1049·6
Do. of serum . . .	1025·8	1026·3	1025·6
Corpuscles	129·2	116·3	99·2
Albumine	65·0	63·7	64·6
Fibrine	3·5	3·8	3·4

Becquerel and Rodier differ from most other experimenters on the blood, in the large amount of their red corpuscles and the small amount of their fibrine.

On reference to the mean composition of scrofulous blood, it will be seen that the corpuscles are considerably under the usual standard. The fibrine in quantity is very variable, but its quality causes the coagulum to be very deficient in firmness, sometimes no coagulation taking place. The albumine, as comprehended in the solids of serum, is, however, increased: but Mr. Nicholson's analysis of the same kind of blood fixes the

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Blood.

The blood's composition the student defines
To be fibrine, albumen, corpuscles, salines:
Isomeric in form, with albumen do range
The organics, save fats and hæmatine—how strange!
The seven parts salts in one thousand may well
Be apportioned one-half to K Na. Cl.;*
T'other half in the phosphates and sulphates resides,
Joined to alkalies, earths, and some iron besides.

Hæmatine.

Give hydrogen five, and give nitrogen ten;
Let iron have six, and give twelve oxygen;
Give carbon the balance, and you will define
The centage components of pure hæmatine.

* K, Na. Cl. the chemical symbols of potassium, sodium, and chlorine.

solids of serum below the standard. The specific gravity, as in all cases where there is a falling off in red corpuscles, is low. The essential cause of scrofula is thought to be an error of nutrition: the theory is, that the blood plasma is below par in organization; and hence the tubercular deposits are called *aplastic* or *cacoplastic*, according as they are either not at all, or only partially organised. The deposits are not only partially but imperfectly organized, and are not mere deposits of fibrine weakly coagulated; for the corpuscles, like those of pus, are of a different character from the white corpuscle, originating in like manner as those of pus from the same germs as the white corpuscle, but matured under a lower form of growth or organization.

STRUCTURAL COMPOSITION OF THE HUMAN BODY.

There is among the solids of the body a class to which the term *amorphous* is applied; their general character is want of structure. The terms *blastema* and *cytoblastema* have been given to them, because they contain nuclei, from some of which fibres have appeared to radiate. The basement layer, of serous, mucous, and epidermic membranes, are formed of this amorphous substance; the walls of cells, the sheath of the fine nerve fibres, the sheath of muscular fibre (sarcolemma), the walls of the air vesicles of the lungs, and the capillaries. All other solids have the characters of structure, or the appearance of a more or less complex formation, and in describing them, certain bodies will be spoken of as making up part of their substance, to which it is now necessary to make some particular allusion. These bodies are called primary forms, and consist of, first, granules, molecules, and what is comprehended under the term *granular matter*. Granules are the smallest of the primary animal substances, their diameter being 10,000th of an inch. It is usual with these bodies to disappear on the application of ether, by which it is inferred that they are partly composed of oily matter, and that the oil is prevented from coalescing by a coating of albumine. They form the molecular base of the chyle; they exist also in milk, and may be imitated in artificial emulsions. They sometimes exhibit the extraordinary phenomenon of motion or constant vibration. The next in size to molecules are nuclei, and these, like their kindred, rejoice in more than one cognomen, to the great perplexity of all concerned in their investigation: *cytoblasts* is the alias referred to. It was at first supposed that they were the germs from which cells were invariably formed,—whence they derived the name of *nuclei*,—but this supposition is not found correct. Nuclei are homogeneous or amorphous bodies; in the development of several of the tissues they take a conspicuous part, making their appearance in the formative effusions, in the "plasticity of the blood" of Carpenter, or the "nucleated blastema" of Professor Paget. According to this able writer, the fibro-cellular or fibrous tissues are generated from nucleated blastema, which is plainly discernible in the embryo and fœtus. Nucleated blastema is the effusion of lymph poured out for the reparation of subcutaneous injuries. It is never to be observed in reparation which is accompanied by inflammation, in which the formative power is increased, and not therefore present in open wounds or injuries. The effusion which is seen in open wounds, adhesions, inflammatory swellings, and granulations, contain, instead of nuclei, nucleated cells. From an effusion containing such cells, the subcutanous areolar tissue is formed, which may be observed in the embryo and fœtus. Areolar tissue, then, is developed from a blastema, containing nucleated cells, and the more solid tissues, composed of fibres, arise from nucleated blastema. The distinction is important to notice, and although this is the usual course of things in development and growth, it is found that the union of divided parts, and the reparations that take place in fibrous tissues, by means of nucleated cells, that such unions are permanent and complete; by which it appears, that the union and reparation of fibrous tissues may take place by either method. The general description of cells, whether nucleated, and belonging to the tissues, or without nuclei, such as those of the blood and the chyle, is, that they are closed cavities, oval, spherical, or discs with fluid contents. Those that are developed into tissues vary their contents according to the structure which they form, and their original shape is then no longer retained. The other peculiarities of cells will be noticed when the tissues are described. The only one that claims further attention in this place, is the nucleated cell we have just referred to, as contained in plastic effusion, from which areolar tissue is developed, and which is contained in the lymph and granulations of open wounds, and in exudations, in which the plasticity or formative powers of the blood are exalted by inflammation. They are slightly granular, from 1-1500th to 1-2500th of an inch in diameter, and have a distinct round nucleus. The first change that takes place in the development of this cell into tissue is in the nucleus, which becomes an oval transparent vesicle, containing one or two nucleoli. The cell then assumes a granular appearance, becomes elongated, and at each end tapers to a filament.

The *fibrous tissues* form an important part of the animal fabric, and demand special attention, on account of entering much into other structures: the properties by which they are distinguished are entirely physical, and the purposes which they fulfil are mechanical.

They are of two kinds,—the *white fibrous tissue*, and the *yellow fibrous tissue*. Most frequently they are found intermixed, which has obtained for them the name of elements: they resemble each other in being both composed of filaments, or fine threads, but in no other feature. The *white* constitutes the tendons, ligaments, the aponeuroses, the dura mater, the pericardium, the sclerotica, periosteum, &c. When this tissue is examined by the microscope, the fibres can be seen, but they are so fine and so adherent that the mass has more of a streaky than fibrous appearance: but, that it consists of fibres there can be no doubt, from its tendency to separate in the longitudinal direction, while in the transverse direction its powers of cohesion are so great as to resist a force that may cause the fracture of a bone or the rupture of a muscle. It is inelastic, and, except when extended, has a tendency to assume a waving direction, like that seen in the filaments of unravelled cord. The capillaries of this tissue are few, and in accordance with its low and almost stationary vitality; little change going on in it by nutrition, and that principally effected by imbibition. No nerves have as yet been found in it, although under diseased vascular excitement it has a certain degree of sensation. Acids, and particularly the acetic, cause it to thicken into a mass, in which the fibres can no longer be distinguished; both this and the yellow resist decomposition, and dry into a hard substance. It is principally composed of gelatine, which it yields on boiling. When macerated in acetic acid, it exhibits some remains of the cells from which it was developed.

The *yellow* fibrous element, where it exists alone, is arranged in bands: the diameter of the fibres is, according to Todd and Bowman, from 1-5000th to 1-10000th of an inch. The main characteristic of this tissue is its great elasticity. It exists alone in the ligamentum nuchæ, subflava, and predominates in many other structures, where it aids muscular action; in the lungs it is no mean agent in expiration; and its use in arterial action may be estimated by the permanent closed condition of these vessels, when cut off from the circulation. This element undergoes no change by acetic acid.

Areolar tissue is composed of a mixture of the white and the yellow fibrous elements, and they respectively abound as the properties of strength or elasticity are needed. The principal purpose it serves is to join together the various structures, and at the same time to allow them to move upon each other, or, by taking part in the formation of those structures, to confer upon them the same physical qualities. By such means, muscles are united to, and allowed to move upon each other; or the contexture of the muscle itself is strengthened, and yet allowed to become distended with blood, or to change the position of its fibres. In areolar tissue, the two elements are placed in a confused interlacement in all directions, and yet the two may be readily distinguished; the white takes the form of zigzag waving bands, the yellow of separate curling fibres, which run into each other. Nucleated cells have been noticed in areolar tissue by Todd and Bowman, which have the appearance of a partial conversion to the fibres, and, while they indicate the origin of the structure, make it probable that they are active agents in its nutrition. This structure is without nerves, except those *en route*. It derives its name, *areolar*, from the areolar appearance it has around the vessels by which it is penetrated. The waving of the *white* bands is admirably adjusted to place certain and fixed limits to elasticity.

FAT.

The organic elements of *fat* are stearine, margarine, and oleine. They are considered by chemists to be organic salts, or combinations of stearic, margaric, and oleic acids with glycerine, which acts as a common base. Stearine, or stearate of glycerine, may be obtained by freezing oils, or by pressing mutton suet between thick layers of blotting paper, which absorbs the oleine. It crystallises imperfectly, like spermaceti, and constitutes the solid portion of all fats, except human and goose-fat, which principally owe their solidity to margarine. The "Composition" candles are almost entirely composed of stearine. Stearic acid may be obtained by a stronger acid, in the form of opaque white crystals. Margarine is less solid than stearine: its acid melts at 140°; while the fusing point of stearic acid is 158°. Oleine is essentially oil, and constitutes the liquid part of fats. It differs from stearine and margarine in being readily soluble in alcohol and ether, while the former are soluble in neither, except when heated. All fats contain the three elements described, in variable proportions: they are softer and more easily fused as the oleine or margarine abound. Glycerine may be set free by saponification by a stronger base: it exists in the form of syrup, which is soluble in water. The following is the analysis of human fat:—

Carbon	79,000
Hydrogen	11,416
Oxygen	9,584
	100,000

Fat aids in supporting the body, facilitates the movements, and also helps to retain heat: it is the main repository for the fuel stored up for combustion in the great furnace of the lungs. There is, in some individuals, a want of power to generate adipose tissue; in such cases hydro-carbon often accumulates in the blood: this interferes with the due oxygenation of the nervous and muscular tissues, by appropriating the oxygen contained in the red corpuscles to the formation of water and carbonic acid, which would otherwise be expended in nervous and muscular operations; the result of which is, languor and loss of power in those systems. In such cases, unless care is taken to use up the surplus matters by exercise, the liver usually makes an effort to free the circulation from the hydro-carbon, and becomes overcharged with bile. The glands of Leiberkühn also lend their aid towards the riddance of the offensive tenant, by furnishing an increased supply of carbonaceous matter, by which means the excretions from the bowels become dark-coloured, and, by the joint operation of these causes, have all the characters that are emphatically termed *bilious*.

Fat-cells are usually spherical: they have nuclei, though they are not always distinguished. The diameter is about 1-450th of an inch: they are formed into masses of considerable size, held together by a fine interlacement of areolar tissue and capillary blood-vessels. No lymphatics have been discovered in adipose tissue, and it is destitute of nerves, except such as pass through it *en route* to other structures.

BONE.

Analysis of bone by Van Bibra:—

Phosphate of lime with a little fluoride of calcium	59·63
Carbonate of lime	7·33
Phosphate of magnesia	1·32
Salts	0·69
Cartilage	29·70
Fat	1·33

By the foregoing analysis it appears that bone is constituted

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Fat.

Say of fat, when for practical purpose you view it,
Two ternary acids, in oil and suet,
Called Oleic and Stearic, and this is the case;
They are joined to Glycerine, an alkaline base;
Of carbon say eighty; H and O say each ten;
Fatty acids contain six times more hydrogen.

The analysis of the five fat-producing articles of food have been before alluded to, and condensed into rhyme: see page 8.

of about one-third animal matter, and the remainder principally of earthy salts; the animal portion, gelatine, may be extracted by boiling, but it nevertheless exists in organic chemical union with the other ingredients, by which it obtains new properties, one of which, its power of resisting decomposition, is greatly augmented, as manifested by the fact that the normal quantity of animal ingredients is found in very old, and even in fossil bones. And as in the structure of bone the earthy portions lose as much of their earthy appearance as if they were in actual combination with an acid, it is probable that in bone the gelatine takes the part of an acid. The structure of bone is traversed in all directions by the Haversian canals: these vary in diameter, the average being 1-500th of an inch, and about 1-250th of an inch distant from each other: around the canals the bony matter is arranged in concentric layers, which give under the microscope a beautiful laminated appearance to the structure. The corpuscles of Purkinje, lacunæ, or bone cells, pervade the whole structure of bone. These cells are of an irregular oval shape, situated amid the laminæ and minute bony tubuli, and may be distinguished proceeding from them in every direction.

The Haversian canals contain about one artery and a little medullary matter. The Haversian canals are the limits of the blood circulation in bone; the tubuli, which open into these canals from the corpuscles of Purkinje, are too fine to admit the blood corpuscles, but they imbibe a fluid from the blood which is appropriate for the nutrition of bone. The cancelli, or the loose spongy structure of the large ends of bone, fulfils the same purpose as the Haversian canals. The lacunæ are transformed from the cells from which the bone was originally developed. The nerves and lymphatics of bone are very few.

Bone on the first view appears a solid structure interspersed with a network of Haversian canals: on a closer inspection the concentric layers around the canals give it the laminated appearance; by a still higher magnifying power the tubuli may be seen protruding from the lacunæ between the laminæ. The tubuli connect the cells with each other, besides entering the

Haversian canals. The lacunæ measure in the long diameter about 1-2000th of an inch, and are filled with a fine granular matter. The main cylinder or medullary canal of bones contains marrow, which is interspersed with blood-vessels and areolar tissue: a fibrous membrane lines this cavity as well as the Haversian canals in which the capillaries are spread out.

RESPIRATION.

The main purposes served by respiration are aeration of the blood, or the introduction of oxygen into the capillaries of the lungs, and the disengagement of carbonic acid and water. Physical forces are active in the accomplishment of this exchange; one of which is the law that impels gases to diffuse, mingle, and equalise their proportions. When we examine the minute structure of the lungs, and consider the physiology of the peripheral membrane of the bronchi, we find that its structure is conducive to this interchange; and, on reference to the physiology to the red-corpuscle of blood, we shall also see that, in whatever situation it is placed, it readily parts with carbonic acid through its walls, and imbibes oxygen gas.

The objects that oxygen fulfils in the blood is the oxidation of the tissues, and the elements of non-azotic food; by which means these matters are resolved into their constituents, and heat is disengaged for preserving the temperature of the body. The oxidation of the tissues is capable of two divisions:—1st, That which is at all times going on in animals, and especially in the warm-blooded, in accordance with the predisposing influence of heat and moisture, and the weak affinities of nitrogen; and, secondly, by that species of oxidation of the

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Analysis of bone according to Berzelius.

Let twelve, two, and fifty present in this rhyme	
The carbonate ^{12}, fluate ^{2}, and phosphate ^{50} of lime; . .	$12 \times 2 + 50 = 64$
For fat ^{1} and magnesia ^{1}, and soda ^{1}, each one;	$.1 + 1 \times 1 = 3$
Same for salt of the kitchen ^{1}; before you have done	1
Give the balance to gelatine; then you will own	31
You've in relative numbers one hundred of bone.	100

nervous and muscular tissues which, according to Dr. Carpenter and other authorities, is an essential condition to every action of a muscle and every operation of a nerve. The first constitutes fermentation and decay, the common lot of organic life—less energetic in the animal when vitality is possessed of her healthful vigour, but in the ascendancy when that power is minished and brought low; and unduly at work, when fading and departing life, already too feeble to restrain the elements that constitute the higher forms of organisation from adopting simpler forms of combination, is on the eve of a still further concession—that of yielding over the organic remains to the dominion of chemical forces, or molecular death. The second division of oxidation of tissue—that consequent upon the action of nerve and muscle—is a chemical change, or union of a certain portion of the elements of the tissue with the oxygen presented to it by red corpuscle. It is a change of a certain portion of the tissue directly from the organic to the inorganic state of its elements; and, without such a change, not a breath can be drawn, and not a finger can be raised. By both kinds of oxidation the elements of the tissues are liberated; the azotic portion is separated by the skin and the kidneys, while the bulk of the carbon and hydrogen are removed in respiration. During the oxidation of the carbon and hydrogen, an important ulterior purpose is fulfilled over and above those already mentioned: the same amount of heat is produced as would be the case by the union of the same elements in combustion elsewhere. This hypothesis is held by Liebig; and there is no doubt that, from this source, the temperature of the body is in part maintained. It is, however, ascertained by the same chemist, that such an amount of carbon and hydrogen would be quite inadequate for the supply of the heat of the body; and it is generally admitted that the non-azotic principles of food—sugar, starch, and oleaginous matters—are appropriated exclusively for that purpose. If from this source a larger quantity of hydro-carbon is introduced into the blood than is needed for respiration, it is stored up in the areolar tissue, and there kept in reserve for future exigencies in the form of deposits of fat. The lungs have been likened to a furnace, but they have a nearer resemblance in their excreting office to the flue of a furnace ; for it is not in the lungs that the union of the combustible matters takes place, and that the heat is generated, but in the tissues generally; and, although the production of animal heat appears to be a simple chemical process, it will be found to be dependent on nervous influence, without which it cannot be supplied. It is only in a comparatively small degree that heat is liberated by the exchange of gases in the lungs; the difference of temperature between venous and arterial blood, as it arrives in the heart, being not more than from one to two degrees in favour of the latter.

Each bronchus, like the trachea, is supplied with rings consisting of chondrine or simple cellular cartilage. The fibres of the muscular coat of the bronchi are arranged on the same plan as those of the intestinal tube, and are of the organic kind. The mucous coat also resembles that of the intestine: first, a fibrous layer, in which the yellow fibrous element predominates, imparting a large amount of elasticity to these ever-moving organs, and then a basement-membrane covered with cylinder epithelium, which is ciliated. The rings gradually disappear as the bronchus diminishes in size; and, according to Mr. Rainey, having arrived at about an eighth of an inch from the external surface of the lung, the membrane becomes so much altered as to lose altogether the character of a mucous membrane. At this point the tubes are about 1-50th of an inch in diameter; and beyond this, apparently, the basement-membrane and a few of the elastic fibres are only continued. The tube still retaining its circular form, now divides into branches, and being enclustered by air-cells, is called a lobule. The outline of each lobule or cluster of cells is defined, and held together by a plexus of capillary vessels. A no less average number than 17,790 cells are grouped around each termination of a bronchus, which constitutes the lobule. The shape of the air-cells is an irregular oval: between their delicate walls the capillaries dip in fine net-work, each layer of capillaries supplying two air-cells, or as many as happen to be in contact with it The bronchus, from the point of ceasing to be a mucous membrane, is named *intercellular passage:* it is perforated on all sides with openings into the air-cells, and as it proceeds is flattened, and terminates itself in an air-cell. No anastomosis, either of the bronchi or of the air-cells, takes place: there is, however, the regular bifurcation of the bronchus. The advantage of this absence of intercommunication is, that when a tube is partially obstructed, air may be slowly drawn in, so as to fill the air-cells beyond, when, by a sudden expulsion of air, as in coughing, the whole volume is concentrated on the obstruction, which would not be the case if the air could escape by anastomosing branches. This anatomy of the lining membrane of the bronchi throws a light on the pathology of the organ. It resembles the liver and the kidneys in a great degree in this particular condition of the peripheral membrane; for we have seen that in the liver the walls of the capillaries are not continued between the lobules. In all these cases such a delicate construction of membrane is favourable to exosmosic discharges, both normal and abnormal: those from the liver have been noticed; those from the kidney, the normal is pure water, the abnormal hæmatine or albumine. The normal discharges from this membrane in the lungs are water and carbonic acid; its abnormal discharges are blood, and the serum tinged with hæmatine, and highly charged with fibrine, that is exuded in the first stage of pneumonia, or on the section of the pneumogastric nerves. The great facility with which these infiltrations are absorbed also confirms this view of the subject. These observations do not refer to the pathology of the mucous membranes of these organs. We were unacquainted with this class of membranes until Mr. Bowman first described that of the kidney. Their structure may be said to be almost structureless, and their functions almost physical. That of the kidney, the corpuscle enclosing the tufts, which has, however, a delicate layer of epithelium, the function of which is insignificant, and probably confined to a lubricating fluid. Serous membranes are generally on the same construction, so far as having a single layer of epithelium for the same lubricating purpose: but the quantity of fluid that transudes serous membranes is necessarily small, and bears no comparison to the quantity that transudes those of the liver, the lungs, and the kidneys; in the latter organs these membranes are passive instruments in important functions. Respiration consists physically of inspiration and expiration. Inspiration is accomplished by muscular action; expiration is partly due to the elasticity of the lungs and the parietes of the chest, and partly to the contraction of the abdominal muscles, which forces up the diaphragm and depresses the ribs. Together with these, there is an elasticity in the ribs and cartilages which gives them a strong inclination to collapse or contract. When the ribs and sternum are elevated, or when the diaphragm descends into the abdomen, the air enters into the chest on the same principle that it rushes through the valve of a bellows when the handles are forced asunder. The amount of elasticity resident in the lungs themselves may be understood by considering how much they collapse when air is admitted into the pleural cavities. The principal part of the information we possess respecting the mechanical part of respiration has been supplied by the investigations of Mr. Hutchinson. *Ordinary* respiration he supposes to be chiefly the work of the diaphragm, the movements of the ribs being scarcely perceptible, the walls of the abdomen only being seen to move. On the contrary, sighing or deep inspiration is effected by the elevation of the ribs and sternum, the diaphragm being quiescent, and no descent of the abdominal walls being perceived. The muscles engaged in this latter operation are the intercostals, scaleni, serrati, &c. In such an inspiration the sternum is raised as much as three inches. The mode of action of the intercostal muscles has been lately investigated by MM. Beau and Maissiat, by whom it is concluded that both sets are muscles of expiration only. Mr. Sibson has decided that they act differently in different parts of the thorax. There is good reason to believe that the force of the expiratory muscles is considerably greater than those of inspiration. The average number of respirations in a minute, according to Quetelet, is—

At birth	44
5 years of age	26
From 15 to 20	20
„ 20 to 25	18·7
„ 25 to 30	16
„ 30 to 50	18·1

There is a striking difference between the ordinary breathing of the male and the female, the movements of the female being principally thoracic ; and it is probable that if it were otherwise the gravid uterus would embarrass the respiration of pregnant women. Mr. Hutchinson has ascertained a curious and unaccountable fact, that a close relation exists between the capacity of the lungs for air, and the height of the person ; and he comes to the conclusion that for every additional inch from 5 to 6 feet, 8 additional cubic inches of air are received into the lungs at every inspiration. This result is grounded on near 2000 cases examined. It does not seem to depend on any increase of size or capacity of chest. The capacity of the lungs is also influenced by the weight of the individual: at the height of 5 feet 6 inches it is not affected under 161 lbs. or 11½ stone ; but above this it diminishes at the rate of 1 cubic inch for every additional pound, up to 196 lbs., or 14 stone. Age also influences the capacity : from 15 to 35 it increases, but from thence to 65 it decreases after the rate of rather more than one cubic inch per annum. Mr. Hutchinson arranges the quantity of air that the lungs contain in four divisions—1st. *Residual* air, or that which remains in the chest after forced expiration, and cannot be expelled by volition, and which is principally confined to the large tubes ; 2d. *Reserve* air, or the amount that may be expelled by the increased efforts after ordinary respiration ; 3d. *Breathing* air, or that which is respired in ordinary respiration ; 4th. *Complemental* air, or the quantity that can be drawn into the chest over and above that admitted by ordinary inspiration.

He describes also two capacities,—the *vital* and the *absolute. Vital* capacity is the quantity that can be expelled from the lungs after the deepest inspiration ; *absolute* capacity signifies the whole amount of air that the lungs can contain, including the residual air : 324 cubic inches of air at 60° Fah. is the average *vital* capacity of the chest of a person 5 feet 7 inches in height. These calculations are well grounded, and much relied on by the medical profession ; and the scale given as to age, weight, and height, is so invariable in its application, that if a person cannot draw into his chest the quantity that may be looked for according to these rules, disease of the lungs may be suspected: unless, indeed, it can be accounted for by some irregularity in the conformation of the chest. He concludes that mobility of the walls of the chest is more effectual for the admission of air than largeness and expanse of structure, and that mobility increases in proportion to the height of the person. The amount of muscular force in respiration is by no means in proportion to the height of the individual, the greatest degree of power being generally found in persons under 5 feet 8 inches, who can raise a column of mercury of 3 inches, whereas those of 6 feet can raise but 2½ inches. These investigations have been made on men: in women the vital capacity is less.

In cases of suspected disease of the lungs, where the measuring machine is put in requisition, it should be recollected that forcible respiration is an exciting cause of disease, and that violent efforts to distend the lungs may be injurious even to healthy lungs, and much more so where there is incipient disease. The physiology of the muscular coat of the bronchus is obscure. In certain parts of organic structures, where much contractile force is needed, it is common to observe the yellow elastic tissue aided by the presence of the non-striated muscular fibre; and it is most probable, for the better securing of the recoil of the lungs after inspiration, that the muscular fibres are found in conjunction with the elastic in this situation: possibly, also, it exerts a power of forcing outwards the air in expiration, similar to the action of the muscular coats of arteries in forcing onwards the blood. The pathology of the muscular coat of the bronchus is peculiar, inasmuch as it is liable to assume a spasmodic condition of a tetanic nature—spasmodic asthma. Though the action of this muscular coat is supposed to be peristaltic, it is, like the muscular layer of the intestinal tube, guided and controlled by nerves; and it is held that in one especial spot in the spinal cord—one little collection of grey nervous matter—the nervous centre of respiration, that the morbid irritation is seated, that is the exciting cause, the primum mobile of asthma: such power is exercised through the pulmonary branches of the par vagum, both in the esodic and exodic view of it. Dr. C. Williams has shown that the lung, after removal from the body, may be thrown into fixed muscular contraction by galvanism: other experiments have produced the same effect by mechanical stimulus to the vagi; but, like other organic muscles, they are not readily acted on through nerves.

The effect of respiration on the air is to abstract oxygen, and impart carbonic acid and moisture. According to the results of the experiments of Andral and Gavarret, a man on an average exhales from 160 to 170 grains of carbon hourly, or about 9 oz. per diem; a woman from 100 to 110 grains in the former period; in pregnancy, 125 grains; and after menstruation has ceased about the latter quantity. Hunger and quietude diminish, satiety and activity increase, the amount of carbon expired. It is greater during the day than night. In disease generally, it is increased, with the exception of phthisis and typhoid fevers, in which cases the quantity is diminished. The higher the temperature of the air respired, the smaller is the amount of carbon expired, and *vice versâ*. Impurity of air is occasioned more by the undue quantity of carbonic acid, than the deficiency of oxygen, for less carbon is exhaled in an air so impregnated. The *law of diffusion* of gases is supposed to aid greatly the exchange of oxygen and carbonic acid in the lungs; but it is not entirely effected by this power, for the results and proportions of the exchange have not been found to be in that exact ratio that would be required if moved entirely by this law. In respiration, the air is first warmed to about 100° Fah., saturated with watery vapour, and then undergoes a rateable *diffusion* between the oxygen imported and the carbonic acid already there; while the nitrogen, which acts only to dilute the oxygen, undergoes (it is now supposed) a slight augmentation in its exit. A certain quantity of oxygen disappears in respiration, or rather, a certain quantity of oxygen is absorbed over and above the volume of the carbonic acid expired. According to the experiments of Valentin and Brunner the proportions stand thus: 1·1742 volume of oxygen is absorbed and replaced by 1 volume of carbonic acid expired, or 1 volume of oxygen in exchange for ·8516 volume of carbonic. This comes very near to Graham's law of diffusion of gases, which mix inversely to the square roots of their densities. By this law, 1·17585 volume of oxygen should, under the same pressure, be absorbed, liberating one volume of carbonic acid, the denser gas. It is generally admitted that the gases are dissolved in the blood. Liebig's theory of the per and protoxide of iron, as the condition in which the oxygen exists in the blood, is not maintained, in consequence of the evidence which there is that the iron of the hæmatine exists in chemical union with the organic matters in a metallic state, uncombined with oxygen. The evidence rests on the fact that the iron in this combination does not respond to the usual chemical reagents, which it never fails to do except when in union with organic compounds. The theory also of Mulder, which seats the oxygen in the oxides of proteine, is not thought a sufficient explanation for the transit of so large a quantity of oxygen, although the fibrine of arterial blood is more highly oxidised than that of venous. We are better acquainted with the facts than the theory, and it is better to be content with the facts than to encumber the memory with an hypothesis that cannot be well supported. We know that the red corpuscle absorbs both oxygen and carbonic acid with avidity, and becoming charged with oxygen in the lungs, by virtue of this affinity and physical agencies it takes it to the peripheries, where a stronger affinity removes it, and throws in its way carbonic acid, which it absorbs by the same rule. Having arrived again in the lungs, under the same laws of diffusion of gases, affinity is again repeated, where it liberates a portion of carbonic acid, and takes in a portion of oxygen. Having failed in obtaining an explanation of the phenomena exhibited by blood in the lungs, in the theories of Liebig and Mulder, the only other explanation offered is the vital theory of cell appropriation or assimilation, which, however true, is difficult to comprehend. According to Professor Magnus, there are 20 volumes per cent. of carbonic acid in arterial blood, and 25 per cent. of the same in venous blood: of oxygen there are 10 volumes per cent. in arterial blood, and about 5 in venous. By this it appears that when the red corpuscle, free from gas, is exposed to carbonic acid and oxygen, it will, by its own affinities, in accordance with the law of diffusion, absorb 20 volumes per cent. of carbonic acid, and 10 of oxygen, and thus become arterial blood.

The interchange, then, of gases that takes place in the lungs is this: 5 volumes per cent. of carbonic acid are given off, and 5 volumes of oxygen are absorbed. The same takes place in blood drawn from the body, and, according to Dr. Carpenter, by the same process of exchange, in some degree through the skin. Blood contains from 1 to 2 volumes per cent. of nitrogen, and is the same whether venous or arterial. The quantity of water that passes off by respiration varies according to the amount of fluid contained in the blood, and the quantity previously present in the atmosphere. It is computed to amount from 10 to 20 oz. in 24 hours.

The effects of the arrest of respiration.—The phenomena consequent upon asphyxia take place in the following order of succession. No oxygen gaining admission to the lungs, the blood arrives at the right side of the heart in a dark state, passes the left side, and is distributed through the systemic arteries, and in this venous state is freely transmitted through all the tissues. At this stage, the absence of oxygen, and the presence of carbon in the blood, begins to act upon the nerve centres, by paralysing the actions of muscles and nerves, of which the cessation of the functions of special sense, unconsciousness of external impressions, and the total inability to move a voluntary muscle, are the first proofs.

Muscular irritability, the movements of organic life, and the diastaltic actions of the spinal cord, are later in becoming affected, but are, however, in an enfeebled state: the heart partaking of the same, the circulation becomes sluggish in the capillaries of the lungs: the right side of the heart becomes loaded with blood, and thence also congestion of the systemic veins, and but little blood moves through them to the left auricle. Great stagnation in the capillaries of the lungs ensues, and the systemic arteries having continued to pulsate longer than the supply of blood to them was kept up, they become empty as the systemic veins become congested.

Mr. Wharton Jones has shown that a stream of carbonic acid directed on the capillaries of a frog's foot immediately produces a congested circulation.

Mr. Erichsen, by circulating arterial blood through the brain and spinal cord of a strangulating dog, did not in the least prolong its life; but he gave some increased action to the right ventricle, by unloading it of some of its blood. There is, therefore, little doubt as to the cause of these phenomena, which is the want of oxygen in the circulation, the effect of which is the paralysis of nerves and muscles: muscles lose their irritability, which is independent of nervous centres, and nerves at their peripheries are paralysed, although the nervous centres may in some degree continue active: this may account for the state of dreaming that many persons recovered from drowning have said to have experienced. Total insensibility, and loss of voluntary movements, occur in 2½ minutes,—thus terminating the phenomena of animal life; the movements of organic life cease in about 5 minutes, the ventricles continuing to move for about that period. The absence of arterial blood in the coronary arteries of the heart, the want of the same in that part of the medulla oblongata which is the nervous centre of respiration, together with the preponderance of carbonic acid in the blood of these organs, are the main causes of the cessation of the movements of organic life that immediately betoken death. In drowning, the glottis is spasmodically closed, the inspirations are ineffectual, and the expirations serve to contract the chest to its fullest extent upon the lungs.

FOOD.

The food of animals may be arranged under two heads—the *inorganic* and the *organic*. Air, water, salts, and ashes, come first in the category, and, though they form a meagre bill of fare for covering the tables at a feast, they are as important to the work of nutrition as the organic substances. The latter are divided into two groups, which are distinguished either by the presence or absence of nitrogen in their composition. The organic substances of both kinds are wholly supplied by the vegetable kingdom; the inorganic also by the same medium, excepting air, a great portion of the water, and the chloride of sodium, which are otherwise obtained. The ashes or salts are in combination with the organic matters. The organic group without nitrogen is composed of the three essential elements, C, H, and O, together with the incidental elements that are found in the ashes or salts; they are comprehended in fatty substances, gum, sugar, starch, organic acids, and alcohol. The organic substances containing nitrogen have more or less the same composition as the class just enumerated, with the addition of nitrogen, phosphorus, and sulphur; they consist of the proteine compounds, vegetable albumine, fibrine, and caseine. The name *non-azotic* is here proposed to be applied to the first division of organic aliments; and to the second division, or those with nitrogen, *azotic.* The adoption of this classification is for the purpose of simplifying a subject that is liable to so much confusion; and also that, since Dr. Prout divided the non-nitrogenous aliments into *oleaginous* and *saccharine* classes, it has been ascertained that the whole of this class fulfils but one purpose and has but one destination in animals,—a statement which is supported by the fact that the chyle consists entirely of an albuminous and an oily base.

No departure, however, from a generally accepted classification of the principles of food would have been introduced here if any such had been in existence. Dr. Prout's, good as it is considered, is not comprehensive enough, it appears, to secure its adoption; and both that and Dr. Carpenter's are not considered sufficient by Dr. Pereira, on the ground that they exclude common salt and the acids of fruit, which are essential principles of food,—the acids in possessing an antiscorbutic property. Dr. Pereira's classification, however excellent in the schools, is too lengthy for practical use.

The principles of aliment, then, are arranged in three groups: one from the inorganic—the *inorganic;* and two from the organic—the *azotic* and *non-azotic:* and, while this will be found to embody the list of principles of food by Dr. Pereira, it should not be lost sight of that gelatine is included in the group with albuminous compounds, and that it can only be so admitted by ranking it as a peculiar variety of organic azotic food.

D

	Sugar-cane juice.	Potatoes.	Rice.	Wheat.	Cow's milk.	Veal.	Carp.
Nitrogenous substances—Gelatine, albumine.	0·12	2·49	6·27	13·96	4·5	20·00	19·00
Non-nitrogenous substances—Starch, sugar, fat.	Sugar 20·94	Starch 17·98 Fat, &c. 3·60	73·65 4·57	47·57 20·74	Sugar 4·0 Butter 5·5	Fat 2·29	1·11
Ash	0·14	0·90	·30	2·36	0·5	·08	0·11
Water, when fresh . . .	78·80	74·95	15·14	15·43	85·5	77·63	79·78
	100·	99·92	99·93	100·06	100·	100·	100·

Animals that supply food for man may be viewed as storehouses in which the two kinds of organic substances are gathered and accumulated from the vegetable kingdom, in whose tissues the albuminous group greatly preponderates; and having forms of organisms in which, for the most part, the three great pillars of the animal kingdom — nitrogen, sulphur, and phosphorus—are highly concentrated. It is customary to consider aliments that abound in nitrogen the most valuable; commercially this is right, and, so far as the difficulty of obtaining them by the greater portion of mankind, would stamp their value; but a much larger quantity of carbon than nitrogen (in the proportion of 1 to 29) is required to sustain animal life. And, for the support of the human fabric, potatoes, poor as the diet is, and inadequate for reinstating the waste consequent upon the full force of the muscular and nervous action, constitute a better diet than the richest animal food, provided, in either case, that no other organic food is taken. The reason of this is, the large amount of carbon consumed in respiration.

Dr. Bence Jones, in his Lectures on Animal Chemistry, makes the following interesting remarks on the composition of the grass under our feet:—" We can dry it, and make hay; we can burn it, and get the ashes; we can treat it with ether, and we dissolve out a green colouring matter, with fat or wax; and, by alcohol, we can separate these. Woody fibre is another constituent; and lastly, we can obtain from the grass an albuminous compound, in small quantity, containing carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus, which is vegetable albumen."

He subscribes to the truth that *all flesh is grass;* but, being true in a physical sense, the still more important truth of the proposition conveyed in its metaphysical application, unfortunately for humanity, is not disturbed, but rather strengthened, by the fact that we recognise in nitrogen the symbol of decay in both the fabrics in question. The foregoing observation respecting the composition of grass is applicable generally to the vegetable food of man in a qualitative sense. The albuminous compounds insoluble in water are reduced by the chemical agencies to which they are exposed in the stomach to a mass named chyme,—a substance from which the vital agency of the villi can separate and appropriate the organic materials in the form of an albuminous and oily matter. Water and soluble salts are principally introduced by the veins of the stomach. Every substance in the lists of aliments is equally essential to animal life; without the oxygen taken in by the lungs, the non-azotic group would be quite inoperative. The non-azotic class, according to Professor Liebig, is not converted into the animal tissues, but is applied solely for generating the heat of the body. Sweeping assertions like the foregoing do not generally hold good in physiology; our best rules are often encumbered with too many exceptions. But it is in the main a valuable truth, and not the less so because the oil-globule forms part of almost every tissue of the body; for though the destination of the whole non-azotic group of aliments is to supply combustible matter, it is well known that fat, so far as it is required for the construction of the tissues, may be formed from the albuminous group: for instance, the embryo chick that has been nourished solely by oval albumine is found to contain the usual quantity of fat in its tissues. Neither essential nor incidental elements from which the body is constructed can be assimilated, except previously organized by vegetation. But this is not true of organic matters that are introduced for other purposes than that of forming the tissues,—such as oxygen, for generating heat and giving vital force to all muscular and nervous operations; the chloride of sodium, the sodium of which gives alkalinity to the saliva, pancreatic juice, and animal fluids; and the chlorine gives in great part acidity to the gastric juice under the form of hydrochloric acid.

There are other conditions necessary to the due digestion of food; for, by supplying an animal with a diet made out upon the principles hitherto laid down—such as starch, gum, albumine, &c.—it would be in imminent peril of starvation. Though this effect would be produced by a diet of albumine or gum, yet together they constitute the requisite proportions of our elements in an inorganic form. It is necessary that we take our food in the forms in which they are provided by the hand that feeds us; for, if we materially alter those forms, though the elements remain the same, the nerves of digestion are ordered to vomit them up. If we deduct from meats the osmazone on which the flavour depends, although the osmazone performs no essential part in nutrition, yet the stomach will reject such food. Magendie's numerous experiments also fully bear out the fact that a mixture of foods is necessary to digestion, and that even a dog will starve if confined to bread and water. The following averages, taken from approved military and workhouse dietaries, may be taken as specimens of full and low diet, both consistent with good health:—Full diet: animal food, 10 oz.; dry vegetable food, (flours), 15 oz. Low diet: animal food, 5 oz.; dry vegetable food, 15 oz. It is necessary to vary the particular aliments in these diet scales, and to exchange a portion of the dry vegetable food for fresh, with a mixture of organic acids from fruit, or there would be danger of scorbutus.

Insalivation and Mastication.—The several functions of the tongue are aided by the moisture given to them by the saliva. Without moisture, taste, touch, articulate speech, and deglutition itself, would come to a stand-still. The saliva aids mastication in the same proportion as water aids the cook in beating up the materials that are incorporated into a pudding. The muscles of the tongue and cheeks are well contrived for collecting the matters taken into the mouth, and placing the same exactly between the grinders. Saliva has at all times a slight alkaline reaction, which, during digestion, is much increased.

The specific weight of saliva, taken by several experimenters, may be expressed by that given by Mitscherlich—from 1006 to 1008. By the same authority, 10,000 parts of saliva consist of 9900 water, and 100 solid matters. Of the latter, 40 are inorganic, and 60 are organic. The principal salts of the saliva are chlorides of potassium and sodium, and phosphates of soda and lime. There are others in smaller proportions, and the salts altogether comprise those of the blood. The concretions from the saliva that fill up the crevices and irregularities of the teeth are deposited from the phosphate of lime; but this salt is in no excess in the saliva as compared with other secretions; for the salts of the saliva do not amount to much more than half those of the blood. Ammoniacal salts have been detected in the saliva. These probably have been disengaged from decomposition of the mucus, or other albuminous matter contained in it. Sulpho-cyanogen is also present, which strikes a red to the sulphate of iron. The urinous taste of alkalies is said to be occasioned by a decomposition of the albuminous matter effected by the alkali, and the liberation of free ammonia from thence. From the tribasic phosphate of soda saliva derives an alkaline reaction. It contains mucus, which is more abundant in the larger salivary glands than the smaller; and saliva from the larger glands is more alkaline than that from the smaller. Saliva has a signal operation on starch—that of converting it into dextrine and grape sugar,—conditions that starch readily assumes. It appears, however, that this power is derived from the mucous membrane of the mouth and ducts—certain particles shed from the membrane on the turn of decay, and which is common to other membranes. In this peculiarity saliva resembles pepsine.

It has been ascertained by Dr. Wright that there are periods of gradual increase of alkalinity in the saliva, and that they synchronise with the periods of secretion of gastric juice. It has also been ascertained by Dr. Bence Jones that the stated efflux of acid in the gastric juice, as chymification proceeds, corresponds with the diminution of the normal acidity in the urine, amounting even to its total withdrawal towards the close of the process. The same thing has been observed by the author in regard to the free acids of the perspiration. Hydrochloric acid is admitted on all hands to be prominent among the acids of the gastric juice: this is supposed to be elaborated by the glands of the stomach from the chloride of sodium introduced in food. In this case, the soda formed by its decomposition is supposed to seize the phosphates, which, we may suppose, have just arrived from the tissues, having been produced there in the shape of biphosphates, by union of the oxygen brought by arterial blood to the phosphorus and the soda disengaged by disintegration and waste, and now changing the biphosphate, or double acid phosphate, which indirectly gave acidity to the urine, to the tribasic or alkaline phosphate that now neutralises the urine and increases the alkalinity of the saliva. It has been satisfactorily shown that the free alkali in the saliva considerably adds to its solving power, and that the soft and pulpy state of the *bol alimentaire* is due to this cause. We therefore see, by this wonderful adjustment of chemical forces, that the same operation that liberates the acid which makes effective the pepsine in the gastric juice, furnishes also the alkali that gives the necessary energy to the saliva.

The animal substance in which the starch-converting principle resides has been named by Berzelius, who first discovered it among the organic matters of the saliva, *ptyaline.* Its relations are similar to the saccharising principle of malt or barley —*diastase.* M. Mialhe has proposed to name this substance *animal* diastase, which is preferable to ptyaline; for M. Bernard has satisfactorily shown that saliva from the parotid or submaxillary glands, unmixed with buccal secretion, has no such power on starch. He has also shown, at the 10th page of the

10th page of the same memoir, that the same effects are produced by a large number of animal substances. Magendie has also shown that it exists in serum of the blood. This principle, and also pepsine, may be regarded as the product of animal substances in a state of incipient *eremacausis*, or on the verge of decay; for mucous membrane, well washed, does not possess the property until decomposition has slightly commenced; and we shall find that decomposition is even present in the body, and is, moreover, an essential condition to the action of every organism. The French phrase for it—*un principe altéré*—though full of meaning, rather misleads. The principle itself undergoes no change, although, like most ferments, it communicates unlimited changes to other substances. Like pepsine, it has strong claims to rank under the head of ferments; and animal diastase and pepsine do not differ more from each other, or from the recognised ferments, than the ferments differ in their characters from each other, though the difference between animal diastase and pepsine will be seen to be great. It is a very interesting fact, and has a very important bearing on the digestion of non-azotic food, that when a portion of membrane in incipient decay is placed in contact either with starch or sugar, that lactic acid is the result. M. Bernard has shown this to be the case, which, however, was previously known to Liebig. Some reasons will be hereafter adduced for believing that lactic acid is a phase in the destination of all non-azotic food; and the subject is mentioned here for the reason that the power of converting sugar into lactic acid is as proper to the saliva as that of converting starch to sugar.

There are, then, good reasons for concluding that the property of saliva of converting starch grains to dextrine, and thence to grape sugar, is due to a substance nearly allied to a ferment derived from the mucous membrane, and common to most other tissues in incipient decay; and also, that the principle of the lactic acid, fermentation, is either the same, or derivable from the same source. It is believed that animal diastase has no power of action on raw starch: the starch-grain must first be broken, either by mastication or by the operation of heat in cooking.

The action of animal diastase upon starch is readily proved by heating a mixture of saliva and potatoes, and observing the bl ue colour that is produced by the common test for sugar—sulphate of copper and liquor potassæ. It differs from vegetable diastase, and also from pepsine, in the fact that its operation is not injured either by a boiling temperature, or by strong acids or alcohol, which destroys the powers of the latter substances.

Among the other organic materials of the saliva is a very small quantity of oily matter, and a more considerable portion of albumine: the albumine, however, is not much above half that contained in the mucus. The whole amount of animal matters in lymph is about five times as much as the same matters in saliva: this is stated, that the loss in ptyalism may be estimated. The 100 parts of solid materials of saliva may be arranged as follows:—animal diastase 17; fat 4; albumine 14; mucus 25; salts 40.

The secretion of saliva is excited by the movements of the tongue, and the presence of food in the mouth. The cerebrum and sensory ganglia have a nervous connection with the salivary glands. The sense of the sight and smell of food excite the secretions and strong passions much as intense fear will dry up the mouth and prevent articulation.

The process of deglutition is divided into three stages: the apportionment and description of each stage by M. Gerdy (XIII.), is more simple and natural than Magendie's, Adelon's, or Muller's.

The first stage is the passage of "le bol alimentaire" to the isthmus of the throat, or the anterior palatine arch. The

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Saliva.

Saliva in alkaline action ascends,
As the stomach its acid secretion expends;
Six parts in a thousand of organic matter,
The salts of the blood, and, as touching the latter,
The soda's tribasic in phosphate; same time
Concretions are formed from the phosphate of lime.

isthmus of the throat, or the anterior palatine arch. The second conducts it through the pharynx to the entrance of the œsophagus to the stomach. The first is a voluntary act by muscles solely excited by volition. The second is wholly a diastaltic or reflex movement, although most of the muscles engaged in it may in other movements be voluntary. The third stage is diastaltic in its upper half, and peristaltic downwards. The first stage is accomplished by a backward movement of the muscles of the tongue and the cheeks. The second, or the transfer of the food through the pharynx, is a muscular act, as complicated as it is perfectly performed. The first act having conveyed the "bol" beyond the anterior arch, the base of the tongue is carried still farther backwards; while the larynx is brought upwards and forwards under a ledge, as it were, formed by the root of the tongue, by which movement the elastic ligaments of the epiglottis are relaxed, causing it by its weight to fall over and cover the glottis, which is already closed by its own muscles. During this movement the sides of the posterior palatine arch are by the contraction of its muscles made to approximate, which, by the aid of the uvula flapping against them, closes the posterior nares, preventing the passage of the "bol" in that direction, and also contracting on it to force it downwards. The larynx being raised, and projecting with its unyielding body into the pharynx, forms an inclined plane from the base of the tongue to the lower portion of the pharynx on which the "bol" descends. The base of the tongue is now returned to the mouth, and to prevent the "bol" or any part of it riding back upon it, the sides of the anterior arch are brought together by its muscles, the palato-glossi by drawing a curtain across the

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The muscles that raise the larynx in deglutition.

The larynx, whose rim is of fibre elastic,
Is raised by the front halves of muscles digastric.*
A notable trio we cannot avoid,
The stylo, the mylo, the genio-hyoid,
Of genio-glossi, so much as can well
With the genio-hyoid arrange parallel.†

* The anterior bellies.

† Those portions of the genio-hyo-glossi that are parallel with the genio-hyoid muscles.

fauces. The last stage of deglutition is the descent of the "bol" through the œsophagus by a rhythmic or waving contraction of its muscles. The pharynx, as well as the larynx, is raised in the second stage of deglutition: this is done immediately by the palato and stylo-pharyngei muscles, and mediately by the muscles that raise the larynx.

Structure of the Stomach.—The muscular and mucous coats of the stomach are more interesting to the physiologist than the serous or peritoneal coat, inasmuch as the muscular is the mechanical apparatus for very important movements; and the mucous is the vital laboratory for furnishing the chemical products that are engaged in its operations. The muscular coat of the intestinal canal, from the pharynx downwards, consists of two layers of fibres—a longitudinal, superficial, and a circular deep. In the stomach the two planes of fibres have a particular arrangement. The longitudinal fibres from the œsophagus are spread equally over the walls of the stomach, except along the short curvature, where they are multiplied into ribbon-like bands, called by French anatomists *cravate suisse.* The fibres in this layer follow the longitudinal course of the stomach, and are the superficial layer. The circular fibres from the œsophagus continue their circular arrangement, and are spread over the stomach. The latter, by their multiplications, form the pyloric sphincter, besides giving a stronger than ordinary investment to about three inches from the pyloric end. The longitudinal fibres from the duodenum are superficial, and are intermixed with those coming from the œsophagus, until they arrive midway between the two ends, when they pass under the circular fibres, and thence become a deep layer for investing the cardiac half of the stomach. Except for this doubling under the circular fibres, they are combined in a straight course from the duodenum to the splenic or large end of the stomach, which they loop around, still continuing their horizontal course. These fibres have been named *oblique*, because they cross obliquely the longitudinal layer coming from the œsophagus, which preserves their course parallel to the curves and centre of the stomach, from the cardiac to the pyloric or orifice. The action of the oblique fibres is to assist in producing the shortening of the stomach, which takes place alternately with the elongations that arise from the contraction of the circular fibres, both movements being proper to chymification. The cardiac sphincter is a multiplication of the circular fibres from the œsophagus.

The natural colour of the mucous membrane of the stomach is pale buff or pus colour, with a shade of light red. It is important to bear this in mind, as the practitioner is frequently called on for his opinion on the appearance which the membrane exhibits after death. The surface of the membrane is always sheathed in a coat of thick mucus, to which it is indebted for protection from the occasionally irritating qualities of food which otherwise would often irritate and excite, and even excoriate its surface. The internal surface, like that of the small intestines, has a villous downy covering, but not so coarse and large as to obtain for it the name of villous. When the mucous surface of the stomach is examined by a magnifying power, certain sexagonal or polygonal depressions, in diameter from about 1-300th of an inch, star the whole surface, giving it the appearance of velvet stamped with a fine star-pattern: the edges of the depressions again are elevated, affording an extra protection to some important openings within them. In these pits from four to six of these openings appear, which are the orifices of tubular glands that elaborate the gastric juice. These glands are seated in the fibrous layer, or that which gives substance and strength to mucous membrane. They have cul-de-sac bulbs based on the submucous tissue, which is the loose bond of connection between the fibrous and muscular coats. In the fibrous layer which immediately is subjacent to the basement membrane, the capillaries and nerves are spread out. The tubuli have walls described by Henle to be hyaline and structureless, resembling basement membrane. They are held together in clusters, and are very distinct, according to Bischoff, in the stomach of a pig. Wasmann has also made the same observation. The contents of the tubes are described by Henle to be "granulations" and nucleated cells. Dr. Sprott Boyd first delineated correctly the microscopic anatomy of this membrane. M. Bernard is an authority that the cells of these tubes elaborate the gastric juice; and if we can depend on his statements, we must infer that the acids that are more or less present in the juice become liberated in the cells as they approach the surface of the membrane, for he has demonstrated that the surface of the membrane *only* is acid. We are constrained to admit that these fascicular clusters of tubes are endowed with the faculty of secreting gastric juice, unless we can suppose that the same is performed by the glands of Lieberkuhn of the stomach—the follicles that pervade the whole surface of the intestinal tube, and to which is generally awarded the function of secreting mucus. It is said that when the stomach is empty no cells are to be seen in the tubes, but that at such times they contain, and their orifices are lined with, the cylinder epithelium that covers the pile-like surface of the membrane in other parts. When the juice is flowing the cells are in rapid growth: they commence in nuclei at their cul-de-sac ends, and are gradually projected to the free surface, where, being matured, they burst and are discharged. The fascicular glands are more distinct, according to Bischoff, towards the pyloric orifice; and, in accordance with this observation, the most powerful pepsine is obtained by macerating this portion of the stomach of a pig.

Gastric juice.—The gastric juice resembles water in appearance, containing one or more free acids and two animal matters, derivable from the mucous coat of the stomach, neither peculiar nor proper to the membrane, but alike common to most animal tissues in incipient decomposition: together with these, the salts of the blood, minus the sulphates. Authors have differed much on the subject of the acids of the gastric juice; and it is only from a summary of the whole evidence that we can gather a sufficient foundation on which conclusions may be based. One of the first is, that hydrochloric acid exists free in the gastric juice. Since Prout first declared this to be the case in 1824, it has been reasserted by Tiedemann and Gmelin, Professor Dunglison, and also by Bouchardat and Sandras, in a memoir to the Academy of Sciences, Paris. The following distinguished chemists in France have pronounced for the lactic acid; but their experiments were made upon the gastric juice of dogs and pigs:—M. Chevreul, MM. Lauret and Lassaigne, MM. Bernard and Barreswil. To these may be added the testimony of our no less distinguished countryman, Professor Thompson, who, from experiments on animals fed principally on non-azotic food, reports that the acid of the gastric juice more nearly resembles the lactic than any other. The acetic acid has also been discovered in human gastric juice by Tiedemann and Gmelin. The butyric acid has also been found, and the acid phosphates by Liebig. A considerable portion of non-azotic aliments taken into the stomach ordinarily pass into lactic acid, and, by a little farther change, into acetic, though the latter change is rather extraordinary than ordinary. The chloride of sodium which supplies the hydrochloric enters so universally into the food of man, that Dr. Pereira has classed it among alimentary principles: phosphoric acid we trace to the phosphorus of the tissues. We see, therefore, the sources from which these acids may be readily supplied; and, relying on the facts advanced by the foregoing experimenters, we may safely infer that the acidity of the gastric juice depends on one or more of these acids,—an inference which is borne out by the fact that gastric juice may be artificially made by either acid. The amount of acid contained in the gastric juice is considerable, if we may judge from the pungent taste of that thrown up from the stomach in a concentrated state; but this probably is stronger than is needed, and is generally diluted by the fluid drank at meal-times. The quantity of acid required in the artificial liquid, according to Purkinje and Pappenheim, is one drop of hydrochloric acid to a drachm of water, with a grain of rennet or the fourth stomach of a calf, at a temperature of 100° F. The name of *pepsine* has been given by Schwann to the organic matter that imparts to dilute acid the power of dissolving albuminous aliments (from πεψις, coction). It is soluble in cold water, but insoluble in hot water, and therefore is best obtained by first cleansing the stomach from its acid secretion and mucus, then macerating it in cold water, and adding alcohol, which produces a greyish-white flocculent precipitate, which, when collected and dried, becomes a yellowish gummy matter—pepsine. It is probable that hot water checks the decay in the membrane, which is essential to the production of pepsine. The analysis by M. Vogel is $C^{57.72}$, $H^{5.67}$, $N^{21.09}$, $O^{15.52}$. From this it appears that it contains more nitrogen and carbon than any of the proteine compounds. One part of pepsine in 5000 of weak acid is sufficient, according to Wasmann, to cause the solution of white of egg. Liebig denies the separate existence of pepsine as a ferment, and supposes it is not a principle, but a quality belonging to animal matter in incipient decomposition: but his theory is not maintained, and is shaken by the fact that gastric juice is antiseptic, and will keep for months. It is held that, although pepsine is produced from tissues in a state of change, it is not in that state itself. It resembles in its origin the organic matters called in physiology *extracts*, which do not exist in tissues, but are produced by the decomposition of tissues. Pepsine possesses an almost unlimited power of coagulating albumine, but no power of dissolving it or any other description of albuminous matter, unless in combination with a weak acid solution. The change that is effected in the components of albuminous substances by the operation of a weak acid, by which they are all altered in form and brought to the state of one peculiar albuminous compound, and which alone comes under the operation of pepsine, appears to be of an *isomeric* nature, or one in which a new compound is formed, the numbers of whose component elements do not differ from those of the original substance. The only difference (as supposed) is a change from a more to a less complicated arrangement of their elements, or,—as was suggested figuratively (see page 6),—by the better fitting together of the planes of the angular bodies to which the numerous elements of organic substances were compared. Such a change is probably effected in all albuminous aliments by the acid in the gastric juice before they can be dissolved by the pepsine; for all such aliments are brought by the action of gastric juice to the state of one albuminous compound, not albumine, but isomeric with it. This probability is strengthened by the facts that, if albumine is mixed with gastric juice and injected into the blood, it is assimilated to the blood; but if unmixed, and so injected.

it passes off by the urine, and that, before albumine can be assimilated, it must be coagulated and redissolved. The albuminous compound formed by the action of gastric juice differs from albumine in not coagulating by heat, and has not the characters of fibrine or caseine. Gelatine also enters into a new form by the action of gastric juice. It is liquified by it when solid, but, when in a liquid state, is not coagulated by the juice; the new form of gelatine cannot again be made into a jelly by evaporation, and it cannot be precipitated by chlorine. This form of gelatine is not a proteine compound; and, when taken into the blood, which is probably done by the veins, it goes only to form and maintain the gelatinous tissues. The other animal substance spoken of as present in the gastric fluid is the same as that described as *animal diastase* in the saliva. We are not at present aware that there is any chemical difference between animal and vegetable diastase; they are both formed from albuminous compounds,—vegetable diastase from the gluten of barley,—and both contain nitrogen. Diastase differs, however, remarkably from albuminous compounds in forming none of the numerous combinations that characterise albumine. It is insoluble in alcohol, except when diluted, and one part of diastase will convert to sugar 2000 parts of starch. The doctrine of MM. Bernard and Barreswil, that animal diastase and pepsine are one and the same principle, has been refuted by M. Mialhe, who takes his stand chiefly on the following grounds:—that diastase possesses that sort of action which Berzelius named *catalysis*, having the power of communicating a change by mere contact, and undergoing no change within itself; this being the nature, also, of vegetable diastase, or the saccharizing principle of barley. Dr. Beaumont, on the other hand, has shown that pepsine is much more limited in its action, and, whatever be the amount of food received into the stomach, the juice will dissolve but a certain quantity. Diastase acts with rapidity,—pepsine more tardily. Diastase converts starch into dextrine, into sugar, and probabiy into lactic acid; while pepsine exerts no action on starch, gum, sugar, fat, or other non-nitrogenous organic principles of food. More has here been said on the differences between these two organic principles, for the reason that they have respectively their important spheres of action in the animal economy. Animal diastase first appears in the saliva, is quiescent in the stomach, is in full operation so soon as the acidity of the gastric juice is absorbed from the chyme or neutralised by the pancreatic fluid, and continues so through the intestinal tube. It is probable, also, that, wherever the non-azotic principles of food come into contact with the animal tissues, whether introduced in the oily base of the chyle, or otherwise absorbed by the veins, that animal diastase is performing some essential transformation, and that a change to lactic acid. The tissues, it is known, are always undergoing decomposition; and Liebig observes that a portion of animal bladder, when introduced into a solution of sugar of milk, quickly changes it into lactic acid; and sugar, moreover, has no power of nutrition unless first converted to lactic acid; for, if injected raw into the veins, it is discharged in the urine. Starch forms a very large item among the non-azotic principles of food, or, as Liebig denominates them, the aliments of respiration. Two or more changes are probably necessary in the course of its assimilation to blood—into dextrine and grape sugar, into lactic acid, and probably into fat. The latter change has been proved by the effect that bile has upon grape sugar—that of converting it into fat; and that the whole of these substances are represented in the oily base of the chyle, although part are absorbed by the veins. These changes in non-azotic aliments are unlike that which takes place in all albuminous aliments, as they assume the form of the albuminous base of the chyle, and which are of an isomeric nature, because the relative numbers of their components differ; but there is reason for thinking that, while pepsine, aided by a weak acid, is the agent in preparing the albuminous azotic base, that animal diastase exercises a like power in producing the oily non-azotic base, or that which goes only to support the temperature of the body. How the non-azotic group of aliments, on their ingestion, in part enter the lacteals, and in part are absorbed by veins, and how the whole of this class afterwards make their appearance in the oily base of the chyle, the author will venture to propound an hypothesis to explain when treating of the liver and bile.

The power of coagulating albumine, even without the aid of an acid, which pepsine so abundantly possesses, distinguishes also this substance from diastase. All ferments have their peculiar distinguishing characteristics. Diastase, which is an acknowledged ferment, does not differ more from pepsine than it does from the alcoholic ferment or the acetic; the former, in giving out carbonic acid; and the latter, in absorbing oxygen from the atmosphere.

It has been before stated that animal diastase is a product from most of the animal tissues on the verge of decomposition. The same observation applies to pepsine. Müller and Schwann, and more recently Blondlot, have shown that the discharge from any mucous surface, rightly acidulated at a temperature of 100° F., possesses an equally solvent power; and C. F. Burdach has prepared an artificial gastric juice from portions of the trachea, from pulmonary tissue, serous membrane, areolar tissue, the liver, the urinary bladder, and even from muscle. The operation of the gastric juice is considered to be essentially chemical and mechanical—mechanical from the assistance it derives from the peculiar agitation that is given to it by the muscular action of the stomach: the process of the solution of food in the stomach is no more the effect of vitality than that of insalivation and mastication; all taking place in situations equally external to the body, or, at least, beyond the acknowledged limitations of vitality; being without the barriers of the blood, or the precincts of its vital changes. The power that pepsine gives to a weak acid of dissolving albuminous compounds is precisely what a temperature of 212° F. confers on a like weak acid solution, as it is fully ascertained that weak acid solutions have the same dissolving power at a boiling temperature. The product of the action of gastric juice—chyme—is a pulpy substance, varying in colour according to that of the food, having an unpleasant acid odour. Though many albuminous substances may have entered the stomach, the chyme holds, as before said, but one of these compounds in solution. Chyme consists also of the other non-azotic portions of food, and these are but little altered by it. The other matters of the chyme are those from the albuminous class of aliments that are not capable of solution.

Gastric juice is highly antiseptic, and may be preserved unaltered for months. The amount secreted harmonises with the amount of waste that the blood has undergone, and which is indicated by the sensation of hunger, and does not at all agree with the amount of food consumed. When, therefore, food is in the excess, the surplus passes undigested; and, in the experience of Dr. Beaumont (in his well-known case of a patient with a fistulous opening in the stomach), becomes a source of constitutional irritation and feverishness. It was ascertained by Dr. Beaumont that the temperature suitable to the secretion of the gastric juice is near upon 100 degrees: raised ten degrees or lowered ten, the secretion is suspended. These are facts of therapeutical interest. Reaction followed the moderate application of cold; from which may be inferred that much exposure to cold, imperfect clothing, and bad shelter, or ice taken at meals, retards digestion; at the same time, a draught of cold water may impart energy to the process, both by the stimulus of cold, and by appropriately diluting the acid of the juice. It was observed that, until the introduction of food, the stomach maintained its pinky pallid colour, which then became flushed by the sudden distension of the

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Gastric Juice.

The solvent power of gastric juice, 'tis fair,
Unto weak acids boiling to compare.
Pepsine *sur l'aile putrescent* gives the key
By which weak acids solve by chemistry:
Azotic vegetable foods and meat
It solves, just at a hundred Fahrenheit.
All proteine forms are into one resolved
By acid; then by fermentation solved.
Blood—salts without the sulphates, acids free;
But what they are the chemists can't agree.
'Twixt the acetic, lactic, hydrochlo,
'Tis best to say we don't exactly know.
Pepsine, without the acid, by the bye,
Coagulates albumine wonderously.

capillary blood-vessels. Then also, and not till then, the clear juice was seen exuding from the walls. Mere mechanical substances introduced occasioned a flow of juice, though in a less degree than food; and pepper, spices, alkalies, and salt, had the effect of increasing its flow, which was also observed by M. Blondlot and Bernard, who maintained fistulous openings in the stomachs of dogs. It was ascertained by these observers that irritation of the membrane, when excessive, whether mechanical or otherwise, suppressed not only the secretion of gastric juice, but also its mucus. Dr. Beaumont's observations on the appearances of the stomach under febrile excitement are valuable from the extreme rarity of opportunities of inspecting the interior of the stomach of a living human being. During the times in which the observations were made, his patient was suffering from slight attacks of gastric fever. "At such times," observes Dr. Beaumont, "there are sometimes found, on the internal coat of the stomach, eruptions of deep red pimples, not numerous, but distributed here and there upon the villous membrane, rising above the surface of the mucous coat. These are at first sharp-pointed and red, but frequently become filled with white purulent matter; at other times, irregular, circumscribed red patches, varying in size and extent from half an inch to an inch and a half in circumference, are found on the internal coat. These appear to be the effects of congestion in the minute blood-vessels of the stomach. There are also seen at times small aphthous crusts in connection with these red patches. Abrasion of the lining membrane, or, in fact, an ulceration, is not an uncommon appearance. These diseased appearances, when very slight, do not always affect essentially the right working of the gastric apparatus. When considerable, and particularly when there are corresponding symptoms of disease—as dryness of the mouth, thirst, accelerated pulse, &c.—no gastric juice can be extracted by the alimentary stimulus. Drinks are immediately absorbed, or otherwise disposed of; but food, taken in this condition of the stomach, remains undigested for twenty-four or forty-eight hours or more, increasing the derangement of the alimentary canal, and aggravating the general symptoms of disease.

After excessive eating or drinking chymification is retarded; and, though the appetite be not always impaired at first, the fluids become acrid and sharp, excoriating the edges of the aperture, and almost invariably producing aphthous patches, and the other indications of a diseased state of the internal membrane. Vitiated bile is also found in the stomach under these circumstances, and flocculi of mucus are more abundant than in health. Whenever this morbid condition of the stomach occurs, with the usual accompanying symptoms of disease, there is generally a corresponding appearance of the tongue."

From the remarks of Dr. Beaumont, it appears that aphthous ulceration is a frequent and also a very unformidable disorder of the stomach. It is probable that the intestinal tube is not exempt from the same ulceration. The physiology of its mucous membrane makes it probable that it is predisposed to it. It will be seen that a layer of fine granular matter, the seeds of cell growth, is subjacent to its basement membrane, which, under exciting causes, readily assumes increased formative powers, producing diarrhœa. At such a time the basement membrane is prone to disappear, leaving ulcerated patches, and the object of this digression is to express an opinion that aphthous ulceration is common to the intestinal tube as well as the stomach; and farther, that as the ulceration is seated in the fibrous layer which gives strength to the membrane, that it is during these ulcerations, that exist unknown to the patient, that perforations of the intestinal tube take place. A case of perforation of the ileum has lately been authenticated, which occurred during a struggle, and after death several white ulcerations of an aphthous appearance were seen in the intestine. Some slight gastric disorder, indicated by the usual enlargement of the fungiform papillæ, and increased mucous secretion of the tongue, generally accompanies aphthous ulceration of the stomach. It was also observed by Dr. Beaumont that moderate exercise hastened the process of chymification. Among that large class of persons who take the minimum amount of exercise, the dinner is the principal meal of the 24 hours, and one meal taken with an appetite is amply sufficient with such persons to reinstate the blood with materials necessary to supply the small amount of waste. Exercise in such cases, by creating a necessity for the food, provokes the stomach to pour out enough juice to dissolve it.

It will be seen from the extracts taken from a large table published by Dr. Beaumont, which gives the time required to digest a great variety of foods, that the average period is from two to four hours, according to the sort of food taken: meat and vegetables are not generally cleared from the stomach under three hours and a half; a breakfast of bread and butter and eggs in two hours. Unless, therefore, the dietary of the patient is well known to his medical adviser, it will not be advisable to prescribe for him medicine that may interfere or be interfered with by gastric juice to be taken in less than 3½ hours after eating, and two hours with children living on milk or farinaceous food. Over-exertion of mind or body retards digestion, and great anxiety and distress, fear, joy, and the strong passions, generally take away the appetite for food, or, in other words, totally suspend the secretion of gastric juice; to the truth of which most of us can respond.

1 *hour.*

Rice.
Pigs' feet.
Pigs' Chitterlings.

1 *hour* 30 *minutes.*

Venison.
Brains.
Salmon trout.
Whipped eggs.

2 *hours.*

Tapioca.
Barley.
Milk.
Bullock's liver.
Soft eggs.
Salt cod-fish.

2 *hours* 30 *minutes.*

Calves' foot jelly.
Turkey.
Roast pig.
Lamb.
Wild-goose.
Roasted potatoes.

3 *hours.*

Oysters.
Beef.
Mutton chop.
Mutton, 3 hours 15 minutes.
Pork, do. do.
Carrots, do. do.

3 *hours* 30 *minutes.*

Bread.
Turnip.
Potatoes.
Cheese.
Hard eggs.

4 *hours.*

Veal.
Duck.
Fowls.

4 *hours* 30 *minutes.*

Salt Pork.
Cabbage.
Salt Beef, 4 hours 15 minutes.

From this list we gain a knowledge of the sorts of food that are the most quickly, and consequently the most easily, dissolved in the gastric juice. When, therefore, a diet is sought for a patient recovering from a disorder, in whose case it appears needful to supply as large an amount of nourishment as the impaired action of the stomach is capable of chymifying, the diet should at first consist mostly of rice, milk, eggs, and afterwards in the following gradations—2d. Venison, game, fish, brains, sweet-breads; 3d. Liver, salt-fish, and eggs boiled soft: in this division are tapioca, gruel, and milk; 4th. Turkey, roast-pig, lamb, and calves-foot jelly; 5th. Mutton, beef, pork, oysters, cheese, hard eggs, and bread; 6th. Ducks, fowls, veal, and beef, and pork lightly salted. If the patient is recovering from a disease characterised by an excess of fibrine in the blood, a diet would be chosen from food which would supply more to the oily base of the chyle than to the albuminous, and this would be that which abounds more in the non-azotic class of food. Brain is the only animal aliment that consists of the two classes of food, azotic and non-azotic, in about equal proportions. Garden vegetables appear, by Dr. Beaumont's list, to be long in digesting; but it does not follow that because this is the case that it is not in other respects the best and most nutritious food, which is the case with some of the meats. The pathology of the fascicular glands of the stomach is comprehended under the general head of dyspepsia, in books on the practice of medicine; there is a diseased condition that is perhaps entirely seated in those glands, but which, being usually considered without the pale of remedies, has not been much referred to in those works. The condition alluded to is the imperfect action of the glands, and consequent scanty secretion of gastric juice, or the deficiency of the acid material. It is generally congenital, and the prominent symptom is a difficulty of digesting foods in which the albuminous matters are in excess. Such children, therefore, have a dislike to animal food, and choose farinaceous diet and vegetables, in which the non-azotic ingredients being in excess, are better suited to the scanty supply of gastric juice, and the otherwise healthy supply of animal diastase, bile, and pancreatic juice, pepsine being thus crippled in its action for the want of an acid. The albuminous base of the chyle and albuminous components of the blood are badly supplied. Digestion is chiefly performed in the small intestines. The albuminous tissues in such persons want strength and rotundity. In the treatment the idea presents itself of a liberal supply of salt in the food to supply the defective acid ; if not, the hydrochloric acid, before meals.

The motions of the stomach.—The experimental researches of Haller, Hunter, Spallanzani, Wepfer, and Magendie, on the normal movements of the stomach, so far agree with those of Dr. Beaumont (the eye-witness of the same in man), as to stamp additional value upon the latter. Contraction first appears to take place in the oblique and longitudinal fibres, which shortens, and then in the circular, which lengthens the organ. The two sets of fibres do not act together, for if so they would tend to force out the contents. The effect is complete, that of intermingling the contents of the stomach, and the direction in which the contents move is first from the pylorus along the small curvature or upper portion to the cardia, and back again to the pylorus by the large curvature,—a movement that occupied two or three minutes, carrying the bulb of the thermometer introduced by Dr. Beaumont at the time, in the stream of the movement, and giving the stem held externally a reverse direction. At this stage the pyloric orifice is closed tightly, but soon opens sufficient to admit a liquid ; and then the circular fibres near the pylorus, which are known to be powerful by their contraction, inject the chyme into the duodenum ; and so effectually is this object attained, that the thermometer was held with firmness, and carried three or four inches in that direction. The pyloric orifice is so far closed during the process of chymification that no food can pass unless in a liquid state, but on the juice ceasing to flow, the sphincter ceases to contract, the circular muscles near the pylorus to collect the chyme, and the surplus food undissolved is allowed to pass to the duodenum to produce its injurious effects. The movements of the stomach, like those of the intestinal tube, are peristaltic, or independent of the nervous system. Dr. J. Reid has done much to establish this fact by extensive experiments on the eighth pair of nerves, by which it is also apparent that both movements and secretions are influenced and guided by the eighth pair, though they can proceed in regular order when the trunks of these nerves are divided. The muscular fibres which form the cardiac sphincter are directly controlled by the vagus, for, on the division of these nerves, the food regurgitates into the œsophagus. The peristaltic action of the stomach differs from that of the intestinal tube, inasmuch as besides the regular vermicular onward movement there are added the movements proper to chymification. These proper movements seem to be principally effected by the muscular fibres that are superadded, so to speak, to the stomach, over and above those common to the intestinal tube—1st. The bands of fibres along the short curvature; on these probably depend the backward movement that takes place when the whole contents are revolved in chymification; 2d. The oblique fibres continued from the duodenum, whose office it is to shorten the viscus; 3d. The fibres of the pyloric valve, and the strong circular fibres near the valve, which have the peculiar and separate action before referred to. On the termination of chymification all the movements of the stomach cease except the rhythmical movement common to the intestinal tube; by which latter fibres, whatever matters are left undissolved in the stomach, whatever of food is taken before the wants of the system are again sufficient to insure the secretion of juice, or whatever liquids are swallowed (after being presented to the veins for absorption), are moved onwards into the duodenum.

The influence of the pneumogastric nerves seems to be mostly confined to the muscular fibres which were described as proper to the stomach, for, if the trunks of these nerves are mechani-

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Motions of Stomach.

The normal motions of the stomach need
No motive power from th' vagus; and indeed
The gastric juice alike preserves its course,
As free as are the movements of the horse.
Like as the horse is ruled by spur and bridle,
The vagus urges on or makes them idle.

"The influence (of the nerves) upon the organic functions may well be compared to that which the hand and the heel of the rider have upon his horse."—*Principles of Physiology*, p. 473, 3d edition, Dr. Carpenter.

cally irritated during the process of chymification, the motions of the stomach are at once increased, and an impulse given to the combined movements of chymification; but when the stomach is empty, and these movements are in a quiescent state, they cannot be so stimulated through the pneumogastric nerves.

It is generally admitted that the stomach, and also the œsophagus, take an active part in the movements of vomiting. The cardiac sphincter first becomes relaxed, and the rhythmical movements common to the stomach and œsophagus become reversed, or *antiperistaltic*. The greater part of the expulsatory power in vomiting is accomplished by the following curious adaptation of means:—By a forced inspiration the diaphragm is contracted, and the chest filled with air; the glottis is shut, which keeps, by the distension of the chest, the diaphragm in a contracted state, and pressing its concave surface against the contents of the abdomen. The diaphragm is now made to increase its contraction, and not being able to draw any more air into the lungs, the glottis being closed, the base of the thorax is narrowed by drawing the ribs towards the spine, which has the effect of pressing down the lesser curvature half of the stomach, when at the same time the abdominal muscles are in full force, driving up the splenic portion and large curvature. The first part may be said to be a deep inspiration; secondly, a further attempt at inspiration; and, lastly, an attempt at expiration, both attempts being made nugatory by the fixed state of the glottis. The fact that the stomach exerts itself antiperistaltically in vomiting, has been witnessed when the organ has been protruded through the walls of the abdomen; and the fact that vomiting may take place unaided by the muscular fibres of the stomach, Magendie has shown by inserting a pig's bladder in its place, and then producing vomiting by injecting emetic tartar into the veins. The fact that vomiting may take place without the aid of the diaphragm, has been proved by its production after the section of the phrenic nerves; but the fact that it cannot proceed without the expelling force of the abdominal muscles has been proved by Krimer, who effectually prevented vomiting by dividing the nerves that supply the abdominal muscles with motion. The action of vomiting is held by Dr. M. Hall to be diastaltic or reflex; the antiperistaltic portion of the movement of the stomach and œsophagus seeming to be capable of excitement, like the peristaltic movement of the intestinal tube by cerebro-spinal influence. The ganglionic centre of vomiting is said to be in the spine, though the spot is not clearly defined. The excitors of the action are various:—1st, the sympathetic (the especial nerve of the blood-vessels and glandular structure) excites vomiting on the injection of emetic tartar into a vein; 2dly, by cerebro-spinal influence, by a blow on the head, disorder of the kidney, &c.; 3dly, the glosso-pharyngeal nerve, by means of a feather or other matter applied to the fauces; 4thly, by the ganglia of special sensations in the cases of seeing or smelling sickening objects, or by recalling ideas of such to the memory; 5thly, by the fifth and glosso-pharyngeal, in their capacity of nerves of taste; and lastly (if it be the last) by the gastric branches of the par-vagum, by its contact with certain emetic substances in the stomach. However physiologists may differ about the seat of sensation of hunger, the hungry man has but one opinion on the subject,—that the "raking of the stomach" is in the stomach: after much investigation, physiologists are inclined in the main to agree with him. On the one hand, hunger is satisfied by the injection of sustenance into the veins; and on the other, is allayed for the time being by the introduction of matter into the stomach which is not nutritious. The par-vagum, Dr. J. Reid concludes, communicates to the mind the condition of the stomach. The sensation of emptiness in the capillaries of the stomach, we may suppose, is made cognisant to the mind by sensory fibres contained in the gastric branches of the vagus. But this physiologist supposed that this was not the only channel for such influence. The animals that lived through the first effects of the section of the vagi, by Dr. J. Reid, took food eagerly,—a fact that has a good deal shaken the belief that the vagus is the only agent. But it is observed by M. Bracket, that we often eat without any sensation of hunger, to gratify only the senses of taste and smell, and in accordance with habit and instinct. The section of the vagi produces an immediate cessation both of the secretion of gastric juice and the movements of chymification. These are considered to be effects due to the shock given to the nervous system by the operation; yet the animals will immediately afterwards eat, if food is presented to their mouths. The sympathetic nerve, so universally spread upon the coats of arteries and capillary vessels, is generally supposed to exercise its sympathising functions in giving tidings of the emptiness of the vessels, by imparting the impressions of hunger and thirst to the cerebro-spinal system of nerves. This is no more than is accorded to the sympathetic branches in the lungs,—that of imparting to the pulmonary branches of the vagi the impression arising from carbonic acid in the capillaries, and thereby enabling the vagi to act their part as the chief excitors of respiration. The sensation of thirst is confined as much to the fauces as hunger is to the stomach, and may be relieved temporarily by washing out the mouth. If in thirst we adopt the same theory as in hunger, we should say the sympathetic covering the capillaries of the tongue and fauces holds a like communication with the glosso-pharyngeal and the gustatory branch of the fifth, proclaiming to them the need of water in the blood: Dr. Carpenter entertains this view. But we are poor in facts regarding the physiology of the sympathetic; and if these ganglia are the instruments for these impressions, we cannot determine whether the power is exerted through the fine fibres that are seen to originate in the ganglia, or whether it is an adjunct quality imparted to the fibres as they traverse the grey matter, or whether it be a modified action given to the axis-cylinder nerve-fibre—the fibre proper to the cerebro-spinal system, which also interlaces the vesicles of the ganglia. The walls of the intestinal tube are composed of three coats—the serous, muscular, and mucous. The muscular coat has two layers of fibres—an external longitudinal, and a circular set, arranged internally around the tube. The colon, besides its share of longitudinal fibres, has a multiplication of them collected into three longitudinal bands, like pieces of tape arranged at equal distances, and being much shorter than the ordinary longitudinal fibres: a gathering-in of the tube is produced along the bands, producing a bulging-out in the loose portion, or sacculi or sacs in the tube. The sacs are well adapted for separating and presenting the material to an extensive surface of intestine, and the bands are well suited to produce motion in the sacs, and prevent lodgment therein. The follicles or *glands of Lieberkühn* are interspersed over every part of the intestines. They are as thickly set as the villi; their construction is exactly that of the fascicular tubes of the stomach, except that they are separate and not held together in bundles; their blind extremities are based in the fibrous substratum with free ends into the tube. They become larger as they descend the tube, and so large in the rectum that the depressions which they cause in the membrane may be seen with the naked eye. The cylindrical epithelium which covers the surface of the membrane is continued into the tubes. Both nuclei and granular matter fill their interior, which is seen to contain perfect cells as it approaches the orifice. The *glands of Peyer* are circular or oval bodies, about a line in diameter, confined to the small intestines, and more abounding in the ileum, near the ileo-cœcal valve. They occur either in patches of a dozen or so, or singly, and thence are called *agminatæ* or *solitariæ,* as the case may be. They are situated in the fibrous layer of the mucous membrane, below the basement, and consist, according to Dr. Handfield Jones, of a solid mass of nuclear granules, with a little granular matter encircled with a capsule, which is distinct from basement membrane, not being lined by epithelium; nor do they open into the intestinal tube. They are various in size, those near the surface being the largest; as seen on the surface of the intestine by the microscope, they are encircled by a row of dots, the orifices of the tubular follicles of Lieberkühn. The villi are sometimes seen on these glands, and sometimes they are absent. It is probable that when they are matured in growth they burst and discharge their contents into the intestine, and disappear. Their gradual progression towards the surface, the villi being seen on their surfaces, and their apparently forcing the follicles of Lieberkühn out of their normal position into a circle around them, by gradually growing up in the midst of them, makes it probable that they are not permanent structures, and that their existence terminates with the discharge of their contents into the intestine. They differ also from the follicles of Lieberkühn in the absence of that characteristic of permanence, the continuance of the basement membrane, with its epithelium, into their interior. Peyer's glands are found chiefly in that portion of the intestine which joins the mesentery. The *glands of Brunner* belong only to the duodenum, which they surround, being imbedded also in the fibrous layer below the basement membrane. They are of the nature of conglomerate glands, resembling clusters of grapes, the stalks of which fitly represent their excretory tubes, which open into the intestine. They may be easily seen by a slight magnifying power, and are most numerous at the upper part of the duodenum. They are permanent structures, and as they represent the pancreas in miniature, they may be considered to fulfil a like purpose to that organ in the process of digestion. The functions of these glands, like those of Lieberkühn and Peyer, are not certainly known: several important matters are excreted from the surface of the tube, but the exact source from which they proceed is not understood. These remarks more particularly apply to the mucus, and the principle or principles contained in it, that are active in the digestion of the non-azotic class of food—first, the animal diastase, and the principle of lactic acid fermentation, which are probably distinct substances; and next, the putrescent matters that are poured into the intestines directly from the blood, forming one of the chief agents in the elimination of carbon, or rather of matters abounding in carbon: these are the result of superfluous ingesta, or matters cast off from the organism, and which are traversing the changes that organic matters undergo when passing from the high to the low forms of organism, before they settle down into the three leading binary organic principles; though in this case only two such are ultimately formed,—the water and carbonic acid. These are normal functions of the mucous membrane; but under the excitement of stimulating medicines, or when there is an undue accumulation of waste matters of the tissues in the blood, as happens when the powers of life are failing, abnormal action takes place. The same results from various organic poisons in the blood,—such as some of the contagions, the introduction of pus into the blood, or the poison that occasionally forms in a food of shell-fish, or roast pork, &c.; in all such cases there is a tendency to exuberant cell-growth in the granular matter that is seated in the fibrous layer of the mucous membrane, the result of which is diarrhœa and ulceration of various parts, and especially of Peyer's glands, indicated by tenderness in the right iliac fossa. With the matters in states of decay, are mixed, in these discharges, some of the valuable constituents of the blood,—the serum, not filtered from a great portion of its solid matters by percolation, as is the case in the interstices of areolar tissue, and other situations, or as it exists in lymph or the sacs of serous membranes, but containing the normal amount of its solid constituents as it exists in the blood. The particular parts that are performed by the Lieberkühn and the Peyer's glands in furnishing either of these various products, whether in health or disease, or whether these matters come otherwise from the surface of the intestines, has not been determined. The pancreas is placed before the second lumbar vertebra, about 2 inches in breadth, 4 ounces in weight, and 6 inches in length, flat, with a large end encircled by the curve of the duodenum, and tapering towards the spleen, which bounds the lesser end, having the large blood-vessels, the vena cava porta, and aorta, behind it. It is a conglomeration of small glands like bunches of grapes thickly clustered, with a common duct that either opens into the ductus communis choledochus or into the duodenum. The pancreatic juice is colourless, having, like the serum of blood, a saline taste, and, like it, being alkaline. It is thick and viscous, hanging in large drops. Tiedemann and Gmelin have obtained from 3 to 5 per cent. of solid matters from the pancreatic juice of sheep; from 7 to 8 per cent. from dogs; and from 5 to 8 in man. That of the dog is made up of osmazome, a matter reddened by chlorine, a little caseous matter, and an albuminous compound, which is very remarkable, differing in some points from other albuminous products, both in its physiology and chemistry, though isomeric in its composition with albumine. Like albumine, it coagulates into an opaque white mass, the whole of the juice becoming solid (this is effected by heat and the inorganic acids, &c. &c.), which is dissolved again by alkalies. It differs chemically in respect of the coagulum that may be formed by alcohol, which, when dried, may be redissolved in water, which is not the case with albumine. The new solution possesses the emulsing properties of pancreatic juice. The pancreatic juice has been said to resemble saliva, but it differs from it both in composition and in its physiology. Saliva has less than 1 per cent. of solid matters in solution, while this has from 5 to 8 per cent., and, moreover, has not the sulpho-cyanogen,—a substance which closely resembles prussic acid in composition, and which, probably, under some other mysterious rearrangement of its atoms, is capable of assuming those terrible forms of poison that sometimes characterise saliva,—the infection of hydrophobia, or the venom of serpents.

M. Bernard has lately asserted that a separation of fat acids from glycerine takes place by the action of pancreatic juice on fatty matters, the free butyric acid being at once perceptible on the mixture of butter with the juice. This phenomenon of saponification without the aid of a soap-alkali cannot be explained by chemistry, excepting on the theory of fermentation; and the albuminous compound of the juice has been looked upon as acting on that principle. M. Mialhe was the first to pronounce it "*un ferment pour le corps gras*," and the weight of opinion inclines to seat the principle of its action in this albuminous matter. Experiments, however, more recently undertaken by Frerichs and Lenz, appear to lead to opposite conclusions, both as to the power of the juice of separating the acids from the glycerine, and also in proving that the absence of the pancreatic juice from the intestines does not prevent the digestion of fat. They tied the pancreatic ducts in cats, and, after keeping them without food for twenty-four hours, as a guarantee that no pancreatic juice should remain in the intestines, food, consisting of meat, milk, fat, and butter, was given them, and, again waiting a due time for its digestion, the animals were killed, and in the lacteals, as well as the thoracic duct, milky chyle was found. In some animals a ligature was placed on the small intestines below the opening of the ductus choledohus, and the same result occurred as in the former experiments when oily matters were injected into the intestinal tube. Experiments are also detailed in which cats were fed on butter, but no trace of the butyric acid could afterwards be found in the bowels, in the lacteals, or in the blood. MM. Bouchardat and Sandras hold that the free alkali of the juice is sufficient for the purpose of solving fat, but the amount of alkali is not greater than that of the serum of the blood, and not by any means so much as that of the bile, which, by the decomposition which it undergoes, liberates into the small intestines a certain amount of soda in exchange for the albumine, which, according to Plattner's theory, unites with its choleic acid. M. Bernard still maintains his theory, and considers that further researches will prove his discovery to be correct. In the meantime the physiology of the pancreatic fluid is in abeyance. It is possible that a mere division of the particles of oily matter only is needed as preparatory to their absorption by the lacteals, and that this may be effected by the albuminous compounds of the various secretions; but the large amount of albumine in the juice, and that differing in its character from common albumine, makes it probable that it fulfils some special purpose. The fact, also, that it is an azotic compound, adds some negative evidence to the opinion that it is a ferment, and which has not been noticed by writers on the subject; "for it is ascertained that organic compounds destitute of nitrogen do not enter into fermentation or decay unless a nitrogenized body be present, which first enters decomposition, and then acts as a ferment, exciting decomposition in the non-nitrogenized body."* The matter fermented (fat) in this case contains no nitrogen, and pure stearate of glycerine, according to this theory, is not subject to decay. Both pepsine and animal diastase contain nitrogen; and if it shall afterwards appear that these observers have not been mistaken in their report of the separation of the fatty acids from the glycerine, we shall per-

* Turner's Chemistry, by Gregory and Liebig, p. 690.

ceive at once a striking difference between this action of the juice and the common saponifying process of alkalies upon oily matters, in which the two acids are impounded by the soap-alkali, and the glycerine set free. It is singular that the animals that consume the most fat in their food have the largest quantity of albuminous solids in the pancreatic juice, and that the domestic cat, which eats more fat than her wild relation, has the largest pancreas. Besides this special action on fatty matters that pertains to the pancreatic juice, there is that also, in common with most other secretions from mucous membranes, —the power of transforming starch into dextrine, sugar, and lactic acid.

The Liver and Bile.—On a close inspection of the liver with the naked eye, it is seen to be composed of a conglomeration of small lobes or lobules, the size of millet-seed, held together by areolar tissue. The portal vein, after importing the blood from the stomach, intestinal tube, spleen, pancreas, and gall-bladder, ramifies again in the liver. The hepatic duct is relatively small, as compared with the size of the liver, and other gland ducts. It is well known that the hepatic artery and duct, inclosed in their sheath of Glisson's capsule, enter the liver, accompanied by the portal vein; and it is equally certain that the three keep company aloof from the hepatic vein, as far as the microscope can follow them. For information regarding the arrangement of the peripheries of the four sets of vessels, in and on the lobules, we are indebted to Mr. Kiernan, whose testimony on these points has not been shaken by other observers. The lobules of the liver are conical in shape, with a flat base; their shape may be compared to a pine-apple, the stem typifying the hepatic vein, as it makes its exit from the base of the lobule; the projections on its surface are fewer and more irregular than the fruit mentioned, not numbering more than 7 or 8. The three vessels—the artery, the duct, and portal vein—form a plexus on the surface of the lobules, but not at the base, and fill up the interlobular spaces. They are enveloped in areolar tissue, which is a prolongation of

Glisson's capsule. Glisson's capsule appears to be the same sort of areolar tissue that forms the external coats of arteries on which their elasticity depends, and in which the yellow fibrous element predominates over the white. The hepatic vein has no covering from this tissue, on which account, when the liver is examined, this vein appears open, while the other vessels are closed. The three vessels conjointly penetrate the lobules, the interior of which (as seen by the microscope) consist of *granular bodies* or *lobulets*, rather transparent, and of a yellowish colour: these are the *acini* of Malpighi and Ruysch, and have usually been considered as nucleated cells by no less a number of anatomists than Purkinje, Henle, Halmann, Vogel, Wagner, Krause, Lambron, Kiernan, Weber, Backer, and Handfield Jones. Others have denied the existence of cells, for the reason that no cell-walls can be distinguished. In 1838, Verger and Dujardin pronounced them to be solid glutinous oval corpuscles, and not cells. No cell-wall can be distinguished, according to M. Rochoux. In an interesting memoir, lately published, this writer says that they are made up of an infinitely large number of infinitely small molecules, to the number of 2,812,000 to each acinus; such molecules having, however, previously been described by M. Ferrein. M. Guillot has lately bestowed much labour on the subject, for the purpose of obtaining a settlement of the question. He reports that they are not cells, but bodies with a granular surface, measuring from 1-800th to 1-1000th of an inch in diameter, and containing minute molecules, sometimes vibrating, and sometimes also nuclei are seen, and that they do not contain bile. The conclusion which we seem bound, therefore, to draw, is, that the granular bodies filling the lobules, and spoken of by all, are not of the nature of cells, but are made up of molecules held together without capsules, and sometimes having a nucleus. The ultimate ramifications of the artery, duct, and portal vein, enter from the surface of the lobule among these granular bodies or lobulets, between which there are canals common to both orders of blood-vessels. The coats of these canals cannot be distinguished. The hepatic vein (as shown by

Kiernan) commences in the substance of the lobule from these canals, and takes its course to the base of the granule, but, like the other vessels, the coats are not seen.

In all vertebrated animals these canals seem to fill the place of capillaries in the liver, and there are remarkable differences between these and the ordinary capillary vessel, inasmuch as no walls can be distinguished; another peculiarity is, that these canals are the common termination for the portal vein and hepatic artery; and from the canals, also, the hepatic vein begins its course. By capillaries, ordinarily two orders of vessels, only, communicate; in the lobules of the liver three orders are connected by means of these structureless canals, which take their course in the angles formed by the union of the granular bodies in the lobules, in the same manner as water passes between the fragments of stone in a rivulet, which would be a better simile if the stones adhered in all parts except in the currents. The canals may be injected either through the vena porta or hepatic vein, and, with difficulty, through the hepatic artery. Before the hepatic ducts penetrate the lobules, they anastomose around the vena porta and hepatic artery in the plexus on the surface, and, on entering, form equal-sized canals throughout the lobules, and these also have no walls; they, however, keep to distant passages between the granular bodies, but by what law of hydraulics, or by what other influence, the currents are preserved separate, and at the same time their respective functions and relative bearings to each other are maintained, does not, in the present state of our knowledge, become apparent.

From the base of the lobules the hepatic veins collect into trunks, and, proceeding to the posterior edge of the liver from every part of its substance, they are concentrated in two main trunks, which open into the vena cava. The nerves and lymphatics of the liver enter the organ with the vessels inclosed in Glisson's capsule, and follow the course of these vessels. The nerves, which are from the pneumogastric, sympathetic, and right phrenic, do not, according to Dr. Handfield Jones, enter the lobules, and are chiefly distributed to the artery and portal vein. The fact, if it be so, that nerves do not absolutely enter the lobules, the arena of secretion, indirectly supports the principle in physiology, that secretion is independent of nervous systems, though influenced and controlled by them. The lymphatics accompany the other vessels into the lobules, and are transmitted through them by the canals, after the manner of the other vessels, and may be injected by the hepatic duct. It has been satisfactorily proved by the experiments of M. Bichet and M. Simon, that the bile is elaborated from the portal blood, and that the arterial blood is for the nourishment of the organ and vessels.

The researches of M. Guillot, and the other anatomists whom we have followed in the minute anatomy of the lobules of the liver, throw a light on the general pathology of the organ. We have seen that the five orders of vessels that penetrate the lobules have canals between the granular bodies, but they are without walls; the canals have not even the delicate coats of capillaries, nor are the granular bodies enveloped in capsules or cell-walls: the three orders of blood-vessels have one common bond of union by the canals in the lobules. The lymphatics and bile-ducts, although preserving their separate passages among the granules, are also, as we have seen, deficient in walls. In such a glandular construction we are not surprised that, under certain increased formative powers, whether the effect of mercurial remedies or dependent upon certain conditions of the blood, the colouring matters, and other grosser portions of the blood, should find admittance into the hepatic duct, and produce a variety of appearances, from the dark-coloured dejection to the intensely black dis-

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Liver.

The substance of the liver, 'tis agreed,
Is lobular, the size of millet seed.
Around each lobule, and in every space,
Three sisters cast their arms in close embrace;
Hepaticus is called the family name.
The artery, the duct, the portal vein,
They penetrate the lobules, and these graces
Fill up the interlobular small spaces.
The granules in the lobules are the source
Where the hepatic vein begins its course,
Taking blood from the base to join the vein,
The cava, that conveys it back again.

charges with which we are all familiar in disordered states of the liver.

The colour of the bile is a deep yellow, with a specific gravity from 1032 to 1040. When newly secreted it has no smell, and no other taste than a strong bitter. By its continuance in the gall-bladder it thickens, from the admixture of mucus, and its colour darkens to a brown. In 100 parts of bile are contained 8·49 of solid matters. The student in physiology is much indebted to MM. Verdeil and Plattner that they have presented bile, bereft of its fat (cholesterine) and mucus, under the form of a single compound—bilic or choleic acid. It is pleasing to reflect that we at last hold, under this one organic acid, the many-headed progeny of bile, the real shapes and also the unsubstantial shadows that have so long started up to bewilder us under the forms of its organic constituents. According to M. Demarcay, it forms into a mass of fine acicular crystals, slightly yellow, with a strong bitter taste, soluble in alcohol, butnot readily in water, except when the acid is fresh. Its per-centage composition is carbon, 63·83 ; hydrogen, 9·05 ; nitrogen, 3·34 ; oxygen and sulphur, 23·78. Its formula by Verdeil—hydrogen, 0 ; carbon, 44 ; hydrogen, 40 ; nitrogen, 809. The sulphur amounts to nearly 4 per cent. Choleic acid may be entirely burnt away, is very prone to change, yielding a great variety of products in its decomposition ; but their physiology is not of much interest at present, for the reason that the different properties of bile have not been attributed and apportioned to each of these products which severally make their appearance in its passage through the intestines. The names given to these products by various writers are biliverdine, dyslysine, taurine ; fellinic, cholinic, and cholic acids ; together with picromel, the sugar of bile. Bile removed from the body, though kept in a low temperature, is disposed to commence its stages of change or decay ; and in the body, where it is in contact with the ferments contained in mucus, and at a favourable temperature, it commences these changes as soon as it is secreted. One of the first products is of a resinoid character, in which may possibly reside the antiseptic quality of the bile ; for, though decomposition is the predominant characteristic of bile, one of its products is antiseptic, and counteracts decomposition in the chyme. This is negatively evidenced by the foul mattery odour that is always present in fæces devoid of bile. The composition, already given, of choleic acid, may be accepted as that of the organic matters of bile. The following is the analysis of ox-bile by Berzelius, which is not known to differ from human bile :—

Water	90·44
Organic matters	8·00
Mucus	·30
Salts.	
Osmazome, chloride of sodium, and lactate of soda	·74
Soda	·41
Phosphates of soda and lime	·11
	100·00

The fatty matters of the bile are made up of cholesterine, margarine, and oleine, in nearly equal proportions. Cholesterine is found also in the brain and blood, and is the chief ingredient of biliary calculi : it forms into large pearly scales, of the colour of spermaceti ; it is insoluble in water and in alcohol, except at a boiling heat ; it is peculiar in that, being a fat, it is not acted on by alkalies, nor fusible at a less heat than 279° F. : it is, therefore, held in solution in bile and blood by means of an unusual agent—soap, that being stearate of soda : its proportion in either of these fluids is small. The readiest way of obtaining it is to dissolve a biliary calculus in boiling alcohol, which deposits it on cooling. Its formula is carbon, 38 ; hydrogen, 33. Margarine and oleine, which together form human fat, exist as such in the bile ; and, as before said, their acids are in combination with soda, forming the bile-soap, differing from human fat in the presence of soda and the absence of glycerine. The colouring matter of the bile is considered by Berzelius to consist of two matters—bilifulvine and biliverdine : they are very evanescent, and are thought to be the same that give the tinge to the serum of the blood, and that they are first formed in that fluid, and afterwards collected and concentrated by the liver in the bile. Traces of peroxide of iron, sulphate of lime, and phosphate of magnesia, are discoverable in bile. As to the amount of bile secreted in twenty-four hours, it is customary to be guided by Haller's calculation on the results of Reverhost's experiments on dogs, reckoning, as he did, that the human liver is four times larger than that of a dog. By the same calculation, and taking in preference, as a guide, M. Blondlot's recent experiments as to the quantity secreted by dogs, we may set down from eight to twelve ounces as the amount secreted in twenty-four hours by the human liver. The secretion of bile is always proceeding, though the quantity is accelerated when the recent digestion of food has replenished the portal circulation.

During prolonged abstinence the gall-bladder is full, and gradually empties itself during the digestion of food. The bile regurgitates into the gall-bladder in consequence of a sphincter at the duodenal orifice of the choledic duct. The sphincter resembles that of the cardiac orifice of the stomach. The bladder and ducts have the same number of coats as the intestinal tube, added to which, the yellow elastic fibrous element, abounding in Glisson's capsule, is extended to the gall-bladder. The nervous action of the bladder is supposed to be reflex or diastaltic, probably through the spinal centres, or by the pneumogastric, which reaches the duodenum by its terminal branches; the fulness of this intestine giving the necessary isodic stimulus or impression. The contraction of the bladder and ducts is aided by their physical elasticity, and also by the peristaltic movement of the muscular fibres of the viscus. Since Haller advanced the following hypothesis, experimental investigation has only illustrated its truth :—" Bilem si Natura voluisset de sanguine expurgare, effudisset in vicinia intestini recti, ne chylum sua admistione temeraret. Sed in omnibus animalibus bilis in principium intestini adfunditur, ut nihil fere alimenti ad sanguinem veniat; quod cum ea non mistum sit." The liver may be considered, in the first view of its operations, as separating from the blood a large amount of hydrocarbon; but it can scarcely be said to be an excrementitious gland, for the whole of the carbon and hydrogen is again absorbed in the intestinal tube. The liver is more highly organised than either the skin or the kidneys, for in the two latter organs the separation of the watery parts of the blood is effected by a process but a little higher than that of physical exosmosis. The comparison of the respective secretions exhibits an equal degree of difference. The bile is highly organised, while the components, perspiration and urine, are little else than inorganic: but, although the elements of bile are returned to the circulation, they serve no other purpose than that of keeping up the temperature of the body, by producing just so much caloric by union with oxygen, according to Liebig, as the same amount of carbon and hydrogen would produce by combustion out of the body. It seems probable that these elements existing in the blood before they are elaborated by the liver, are in too high a state of organisation for combustion till they have been separated by the liver, and undergone the many changes, and the regression in the scale of organization, that the bile is known to undergo in its transit through the intestinal tube. That the choleate of soda is a highly organised salt is evident from the numerous changes that it undergoes, and its proneness to fall into more stable combinations. In the fœtus the liver has the same function as in after-life, except that the reabsorption of the elements of bile is not needed for upholding the temperature of the body: they therefore accumulate in the intestinal tube in the form of meconium. The first purpose served by the bile, then, is the disorganisation of a large quantity of hydrocarbon, preparatory to its readmission into the blood. During this descent of bile in the scale of its organisation, some important purposes are served in the digestion of food. When the bile is prevented entering the duodenum, and the duct of the pancreas at the same time is left pervious, we have the conclusive evidence of M. Blondlot, amongst others, that no difference can be observed in the chyle. His words are:—"Je retrouvais chaque fois du chyle blanc parfaitement élaboré dans le canal thoracique et dans les vaisseaux chylifères." And Mr. B. Phillips is equally explicit on the subject; and the dogs that had a portion of the choledic duct excised, and the whole of their bile discharged through a fistule, in some instances were restored to health. However much, then, the bile may contribute mediately to promote the process of digestion, it is not immediately and absolutely necessary. MM. Leuret and Lassaigne have proved the same by direct experiment: they immersed bread, meats, and fruits, in bile free from pancreatic juice, for 12, 18, and 24 hours, and found the substances but slightly altered, and but little decreased in weight. But though the organic groups of aliments may be dissolved and arrive in the blood without the aid of the bile, we need no experiment to assure us that it is essential to the perfect and complete digestion of food, and to the health of the body. One of its obvious uses is the property of suspending all fermentation and decay in both classes of food, except such fermentation as is needful for their solution and absorption. The first part of the proposition, its antiseptic power, is borne out by the experience of most of us, by the experiments of Herbert Mayo, and Tiedemann and Gmelin; and, as to the second, its non-interference with digestive fermentations, M. Bernard remarks that it does not prevent the formation of sugar in the intestines (that is, the starch fermentation by animal diastase), but that it does arrest the alcoholic fermentation. We have Professor Thomson's evidence, amongst many others, that it does not suspend the lactic acid fermentation; and we have Professor Plattner's (whom we shall presently cite) that it does not interfere with the acetic. Lastly, we may advance the authority of Eberle, that spontaneous decomposition of aliments is arrested in the intestinal tube by means of the resinous and bitter principles of the bile. The following is Professor Plattner's interesting theory of the operation of bile on the chyme:—On the mixture of bile and chyme in the duodenum, that one form of albumine which we have described in union with, and held in solution by, the gastric juice, is decomposed; the choleic acid unites with the albuminous matter, forming choleates of albumine, fibrine, and caseine (it being known that it is the common behaviour of albumine to take either the part of an acid or a base). We would rather that the Professor had spoken but of one albuminous compound as present in the duodenum, because the present theory of the action of gastric juice is, that it conforms all albuminous matters into one compound, which alone is soluble in gastric juice; but it must be observed that his experiments were made on these substances with artificial gastric juice. Now these choleates are insoluble in water, in alcohol, and hydrochloric acid, but are readily soluble in acetic, and in solutions of the alkaline carbonates. A precipitate may therefore be looked for on the mixture of bile and chyme; and the fact of such precipitate we were not strangers to before Plattner wrote on the subject, and concerning which Dr. Elliotson has cited Dr. Blundell, in his work on Physiology. A precipitate being thus formed on the first mixture of bile and chyme, and that precipitate being almost insoluble to the common solvents, it is evident that bile, when present in the stomach during the process of chymification, must be injurious. We are aware that the free acids that the chyme contains when it enters the duodenum are removed, most probably, by the process of absorption, before it reaches the jejunum; and that, in both this intestine and the ileum, not only is there a formation of the alkaline carbonates, but it is in these districts that the acetic acid fermentation is set up whenever the qualities of the non-azotic food ingested conduce to that process. We see, therefore, the source from which a solvent is obtained, and is at all times ready at hand to dissolve the choleate of albumine. It is an hypothesis greatly to be admired, and requires only to be tested by the experiments of future observers.

The advantage gained by this combination of choleic acid and albumine resides probably in the property of the new substance of withstanding decomposition. This definite form of albumine, while it is exposed to the influence of several ferments, is thus protected from the ordinary fermentation and decay of animal matter, in a situation that powerfully conduces to those changes, by its union with choleic acid; choleic acid being itself a strong bitter, and, in its after-states, resinous. The choleates of albumine are thus effectually presented to the walls of the intestines, and both substances are wholly assimilated to the chyle, or absorbed by the veins; for Tiedemann and Gmelin report that neither osmazome, picromel, nor choleic acid, are present in the fæces, and are not present as such in the blood. A very important feature in the properties of bile is that of converting sugar into adipose matter. This was discovered by H. Meckel, by mixing bile with grape sugar. By aid of a gentle heat for some hours, he obtained nearly double the amount of fat contained in the bile, which, however, is but small. The circumstance of the bowels generally becoming costive in jaundiced persons is a proof that it acts as an aperient in exciting the peristaltic action of the intestines; but how this is accomplished, and in what resides this property, which is possessed in a like degree by no other substance, is unknown. Having traced the two principal classes of food through the changes they undergo in the intestines, we arrive, as it were, on the borders of another territory. The complicated operations that we have seen proceeding in the food have been carried on hitherto by chemical agencies; and we now find ourselves on the verge of the still more complicated vital operations, and in the next step we are perhaps in as much obscurity as in any part of physiology. Having arrived at the frontiers of the blood, we find affairs in the following position:—Without the barriers (the basement membrane of the intestinal tube) we have the aliments in a highly wrought condition by chemistry; and within, we have, on the one hand, chyle consisting of an oily and albuminous base, and highly molecular; and, on the other, the portal blood, having no increase of albumine, but loaded with granular matter and cytoblasts. There is a sort of chasm existing between the external and internal state of affairs. The introduction of albuminous aliment into the blood, and that part of non-azotic food which is arrived at the state of lactic acid, is less difficult to comprehend than the origin of the oily base of the chyle,—for the reason that we observe the stream of chyle coursing along the thoracic duct holding the same proportions of its albuminous and oily base, although no oil or fat may be taken in the food. We are therefore constrained to infer that the oily base is produced generally from the non-azotic class of food, and not exclusively from fatty matters. On that subject the following hypothesis is suggested by the author :—It has been shown that a considerable portion of the elements of non-azotic food, before they can be fitted for the purpose for which they are introduced into the blood—their combustion with oxygen—must make two full circuits of the intestinal tube; first, on their ingestion, and, secondly, in the bile. On the second round they are elaborated, by means of the liver, into a more highly organised substance than that of their original state, choleic acid; and then in the various products of this substance they descend the scale of organization. Choleic acid can, by a chemical action, convert sugar to fat, but in a ratio much too small to account for the origin of the fatty matters of the chyle. In the absence of a better theory, it is suggested that the chyle is formed from choleate of albumine; the albumine furnishing the albuminous, and *the choleic acid the principal part of the oily base.* It is well known that fat is a lower-organised substance than any of the non-azotic class of food, and we have already seen that the elements of this class of food, when elaborated to choleic acid by the liver, are in a state of peculiar proneness to run down the scale of organization,—a proof of which we have in the numerous products which arise from its decomposition. When it is said that the principal part of the oily base of the chyle is derived from choleic acid, it must be recollected that the oily matters that are taken as food are admitted in that state into chyle, which is evident from the emulsive state of the blood when fat has formed a large ingredient in the food.

In answer to this theory, it may be said that it cannot be supported by experiment, and that there is an accepted principle in physiology, that if the pancreatic juice gains no admission to the intestines, fats and oils pass the intestines undissolved, and there is, moreover, in that case, no emulsive or oily base in the chyle. It is true that without the pancreatic juice fats are undigested, but it is not proved that the chyle does not contain an oily portion; such chyme has not been analysed, and the opinion rests on the fact of its having lost its emulsive appearance, which may be well accounted for by the withdrawal of that amount of fat which would have entered it by villous absorption, if the pancreatic juice had been present in the chyme. The proposed hypothesis rests on a strong probability, such as is not usually rejected when facts cannot be obtained to elucidate obscure subjects. We know that, though the formation of fat may be effected by a chemical process out of the body, from the non-azotic elements of food, such a process is so difficult as to be almost beyond the reach of the chemist: seeing, then, that the azotic class of food is brought to the state we see it in the chyle, by chemical agency, and bearing in mind the difficulties that intercept the conversion of starch, &c. to fat, it is but probable that it may become needful for the elements of non-azotic food to assume a form more easily convertible to the fatty substance, and that that form should be the bile, which, of all organic fluids, is most prone to assume new combinations.

Defecation, and Phenomena of Digestion in Large Intestines.— Although the fæces contain little else of the bile than the fatty and colouring matters, it is evident that the odour which is proper to them is derived from the bile. Such a conclusion rests on the fact, that when, from icterus or other cause, the bile does not reach the intestines, the peculiar odour is absent, and the odour then persistent is totally different, although more intensely offensive. The peculiar odour is not perceptible until the excrement has reached the large intestines. We are aware that most offensive odours are products of organic substances in their descent towards the inorganic state; and we may there-

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Bile.

Six objects the liver effects: to be brief,
To liberate carbon we'll say is the chief;
By the bile it excites peristalsis we'd urge,
Which acts in the chyme like a natural purge;
Its choleine, while staging each change of decay,
Is in chyme antiseptic the whole of the way;
The fourth, by a chemical action, is that
It effects the conversion of sugar to fat;
By the fifth all its parts undergo a renewal,
Again to return to the tissues for fuel;
And lastly, the oily base of the chyle,
According to Cottle, comes out of the bile.

fore look upon the one in question as proceeding from some organic matter in the bile, which is not contained, as such, in the bile, but is a new creation—some more simple organic adjustment of the elements of bile while on the verge of becoming inorganic, and which, in the analysis of the fæces, is contained in those substances denominated "extracts." Liebig has succeeded in producing a nearly similar odour by the action of powerful chemical reagents on albuminous matter. By this we infer, that although the organic matter on which the odour depends may be produced from animal substances by chemical agents, yet there are no such chemical agents in the other secretions of the intestinal tube, otherwise the odour would characterise the fæces when no bile is present in the intestines, which is not the case. It is probable that the action of the substance in question is rather to modify than to give odour to the fæces, for we have seen that a more powerful odour is present without the addition of bile. The usual odour is present in evacuations from the bowels, although no food has been taken for many days; such evacuations must, therefore, consist of the excretions poured into the intestines. These are generally abnormal in such cases, and contain the serum of the blood, together with the carbonaceous waste of the tissues, which, at such times, is generally abundant. But it should not be supposed that the matters are poured out from the blood in the fœtid state referred to; the fœtor is the result of the decay of the organic matters contained in the excretions spoken of, which is promoted by the chemical agents and ferments that they are exposed to in the intestinal tube.

It has been already shown that the contents of the small intestines are alkaline. After having passed the valve of the cœcum, they immediately assume an opposite state, becoming acid. It has been considered by Blondlot that this change arose from the action of the lactic acid fermentation on non-azotic food, or rather on the sugary portion of it; and a much larger amount of acid is found in the cœca of animals fed on starch and leguminous vegetables. This also finds confirmation in the fact that animals that feed on bulky vegetable food, especially the rhinoceros, have the cœcum much developed, and resembles the stomach in configuration. But it is more probable that the secretions are themselves acid at the commencement of the colon, for Tiedemann and Gmelin have shown, in their researches on digestion, to which we have often referred, that the contents of the cœcum are found acid in animals that live on food that cannot furnish lactic acid, and this in the same animals fasting. The acidity is by no means inconsiderable, for we have the testimony of M. Mayer, that, after disappearing in the small intestines, it was present in the cœcum with an intensity equal to that of gastric juice. Fohmann says that an acid juice may be expressed from the follicles of the large intestines. Eberle has also expressed himself in like manner. It is therefore more probable that the glands of the cœcum and the neighbouring part of the colon (like the stomach) produce an acid secretion, but that the acid is comparatively much less than the lactic acid liberated by its own ferment from saccharine matter in the large intestine. The formation of lactic acid, and its assimilation or introduction into the blood, is the completion of the last stage of the digestive process. The first part of the process is carried on in the stomach on azotic food, which is there brought to a unique albuminous compound, fitly prepared for introduction into the blood. Having passed the stomach, that it may resist the common decay of animal matter until it has been duly presented for absorption, it is converted into a choleate of albumine by the action of bile. In the small intestines the assimilation to the blood of this albuminous compound takes place, and also it is here that the fermentations are carried on that are proper to non-azotic food, including the especial ferment of adipose matter contained in the secretion from the pancreas and the glands of Brunner. Non-azotic food doubtless for the most part finds an entrance into the blood in the small intestines, but in the large intestines the digestion of this class of food, as compared with the albuminous, has the ascendancy; and it is here principally that sugar, having undergone its previous conversion from starch, assumes the form of lactic acid,—a form more agreeable to the assimilating and absorbing powers of the intestinal walls, and more nearly approaching the type of the blood—a fitness for combustion.

The alkaline state of the contents of the jejunum and ileum we have seen to be favourable for the solution of choleate of albumine in that part of the intestines where the lacteals that act upon it are most abundant. The acid state of secretion of the cœcum is involved in some mystery; it is here, probably, that undissolved albuminous matters are subjected again to the solvent power of pepsine, and an acid, without again becoming alkaline; the large intestines being, as it were, as far as non-azotic food is concerned, a receptacle for materials duly prepared for the lactic acid fermentation. It should be observed, that the fermentation theory, and that also of Professor Plattner, of choleic acid, are not settled on experimental fact. An attempt has been made to lay the whole subject of digestion in one view before the reader, and in doing so it may happen that the obscure and unintelligible parts of the picture may be found to be brought out with colours not in accordance with the original design of the Great Painter; or, in other words, theories may have been advanced which may not be found true to nature: if, however, important parts of a picture are become invisible, the blank and defective portions of the canvas must by all means be filled in, or the scope and intention of the whole will not be entertained: and in supplying those defects the artist cannot go beyond the discoveries of his age.

The alimentary and fæcal materials, as they make the transit of the large intestines, become darker; the watery portion, together with the nutritious matter, being gradually removed in their progress. The rectum is found to contain little else than indigestible matters consisting of the offal of the food, such as colouring matters, woody fibre of vegetables, and insoluble portions of animal food; a considerable portion of the mucus which abounds in the tube, the colouring and fatty matters of the bile, and the insoluble salts, among which there is a very large proportion of the phosphates of lime and magnesia. The average quantity of solid fæcal matter voided in the twenty-four hours, including the watery part, is, according to Liebig's analysis of the fæces of soldiers, 5½ oz. The following is the result of the experiments of Berzelius on the excrements of a healthy man, whose diet was bread and meat. The phosphates of lime and magnesia, and the silica, are the insoluble inorganic salts of the food.

Water		75·3
Bile	0·9	5·7
Albumine	0·9	
Extracts	2·7	
Salts	1·2	
Insoluble residue of food		7·0
Insoluble matters derived from the intestinal canal—mucus, bile, resin, fat, and particular animal matter		12·0
		100·0

The ashes of the human fæces have been analysed by Enderlin, and the proportions obtained appear below :—

Chloride of sodium and alkaline sulphates	1·367	soluble in water.
Bibasic phosphate of soda	2·633	
Phosphates of lime and magnesia	80·372	insoluble in water.
Phosphate of iron	2·090	
Sulphate of lime	4·530	
Silica	7·940	
Loss	1·068	
	100·000	

According to the foregoing observations, the usual colour of the fæces is not an indication (as is frequently supposed) of the presence of a quantity of bile, but merely that a due portion of bile has entered the duodenum, there being in reality no bile in the fæces. Medicines that stimulate the liver, and, at the same time, promote the peristaltic action of the tube, cause the presence of bile in the fæces. Dr. Golding Bird has analysed the green spinach-like matter that often constitutes the stools of children after the liver has been much stimulated by calomel: he reports that such matter contains no bile, but is the colouring matter of the blood having transuded the capillaries (the canals in the interior of the lobules) of the vena porta in the parenchyma of the liver, turned green by the alkaline secretions of the intestines. The minute anatomy of the liver, according to the researches of M. Guillot and other anatomists whom we have followed, would lead us to anticipate the conclusion of Dr. Golding Bird (see page 84).

The nature of the gas contained in the intestinal tube was accurately described by Van Helmont full a century and a half before the combinations of oxygen with carbon, and hydrogen with carbon, were known respectively to support and extinguish flame; and it is, perhaps, written in language more forcible than could be expressed in English. *Ructus sive flatus originalis in stomacho prout et flatus ilei extinguunt flammam candelæ; flatus autem storcoreus qui in ultimis formatur intestinis, atque per anum erumpit, transmissus per flammam candelæ, transvolando accenditur, ac flammam diversi coloris, iridis instar exprimit.*

The following analyses of the intestinal gas have been selected from those of M. Chevreul, and arranged in the following table for this work:

	Stomach.	Small intestines	Large intestines	2nd Case. Large intestines
Oxygen	11·00	—	—	—
Carbonic acid	14·00	24·39	43·50	70·00
Hydrogen	3·55	55·53	—	11·60
Nitrogen	71·45	20·08	51·03	18·40
Carburetted, with a trace of sulphuretted hydrogen	—	—	5·47	—
	100·00	100·00	100·00	100·00

It has been already said that the bulk of the matters enclosed in the intestinal tube is an exciting stimulus to the peristaltic movement. The bulk of gas there contained, as taking its part in the same beneficial operation, is also entitled to its share in our estimation. Persons, therefore, tardy in the peristaltic movement, should not be anxious to unload the rectum from solid matter or gas, either by their own efforts or by enemas, but should rather encourage the accumulation until, by its presence, it excites the desired movement through the whole length of the colon, and a more effectual evacuation of the bowels is obtained. The presence of gas in the intestines serves, by its mobility, to preserve an equal distension of the tube, and prevent spasm; and the materials, whether of gas or solid matter, give the stimulus by which both the peristaltic action of the tube, and the impression by which the diastaltic movements of the muscles concerned in defecation are produced.

Movements of intestinal tube.—The movements of the intestines are peristaltic, having a *vis insita*, or power of action independent of nervous systems; they have been called *vermicular*, because the movement resembles that observed in the creeping of caterpillars, extending in a wave-like motion from head to tail. Such movements are more difficult to excite by direct stimulus, and, being excited, alternate contractions and relaxations take place for some time in succession from the part stimulated. A movement of this sort being excited by the contents of the intestine, contraction of both layers of fibres commences, which forces onwards a portion of matter, and this being increased in bulk as it proceeds, a new stimulus is given, and the movement insured through the tube. The effect of the contraction of both sets of muscular fibres behind the mass to be projected onwards, is the narrowing of the calibre of the tube almost to obliteration, and is much the same in effect as drawing the intestine between the finger and thumb pressed together, or the same effect as that of stripping a leech from its blood. The intestine is apt to take a retrograde or anti-peristaltic movement, which is a normal action, and necessary for representation of the matters to the selecting surfaces of the intestinal walls. The effect of this is, when continued in the duodenum, to cause the passage of bile into the stomach. This case with the stomach happens mostly when diet of oily and vegetable food, containing little azote, calls for less of the pepsine principle of fermentation, and more of animal diastase ferment, for its solution, or less of gastric juice and more of the bile and pancreatic juice,—when, in fact, the contents of the duodenum are alkaline instead of acid. An effectual valve is placed at the commencement of the large intestines—the ileo-cœcal valve, formed by two elongated folds of intestine continued into the cœcum, which, besides being perfect in its mechanical fitness, has a continuation of the muscular coat of the intestine between the folds, giving it additional power. The valvulæ conniventes are continued from about the middle of the duodenum to about the middle of the ileum; folds of membrane extending more than half round the tube, which tend to divide and intermix the materials which are passing in either direction, and offering but little obstruction to either movement. In proof of the latter, the jejunum is generally found empty, and the lower part of the ileum full, which would not be the case if these partitions obstructed the passage. At the same time they do not act as valves; for the statement of Vieussens, and some other anatomists, that they are convex in their upper, and concave in their under surfaces, is found incorrect. The rumbling sometimes heard in the intestines is not caused by air and fluid passing these membranes, but by the same materials pressing themselves through the closures made in the approximation of the walls brought about by the peristaltic contraction. The contraction, as it is gradually transferred along the tube, carries before it the solid matters, but allows the fluids to be pressed through the temporary closure. The notion that the antiperistaltic movement of the tube is a normal and necessary action, though not found generally in books on physiology, was well known to Haller, who makes the following remark:—"Inde motus *antiperistalticus* intelligitur, quo fit, ut diutius actioni molliter terentis intestini et diluentis succi et resorbentium venarum massa ciborum exponatur." M. Bérard, Senior of the Faculty of Medicine of Paris, and otherwise a good authority, makes the following observation on the subject:—"Ainsi, pour la progression régulière et normale des parties, il y a des contractions dans deux directions differentes, mais avec prédominance de celles qui conduisent les matières de haut en basé." When one of these movements is present without the other, the result is either vomiting or a certain form of diarrhœa, as the case may be. The muscular and mucous coats of the large intestines are stronger in proportion to the greater force required for propelling the more bulky materials which they contain. The sphincter ani is not a continuation of the fibres of either of the muscular layers of the rectum, and, like most of the sphincters, it is placed under the control of the spinal cord.

Since Haller pronounced the movement of the intestinal tube to be a *vis insita*, or an independent inherent power, different doctrines have been held, but the truth of the maxim still is generally maintained. The intestines, after removal from the abdomen, and divided in portions, exhibit the movements by the stimulus of galvanism, provided the mesentery remains attached to the tube. It is, then, surprising that a large plexus, both of sympathetic and cerebro-spinal nerves, should be placed in front of the abdominal aorta, a great portion of which accompanies the mesenteric arteries to be distributed to the intestines. From this plexus (the solar) the stomach takes a proportionate share in the form of the gastric plexus. The movements of the stomach we have represented to be peristaltic, and, though influenced and guided by its pneumogastric branches, they are considered to be so far independent of such influence as not to come under the designation of diastaltic, excepting its cardiac sphincter. The same observations apply with equal truth to the remainder of the intestinal tube, though physiologists are by no means agreed that the nervous influence is of this indirect kind. M. Brachet has shown that the movements of the duodenum and jejunum are produced by irritating the pneumogastric nerves — the ileum and large intestines by the spinal nerves. M. Budge, Müller, Longet, Wutzer, and Valentin, furnish a large amount of experimental evidence which more or less bears out the following facts:—that the stomach may be made to contract by irritation applied to the vagi, the cervical nerves, and the thoracic ganglia of the sympathetic; the duodenum and jejunum by the phrenic, the splanchnic, and pneumogastric; the ileum and large intestines by the spinal and the ganglia of the sympathetic, which also affect the duodenum and jejunum. The movements of the intestinal tube are of a totally different character from those called diastaltic or reflex. It is with difficulty that they are produced, and the effects of stimuli upon them are by no means constant; while, on the other hand, ordinary reflex actions are characterised by their energy and ready respondence to the applied stimulus. All nerves, whether composed of one or both sorts of nerve-fibres, before entering organs, either pass through or communicate with the sympathetic ganglia. Some of the nerve-branches that supply the intestinal tube and other organs are composed wholly of the fine fibre; others are composed of both kinds of nerve-fibre.

Some of the fine kind originate in the sympathetic ganglia, and these no doubt exercise some direct influence upon organic life; others, again, of both kinds, are merely transmitted through the ganglia. Now, as the cerebro-spinal nerve, when present in organs, appears to be divested of common sensation, and to be especially changed in the motor phenomena that elsewhere distinguish it, it is held that whatever change is wrought in the action of nerve-fibres in the organs is effected by the sympathetic ganglia. Not only do the sensory fibres become insensible, and the motor fibres changed and moulded in their action to those peculiar to muscles of organic life, but they moreover undergo some obscure adaptation and fitness for guiding and supporting the functions of secretion and nutrition: if, indeed, this is not fulfilled by the fine fibres which are seen to arise from the grey vesicles in the ganglia. It is probably through some change produced, some modified action of the gastric branches of the pneumogastric nerves, that terror and distress of mind suspend the action of gastric juice, and annihilate the appetite for food. The same emotions, by means of the phrenic nerve through the same ganglia, are known to check the secretion of bile, and produce clay-coloured evacuations from the bowels. The same emotions, acting through the spinal nerves and sympathetic, may excite the peristaltic movement of the intestines, and produce a sudden movement of the bowels as the effect of fear.

NUTRITION.

The vital properties of animals do not admit of a physical explanation, or come within any recognised law of chemistry or mechanics. Among these are development, growth, nutrition, secretion, muscular irritability, nervous polar force, animal heat, &c. It has been already said that there exist in animal bodies two physical forces that tend to resolve the elements of animal life from the organic to the inorganic state; one being the natural use and action of nerve and muscle, which, by the aid of oxygen, effects a chemical arrangement of the elements of the tissues in question; and the other the fermentation and decay—the common lot of animal matter, whether alive or dead. There is a law appertaining to animal life which does not bear a physical explanation, which greatly aids and abets the two physical forces just spoken of, in reducing animal matter to its chemical finality—a law that every particle of the body has but a limited duration independently of other laws in operation regarding the general dissolution of the whole. Dr. Carpenter first promulgated this fact. It is best exemplified in tissues that are formed from cells, or that contain nuclei in their structure, of which are epithelial or epidermic cells, and those continually passing off in glandular secretions. The nuclei to be seen on the sheath of muscular fibre in nerve-tubes, the cells of cartilage and corpuscles of bone, bear evidence that the law of transformation is written upon them; for when, from any cause, nutrition becomes tardy and inactive in these tissues, such as from inaction, the nuclei become indistinct, as is commonly seen in paralysed muscles. The history of hair, from development up to its death or falling off, is, perhaps, the best evidence of the truth of the proposition. But though every tissue is thus by degrees giving up the particles of which it is composed, the tissues themselves are not seen to diminish in size, in consequence of interstitial renewal that is continually going on. Such renewal must be rapid in the secreting glands, whether composed of cells or otherwise. For instance, the liver, which is not cellular, according to the latest view of its structure, is constantly giving up the molecules that compose the bodies that fill its lobules, and yet the lobules do not diminish in bulk in consequence of the renewal that is constantly taking place. The materials for the renewal of this and every other organ exist in the blood, the separation or elaboration of the materials is proper to the organs; and it is in accordance with the physiology of secreting organs, though not necessarily the case, that when such materials are in excess in the blood the organs become enlarged or hypertrophied, from an increased number of the particles or cells of which they are composed. This is the case when the liver becomes enlarged from a residence in tropical climates, when the elements of the non-azotic class of food are pent up in the blood, the hydrocarbon not being required to keep up the temperature of the body. The enlarged liver peculiar to intermittents arises from nearly a similar cause. The extraordinary action of muscles, provided the general nutrition is well preserved, whether of animal or organic life, attracts an increased capillary circulation to their structure, and produces a like increase of growth and enlargement of substance. A similar cause is in operation in hypertrophy of the heart, and the thickened coats of dilated arteries. Thickening of the dermis is the result of the same cause from pressure; and in all such cases there is a tendency, on the removal of the cause of the increase, to return to the normal dimensions. It may be stated to be a law in physiology, that the activity of interstitial change diminishes as the life of the individual advances. In children, therefore, it is active; and, as the rule applies equally to the solid structures, it accounts for the ready absorption and removal of the interior of bones, and the deposit of new materials on their exterior.

SECRETION.

By means of membranes and glands, three great purposes are effected in the animal fabric:—1st. The separation of excrementitious or rejected matters from the organism under the forms of organic and inorganic matters. The organic are—urea, uric acid, organic acids. The inorganic matters are—water, carbonic acid, ammonia, alkalies, earths, metals, and mineral or inorganic acids in various combinations; 2d. The elaboration of fluids, whose destination it is to fulfil some ulterior purpose in the animal economy, and which do not exist as such in the blood—such as bile, gastric juice, semen, or saliva, &c.; 3d. To modify the condition of the blood, or rather the materials that enter that fluid,—materials that have just undergone certain definite chemical changes in the digestive process; to act further upon these, and raise them into various organic shapes, and assimilate them to the types of the various structures into which they will be finally elaborated by nuclei, cell-growth, or other form of nutrition. The machinery for this process are the vascular glands, or glands without ducts, including the spleen. The glands which serve for the two first purposes—excretion and secretion (excepting those called temporary glands)—are supplied with ducts.

Vascular glands have other offices assigned to them, which will presently be considered. The structure essential to secreting membranes and glands is a basement membrane with capillary vessels on the under, and cells on the upper surface. Whatever may be the size of a gland, it consists of a multiplication of these three forms of structure, excepting the liver and lungs, which deviate from the rule, inasmuch as in their ultimate structure they are without epithelium cells, and the liver is not even membranous in the lobules that secrete the bile. The matters excreted, which have just been enumerated, generally exist in the blood; as urea, organic acids, and inorganic salts. In the interior of glands, the cells by which the external surface of basement membrane is overlaid are greatly multiplied: the membrane also undergoes the most complicated inversions in the form of blind sacs, or follicles and canals. The basement membrane, whether of mucous or serous surfaces, or of the skin, derives its support and firmness from an internal layer composed of areolar tissue—the *fibrous layer;* in this the capillaries are seated. The process of elaboration which is accomplished in the cells appears to confer on the basement membrane which they cover the property of admitting through its texture, from the blood, the various and peculiar products that the cells elaborate.

Serous membrane differs essentially from mucous membrane, but less anatomically than in its physiology. The fibrous layer on which the basement membrane is placed is neither so strong nor so abundant in capillaries as mucous membrane; neither is the fibrous layer penetrated with the inversions of the basement membrane, that constitute the mucous follicles, or crypt, known as glands of Lieberkühn, in the intestinal tube, and which, with few exceptions, abound throughout all the mucous membranes that secrete a viscid mucus on their surface. The cells that form the external layer of serous membrane are nucleated, the nuclei of which are furnished by the blood which is in contact with the basement membrane. These cells are deposited in a single layer, assume a flattened polygonal shape, and are fitted evenly together as a *tesselated* epithelium. The office they fulfil is to impart to the membrane a slippery shining surface, and, as they are cast off, probably to furnish to the serum its solid constituents. The parts covered with this membrane are the pleuræ, pericardium, peritoneum, tunica vaginalis testis, tunica arachnoidea, the anterior chamber of the eye, and the synovial membranes. The purpose served by the serum is to furnish that moisture to the membrane which is necessary to the movement of the surfaces upon each other without friction. The serous membranes being closed sacs, and protected from evaporation, the quantity of fluid secreted must be very insignificant. There is reason to suppose that the watery portion of the serum, if not the whole, enters the various cavities by the mechanical process of endosmose or transudation. The components of serum resemble the serum of the blood in a diluted state ; they are alkaline, and contain the salts and a little albumine and fibrine. There is no doubt that the serum is removed from these cavities, by absorption, in the same ratio as it is secreted ; and when this balance is not maintained, and secretion exceeds absorption, a dropsical deposit is the result. In dropsical effusions albumine is frequently found to be as much as 10, 20, or even 30 per cent. Synovia differs only from serum in containing a large quantity of albumine.

The *mucous membranes* may be said to line all cavities of the body that have external communications. They are constructed of the same three principal layers as serous membranes—that of cells, a basement, and fibrous or vascular coat : mucous membrane is thicker than the serous, but especially so where its functions are active, as in the intestinal tube. Except in the branching canals of glands, and in fine ducts generally, mucous membrane is studded with depressions which lead to follicles or small openings with closed extremities, into which the membrane is continued or inverted. It is probable that these furnish viscid mucus. Epithelia are of two forms—the tesselated, which has already been spoken of, and the cylinder. The tesselated, which in the serous membranes is a single layer, is here multiplied. The cylinder form has by far the most extensive range, covering the whole intestinal tube from the cardiac sphincter downwards, being continued into the mucous follicles and the large ducts leading from glands,—the nasal fossæ, pharynx, larynx, trachea, and bronchi, together with the genito-urinary apparatus. The tesselated is found in other situations, lining also the minute canals of glands, as well as the interior of blood-vessels: both kinds are nucleated, within which is seen a nucleolus. The cylinder kind are oblong tubes arranged side by side, produced by rapid growth from the basement membrane. It seems probable that the office of both kinds is to elaborate the secretion coming from the membrane, and that their function is suited to the particular products that are proper to each district of the membrane, whether it be the acid contents of the gastric tubuli, or the urea of the tubuli uriniferi, or even each particular mucus that appertains to each membrane. The cylinder epithelium of some of the parts described is mounted with vibratile cilia (see Cilia). The especial advantage of the cylinder over the tesselated is mechanical,—that of giving a greater protection, and holding and retaining between the villi a sufficient complement of mucus to secure the full and effectual lubrication of parts that have to be traversed by matters that are armed both chemically and physically with the power of irritation. It has been before observed that the class of glands which constitute the machinery of secretion are uniform in the principles that characterise their structure, which is a fibrous layer and a basement layer strewed with cells; its most complex form in the kidney is but a modification of its simplest form in the mucous follicle: the difference between the structure of the testis and kidney, and those which are termed conglomerate, such as the salivary, is that the latter are prolongations of cul-de-sac canals.

Mucus differs in its characters according to the membrane from which it is obtained. That from membranes that are furnished with follicles is thicker, more viscid, and may be described as a transparent gelatinous fluid without taste or smell: it mixes very imperfectly with water, and not at all when deprived of the little soda it contains. The water with which it is naturally in combination is held in union by means of soda: a separation (coagulation) is effected by acids. The true mucus from the bronchial membrane is less mucilaginous, more jelly-like, of a bluish cast of colour, and has a saltish taste. The insolubility of mucus is a quality very essential to the protection it affords the membranes. It holds its water in close chemical union, resists evaporation except by a slow process, and does not boil except at a temperature raised much above 212° F. If the surface of the body is smeared with mucus it intercepts the transmission of caloric, and enables persons to bear the temperature of an oven: by these latter qualities it probably protects the internal surface of the lungs and air-passages from evaporation, and enables the stomach to bear the temperature of fluids that would otherwise excoriate. Some of the cells of mucus are larger than those of the blood; these are probably from the follicles.

VASCULAR GLANDS.

The *vascular* glands without ducts are the spleen, the thyroid and thymus glands, and the supra-renal capsules. They are described as consisting, in their interior, of sacculi or lacunæ, which are composed principally of the *yellow fibrous element*, having an external investiture of the same material. By virtue of the latter element they are capable of much

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Mucus.

Suffice it if only of mucus we state
'Tis a compound of soda, an albuminate;
Transparent and viscid, in water 'twill fall
To the bottom, not mixing together at all
The salts of the blood, epithelium in sight,
And that mucus-corpuscles are larger than white.

Pus.

Pus is albuminous matter, d'ye see,
Arrived at first station *en route* chemistry :
First station's low life, its corpuscle you'll note
Is misshapen in figure, and ragged in coat;
In high life begotten, from white cell; but fate
Cast a slur on its birth, 'tis illegitimate.

distension, and adapted to receive an uncertain influx of blood, which is conveyed to them in vessels much larger than would be needed for their mere nutrition. It is supposed that these glands, like true lymphatic glands, act upon the blood by altering and reconstituting certain of its materials, and bringing them to a state of existence that is suitable and in keeping with the complicated functions that it has to fulfil; and that this change is one in which the elemental atoms enter into forms of combination in which the compound atom of the new product is more bulky, and is made up of a larger number of elemental atoms, than the materials from which it is eliminated.

This process of elaboration is accomplished in the sacculi, which are about half a line in diameter. We find their walls surrounded by a plexus of capillary vessels, and their interior filled with cells, nucleated blastema, and granular matter. Dr. Ecker has minutely investigated this subject, and as he has been unable to discover lymphatics in these glands, except in the spleen, he concludes that the elaborated contents of the sacculi must pass directly into the veins by exosmosis. The contents of the sacculi are first produced by growth on the surface of the basement membrane that lines the sac, being furnished by the blood circulating on its capillary surface. In what state the elaborated fluid is afterwards absorbed by the veins, we are at present ignorant; but it would not be inconsistent with the physiology of structureless membranes to suppose that granular matter and nuclei, and even cells, may penetrate them by absorption. The vascular glands exert their greatest activity in the earliest periods of life; they are all larger in the embryonic and fœtal states, shrinking their dimensions as age advances. The function of the thymus appears to cease after the first year of extra-uterine life; for from this period it not only ceases to grow, but the usual contents of the sacculi become degenerated into fat-globules. The supra-renal capsules are considered to be a diverticulum for blood in some way appertaining to the kidneys; the thymus for the lungs, and the thyroid for the brain. Their secreted matters furnish no evidence that they have any especial connection with the functions of these organs; the secretion being a proteine compound, and not therefore furnishing the fatty materials, of which full half cerebral matter is composed, neither the hydro-carbon which is separated by the lungs, nor any material having an orgånic likeness to urea.

The spleen.—The texture of the spleen, like the others of its class, is chiefly composed of the *white* and *yellow* fibrous elements, which, after constituting the strong fibrous covering of the organ, branches in a net-work throughout the whole area of its interior. By this means the spleen is partitioned into cavities of irregular shape, communicating with each other, and measuring from half to two-thirds of a line in diameter. These cavities, which were formerly known as the succuli or lacunæ of the spleen, were, till lately, supposed to have a direct communication with the splenic vein, and to be lined by epithelial membrane; neither of which is found to be the case. The vessels of the spleen are contained in its tissue. The *white* fibrous element in this tissue is not indiscriminately mixed with the *yellow.* It exhibits its usual characteristic arrangement, as seen in areolar tissue, of waving bands of parallel fibrillæ; while the yellow for the most part is observed between the layers of the white, and is distinguished by the irregular net-work into which the fibrillæ are thrown. Professor Kölliker has discovered microscopic muscular fibrillæ in the tissue of the spleen of the pig, dog, ass, and cat; they are of the unstriped kind, having a long nucleus. In this report he is supported by Professor Ecker, of Basle, and was long ago anticipated by Malpighi, and some of the older anatomists, who have spoken of muscular fibres in the spleens of certain animals; in man, however, they have not been detected. The *liquor lienis*, or spleen-pulp, is contained in the cavities just described; it is a sero-sanguineous fluid, which is easily washed from the cut surface of the organ. It consists of nucleated spherical cells, free nuclei, granular matter, and plasma; these are its colourless ingredients, and, in whatever way it is obtained, it is mixed with the red corpuscle, and in proportion as either of these two sets of ingredients (the white and the red) more or less abound, it is in the same ratio either serous or sanguineous. The white cells are of all sizes, from the chyle-corpuscle downwards. An extensive comparative investigation of the spleen-pulp has led Professor Kölliker to the conclusion that the condition of its ingredients varies almost from hour to hour; sometimes the larger cells, sometimes the smaller, and sometimes the nuclei only, are seen, while at others no cells are observable. He considers that a rapid process of cell-growth progresses in the spleen, by which the lymph-cells are formed around nuclei, and the matured ones disappear. The variable states of the pulp are regulated by the ingesta, which is the fundamental pabulum for such growth. The manner in which the destruction of the red corpuscle in the spleen aids in this cell-production, we shall presently consider. Contained in the spleen-pulp are the Malpighian corpuscles, which are spherical bodies of about one-third of a line in diameter, the number of which may be estimated by the fact that on the average the space intervening between the corpuscles is rather more than a line. They contain the several *colourless* ingredients of the spleen-pulp. They are closed sacs, with walls composed of the two elements of fibrous tissue, with no epithelial lining. They are therefore of the nature of Peyer's glands of the intestinal tube, and, like them, are probably transitory in their functions—that, having matured their contents, they burst and disappear. It is probable that the cell-growth of the spleen-pulp in a great degree takes place in these bodies: for it is agreed by Müller, Kölliker, Saunders, and other authorities, that the contents of each are the same. These bodies resemble in their anatomy the lobules of the liver, inasmuch as the walls of each are destitute of a limitary membrane. They resemble the air-cells of the lungs in the fact that in each the cavities are without an epithelial lining,—subjects full of signification to the pathologist. Each Malpighian body has a fine branch of an artery in contact with it, which spreads over its surface. The large blood-vessels, as they enter the hilus of the spleen, both vein and artery, take an extra coat from its fibrous tissue, which they retain to their finest divisions; they are held in situ by adhesions to, or by being seated in, the partitions or walls of the lacunæ. It is in this way that the capillaries may be said to be incased in the fibrous tissue, and in the same capillaries are described as intersecting the spleen-pulp, and spreading themselves in it: they do not, however, enter the Malpighian bodies. The same observations apply to the lymphatics. The sheath thus derived by the arteries is about three times thicker than that of the veins; added to this, the size of the trunk of the splenic vein is four times larger than that of the artery. The terminal branches of the vein are computed to exceed the arteries as 20 to 1. The splenic vein has, moreover, no valves. The foregoing statements are introduced as affording some explanation of the fact of the exceeding delicacy of the capillaries of the spleen, and the frequency, and almost the constancy, with which extravasation of blood into the spleen-pulp takes place. The changes which occur in the red blood-corpuscle, whereby a great revolution amongst the constituents of the blood is effected, was not overlooked by Malpighi, who, in 1666, wrote " de quibusdam corporibus per lienem dispersis :" he describes them as vesicles or glandules abounding in splenic blood, forming and disposing themselves into groups of 7 or 8; plainly to be seen in the ox and sheep, but not generally to be distinguished in man, in whom the spleen may be said to be almost invariably in an abnormal state after death, and for which reason the Malpighian bodies are seldom found in the human subject. If the microscope of the last-mentioned illustrious anatomist had been equal to those of our own day, it would not have been reserved for writers of our time to have explained the physiology of these metamorphoses. The accounts given by both Dr. Ecker and Dr. Kölliker are, that the red corpuscles of the splenic pulp become smaller, corrugated, and of a deeper colour, and collect together in groups of from 1 to 10, surrounded by a capsule or cell. The red corpuscles become darker, till nothing but dark pigmentary matter remains. The external capsule is of a very evanescent character, for it disappears on contact with water. Many of the red corpuscles contain only a pale yellow granular mass, and some appear as transparent as the chyle-corpuscle. The spleens examined were those of dogs, sheep, rabbits, calves, tritons, and frogs; and the hypothesis deduced from the investigation is, that the red corpuscles of the blood undergo in the spleen *disintegra-*

tion, either before or after they become inclosed in these capsules, in which the hæmatine first concentrates and then disappears. With all the research that has been brought to bear upon the functions of the spleen, we are constrained to say with Haller, "hic in conjecturas demergimur;" we have obtained certain important facts relating to splenic blood, but they can scarcely be regarded at present as sufficiently established to build theories upon. Blood is wont to lose, in its passage through the systemic capillaries (by which it passes from the arterial to the venous state), 28 parts in 1000 of solid matters. A signal exception to this rule is furnished by the blood traversing the capillaries of the intestinal tube (the portal blood), which shows a gain of 28 parts in the 1000. It appears that between the amounts of solid matters in blood, as it enters and as it quits the spleen, there is nearly an equal balance of these materials; such quantitative analyses having been made by M. J. Beclard, who has thus brought chemistry to the support of the microscope. The following table gives a comparative view of systemic, splenic, and portal bloods, in four trials on the blood of a dog, in which is perceived a striking diminution in the amount of red corpuscles in splenic blood, with a corresponding increase of albumine. In other analyses by M. J. Béclard, the balance between the two materials in question was more equal.

	External Jugular Vein.	Mammary Artery.	Splenic Vein.	Vena Portæ.
Water	778·9	750·6	746·7	702·3
Solid materials . .	220·11	248·14	252·13	297·7
Albumine . . .	79·4	89·5	124·4	70·6
Corpuscles and fibrine .	141·7	156·9	128·9	2 27·1

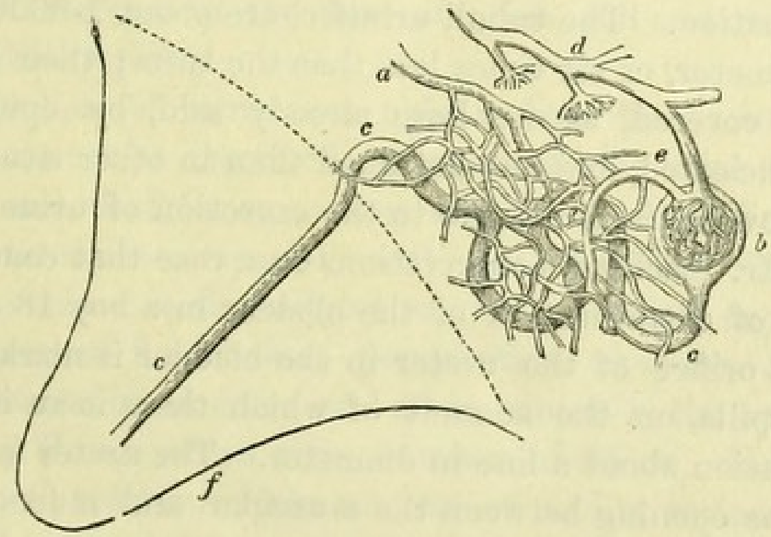
The mean augmentation of albumine in sixteen other trials was 13·02.

Although a notable change is effected in the red corpuscle, it must be observed that it is one of disintegration, and not of waste; it is a change wrought by vitality, and, according to the present limits of our knowledge, is not effected by chemical agency. It bears no likeness to fermentation and decay, for in it there is no loss of the original constituents of the blood. It appears from these computations that the mean amount of organised matter of the blood is not diminished in its passage through the spleen; for the corpuscles that disappear, albuminous matter in another shape makes its appearance. The lymphatics of the spleen, it is true, are not more numerous than those of other organs; but the lymph contained therein forms an exception in its colour to lymph in general, in being of a reddish colour, as seen in calves and sheep by Dr. Ecker. It is not, however, implied that there is any thing special in the quantity or the quality of spleen lymph. The red tinge is due to the red corpuscle, and its presence there is supposed by Kölliker to be due to the tendency that pervades the vessels of the spleen, to extravasation of blood in their normal as well as anormal conditions. But although nothing special is claimed for the spleen as a lymphatic gland, as inferred from the paucity of its lymphatics, it must be conceded that a revolution takes place in its substance in the serous as well as in the corpuscular materials of the blood: and it may be justly concluded, from the increase of albumine in splenic blood, that the spleen is, amongst the vascular glands, by far the most active agent in its work of replenishing, reorganising, or otherwise perfecting the *solids of the serum*. The express office of the spleen as a lymphatic gland, though contended for by authors from Hewson down to Tiedemann and Gmelin, is not held by Kölliker, for the reason that he can detect no more lymphatics in the spleen than the lungs or other organs. In answer to this it may be said that the essential constituents of lymph are the solids of the serum; and in refutation of this opinion of the Professor, we may cite his own assertion, that they pass directly into the blood, as well as indirectly by the lymphatic vessels. At page 796 of the Cyclopædia of Anatomy and Physiology, he observes that the white cells in the splenic pulp "elaborate the fluid, which, after a certain kind of assimilation, again part with it, *and through the blood and lymph vessels transmit it to the general circulation.*" It is, therefore, but fair to infer that the powers of the spleen in elaborating the constituents of lymph should not be measured by the number of its lymphatics; and seeing that a marked increase of the constituents of lymph is represented in splenic blood under the form of albumine, and that a corresponding increase of cell-formation is present in the spleen, and is recognised as that usually appertaining to the elaboration of lymph elsewhere, we cannot detract from the spleen its conspicuous character as a lymph gland, without depriving the cell-growth in the pulp, and the albumine of splenic blood, of their reasonable and apparent signification. Ecker considers that the disintegration of the corpuscles may take place in the separate state of the corpuscle, or, in other words, that their aggregation and the formation of a capsular envelope is not essential to the process; and at certain times, in some animals, nothing but detached bright yellow or dark-coloured corpuscles are observed, which constitutes a regular phase in the dissolution of the corpuscle.

Part of the hypothesis of Kölliker on this subject is that the hæmatine of the disintegrated blood-corpuscles becomes the colouring matter of the bile, by elaboration of the liver: such an opinion implies the decomposition of the hæmatine; for an essential part of the physiology of this body is that it is of a red colour; and we suppose that it cannot become yellow or green without a radical rearrangement of its atoms. The present doctrine that we hold respecting the source of the colouring matter of the blood—that it is elaborated in the *serum* of the blood, and separated by the liver, thus mixing with the bile—explains the matter without thus theorising on the reconstitution of atoms; moreover, too, the colouring matter of bile contains no nitrogen, while hæmatine has 10 per cent. of that constituent. If, then, the hæmatine, in the process of disintegration, is resolved into its proximate constituents, and does not reappear as the colouring matter of the bile, we need scarcely remind the reader that the kidneys, lungs, and skin, are the principal outlets for such excrements. The spleen is supposed to perform the part of a storehouse or diverticulum for portal blood: the elastic material of which it is composed, and its cavernous structure, gave this notion to Haller, who observed—*ligata portarum vena lien turget.* The large dimensions of the portal vein also favour the idea of this regurgitation of blood; and such a diverticulum seems to be called for by the fact that the secretion of bile is a slower process than venous absorption from the intestinal tube; the supply of the bulk of the blood to the portal system depending on the uncertainty of meal hours and the supply of food; whereas its passage through the liver is constant, though in greater activity during the process of digestion. The portal circulation is in its fullest state about five hours after a meal, and at this time the spleen is most distended: this is allowing three hours for the stomach to become empty, and two for venous absorption from the intestines. If, after this, no food is taken, it will be found that in twelve hours from the meal the spleen will have regained its smallest dimensions, at which period also the portal system will contain but little blood. The effect of the removal of the spleen from animals is that they become liable to die of apoplexy, and that the lymphatic glands generally become enlarged; from which we gather that the spleen acts as a reservoir for overplus materials of the blood, and also that it acts the part of an ordinary lymphatic gland, the absence of which, by producing an accumulation of unassimilated materials of blood in the circulation, causes the other glands to enlarge,—a principle of physiology which is also manifested by the enlargement of one kidney when the other is impaired or destroyed by disease. It has been ascertained from experiments on animals, undertaken by M. Bernard, in the presence of Magendie, that strychnine has, when administered internally, a remarkable effect in diminishing the size of, and of corrugating the surface of the spleen: Müller also admits that such is the case.

THE KIDNEYS, AND THEIR SECRETIONS.

The kidney is composed of two principal structures—an external vascular or cortical, and an internal tubular or medullary. The tubular portion consists of masses of the tubuli uriniferi arranged in the shape of cones or pyramids, with broad bases continuous with the cortical portion, and apices projecting into the infunbibula or centre cavities of the kidney, and numbering about a dozen. The tubuli, of which the cones principally consist, are straight, and being about the diameter of human hair, and paler than the cortical portion, may be easily distinguished with the naked eye. At the apex of each cone, which is called the papilla, the tubuli terminate by several openings. Around each papilla there is a circular investment of mucous membrane, by which means the papilla is seated in an open cup or *calyx*. The cortical portion is composed of tubuli and blood-vessels; both sets of vessels being much convoluted, and each having a particular arrangement. This portion of the kidney is redder, and, besides forming the external part, is continued between the cones, some of which it surrounds. On a close inspection of a section of this portion of the kidney, it will be seen to be covered with red circular spots about 1-100th of an inch in diameter. These are the Malpighian bodies or tufts, and are balls of capillary vessels, situated either at the extremity or attached to the termination of each tubulus, one or two belonging to each tubulus. Mr. Bowman, who first described the connection between the tufts and the tubuli, and also their functions, sup-



a, Renal vein; *b*, Tuft; *c c c*, Tubuli uriniferi; *d*, Artery supplying the tuft; *e*, Vein coming from tuft to form the portal plexus; *f*, Tubular cone.

posed that the capsule of the tufts was a dilatation or pouch at the end of each tubulus. It appears, however, from the researches of Gerlach, Kölliker, Valentin, and Toynbee, since undertaken, that this is not the case, and that the tufts are covered with a tunica propria, besides the external coat that forms the capsule; in the same manner as the heart has two serous coverings—its own, and that of the pericardium, and both formed from the reflections of one membrane. By imagining a membranous tube opening into the pericardium, we have a fit representation of the tuft with its two coverings, the heart representing the tuft. The tubule, the neck of the capsule, and part of the tuft adjoining, are covered with ciliary epithelium, and the remainder of the cavity is covered with fine tesselated epithelium. The capillary vessels of the tuft are supplied by a small artery, which, although appearing to penetrate the capsule, is as much external to it as the coronary arteries of the heart are external to the serous sac that covers the heart and pericardium. The capillaries composing the tuft terminate in a vein which is smaller than the artery, and recedes from the capsule by the side of the artery, and again ramifies and spreads itself on the surface of the nearest tubulus uriniferus, and by this double ramification, first in the tufts and then on the tubuli, constitutes the *portal circulation of the kidney*. This was first pointed out by Bowman, and the fact is pregnant with interest and signification. The tubuli uriniferi are about 1-600th of an inch in diameter, or six times less than the tufts; their internal surface is covered, as we have already said, by epithelium, which is nucleated, and less flattened than in other situations.

The following facts relative to the excretion of urine are the result of Mr. Erichsen's observations on a case that came under his notice, of extravasation of the bladder in a boy 13 years of age. The orifice of the ureter in the bladder is marked by a conical papilla, on the summit of which there is an irregular oval depression about a line in diameter. The ureter is usually described as opening between the muscular and mucous coats of the bladder; but this does not seem to be the case, for the muscular fibres appear to surround the opening, and give to it a sphincter-like action. A few drops of urine accumulate in the ureter, and, by distension, cause the orifice to open, which is afterwards seen to close: during fasting the ureters opened about three times in a minute, on the average discharging three large drops in a minute. The sphincter action is by no means strong, for a deep inspiration, coughing, &c., produced a jet of fluid from the ureter. Mr. Erichsen ascertained that prussiate of potash was absorbed and passed down the ureter in the space of one minute from the time it entered the stomach. Five minutes after taking ʒij. of bicarbonate of soda with lemon-juice, the urine increased in quantity to 9 drops in a minute, and in 28 minutes it became perfectly alkaline, being previously in its usual acid state. In seventeen hours after the dose, the urine, on examination, continued alkaline, and so strong was the diuretic effect of the medicine that the urine passed at the rate of from 16 to 18 drops in a minute. The urine continued alkaline until the 4th day, and did not regain its normal acidity until the 6th day after taking the citrate of potash. On the legs being immersed in a strong solution of acetate of potash, the urine changed from its acid to an alkaline state in an hour, with an increase of quantity of 3 drops in a minute. Several other salts were tried in the same way without effect. Digestion had the effect of diminishing the flow for about twenty minutes after a meal, and then to increase the quantity, which continued until the process had ceased. Active exercise produced a considerable increase in the flow of urine, and rest was attended with a diminution.

The colour of urine is a light amber; the odour, like most odours, cannot be described. Frequently the urine is clear and limpid, and as often, on cooling, deposits cloudy sediments, both which states are compatible with good health. The quantity of urine voided is also subject to great variation, depending on the amount of fluid taken, perspiration, exercise, &c.: 30 oz. in 24 hours in summer, and 40 in winter, is the amount computed by Prout, which gives a mean of 35 oz. Human urine has an acid reaction. The amount of acidity varies during the day, and is also in a measure regulated by the diet, whether it is of vegetable or animal food; but a vegetable diet has the effect of rendering the urine alkaline, as might be looked for from the alkalescent state of the urine of the herbivora. Some important facts relative to the acidity of the urine have been obtained by Dr. Bence Jones. This gentleman has ascertained that the acidity of the urine is regulated by the secretion of the gastric juice. If no food is taken, and consequently no gastric juice formed, the urine has an acid reaction, and varies little from that state; but, as soon as the juice appears in the stomach, the urine begins to decrease in acidity, and continues so to diminish until the juice ceases to flow, when it is neutral, and sometimes slightly alkaline: it then gradually recovers its acidity, and acquires its full complement of acid when the stomach is empty, and hunger gives the summons for another repast. The effects of animal and vegetable food are remarkable: animal food lessens, and vegetable food increases, the periodical acidity. This Dr. B. Jones attributes to the fact "that the urine may from these substances (vegetables) receive many acids, which, when animal food alone is taken, may be altogether absent." But there is perhaps a better explanation, which appears to have escaped his attention—the fact that vegetable food requires less gastric juice for its solution than animal food, and that the non-azotic proximate principles of food are not solved at all by gastric juice. If this oscillation of acidity in the urine is to be explained on the principle that, as soon as the fascicular glands of the stomach begin to secrete this acid, they decompose a salt of the blood (say the chloride of sodium), and thereby set free its base to circulate in the blood, seize the free acids, and neutralise the acid salts previously there, we may understand how it is that the urine loses its acids so soon as this drain begins upon the blood; and also that, if food is taken that requires a less amount of gastric juice for its solution, there will, for obvious reasons, be in that proportion so much more acid pent up in the blood during digestion, and so much more acid disengaged to go as offal to the urine. Dr. Wright's observations on the saliva remarkably confirm this view of the condition of the blood when digestion is proceeding. Dr. Wright observes that the alkaline state of the saliva is most obvious when digestion is in progress, and that its alkalinity increases and keeps pace with the secretion of gastric juice. The author has observed that the free acids in perspiration bear a direct ratio to the acids of urine (see Skin). Prout averages the specific gravity of urine at 1020,—"that is," says Dr. Bence Jones, "a bottle which, when filled with distilled water at a temperature of 60° F., weighs 1000 grs., when filled with urine at the same temperature will weigh 1020 grs." Dr. Bence Jones places morning urine, or that secreted during sleep, at 1019; three hours after breakfast, 1016; and that after active exercise at 1024, at which period there is also the smallest quantity secreted. The diminution of water is explained by the increase of perspiration during exercise, and the solid matters by the increased disintegration of animal tissues.

The following analysis of healthy urine by Simon is selected because nearly agreeing with Becquerel's and Day's:—

Water	963·00
Solid constituents	36·20
Urea	12·46
Uric acid	0·52
Alcohol, extract, and lactic acid	5·10
Spirit extract	2·60
Water, extract, and mucus	1·00
Lactate of ammonia	1·03
Chloride of ammonium	0·41
Chloride of sodium	5·20
Sulphate of potash	3·00
Phosphate of soda	2·41
Earthy phosphates	0·58
Silica	a trace

Urea is the ingredient which claims the greatest attention amongst the solids of the urine, for the reason that it holds nearly all the nitrogen of the urine, and amounts in the above analysis to more than a third, and in most others to nearly a half, of the whole solid matters of the urine. Urea may be obtained by evaporating fresh urine by a gentle heat to the consistence of syrup, and then adding its own volume of nitric acid, which becomes a thick crystalline mass—nitrate of urea; the urea taking the part of a base, but not neutralising the acid. On the addition of the nitric acid, gas is disengaged by the decomposition of colouring matter, and crystals of the nitrate are formed. The crystals, dissolved in water, are then decolourized by animal charcoal, evaporated, and redissolved in alcohol, which yields pure urea by evaporation. The crystals are colourless, transparent, four-sided prisms, not having the odour of urine, and are very soluble in water and alcohol. It is not deliquescent when pure, fuses at 248°, and is decomposed a little above this temperature. Both urea and uric acid exist in the blood. The formation of uric acid in the blood is best prevented by diminishing albuminous aliments, and using up these matters, already too abundant by promoting the waste of the tissues, by exercise, and the renewal of structure consequent thereon. The atomic constitution of urea is $C^2 H^4 O^2 N^2$, and may be regarded, by the following analysis, to be a hydrated cyanate of ammonia, with an equivalent number of 60.

1 eq. cyanic acid = 1 eq. cyanogen, and 1 eq. oxygen	C^2	N	O	
1 eq. ammonia = ...		N		H^3
1 eq. water = ...			O	H
Uric acid	C^2	N^2	O^2	H^4

Urea is an organic salt, and, owing to the large amount of nitrogen it contains, is readily decomposed by heat and moisture, when it becomes carbonate of ammonia. Its nitrogen and hydrogen form ammonia, and its carbon and oxygen form carbonic acid. The presence of an excess of urea in the blood —which is the case in certain diseased states—is attended with deleterious effects. The amount of urea secreted depends more on the waste of the tissues, which include both kinds of oxidation of tissue, than on any other circumstances. It has been computed that about 400 grains is the mean amount of urea excreted by men in twenty-four hours, 300 by women, 200 by children of eight years of age, and 100 by men of ninety years of age. It has been ascertained that active exercise increases the secretion of urea one-third; but, although this is the case, there is no doubt that its proximate source is the elements of azotic food that are surplus in the blood, or which are liberated when lower organic compounds are formed from the higher forms existing in the blood,—as when the gelatinous are formed from albuminous compounds. Exercise promotes the discharge, while the supply of azotic food is the greatest source of urea. The observation also applies to uric acid.

Uric or lithic acid is deposited from urine, in combination with ammonia, in the form of a reddish-brown rough powder like cayenne pepper. In a pure state it appears in fine shining white silky rhombic crystals, tasteless and inodorous, insoluble in alcohol, almost insoluble in water, but soluble in urine. Uric acid is an organic substance of the following formula:—$C^{10} H^4 O^6 N^4$. It forms a normal constituent of the urine of man; and in birds and serpents it exceeds the urea. Human urine contains ½ a grain to 1000 on the average; and, admitting it to be in this proportion, it would be discharged, in average health, after the rate of about 8 grains in twenty-four hours. It exists in urine in combination with ammonia, and, according to some chemists, with soda. The urate of ammonia thus formed is held in solution in the urine, according to Dr. Bence Jones, by means of the chloride of sodium, and other salts of the urine, water having no power to dissolve it unless diluted in a much greater proportion. It is, however, perfectly dissolved in urine, and not precipitated from it on cooling. It is, moreover, very readily precipitable under one principal and common condition of the urine, which is an increase of its normal acidity,—that is, it is stationary in solution in urine normally acid, but deposited if that acid is in excess, the result of which is a cloudy precipitate on cooling. These are the conclusions of Dr. Bence Jones, who observes "that a slight excess or increase in the acidity of urine will cause the precipitation of urate of ammonia;" and, on the contrary, "if the urine tends to alkalescence, an excess of urate of ammonia may be dissolved." This accomplished physician also concludes that the normal amount of uric acid is not much influenced by the diet, whether it be animal or vegetable. It is no doubt a product from the same source as urea, and its origin admits of the same explanation. The formation, also, of uric acid crystals in urine is the consequence of acidity, and is an indication that the amount of acid has exceeded that point which governs the precipitation of the urates of ammonia: the free acid of the urine has, in fact, combined with the ammonia and liberated the uric acid. The changes that take place in salts of uric acid are very tardy and gradual in their chemical movements, requiring forty-eight hours in some instances before the change is fully accomplished. In consequence of urea being, as supposed by Liebig, a product of the oxidation of uric acid, and which its formula confirms, the introduction of oxygen by air and exercise has been considered the best means for cleansing the blood from an excess of that material. But it is not the merely bringing oxygen and uric acid together in practice that will effect the union, which appears so palpably easy in theory; or else how is it that the uric acid of birds does not become urea by the free exposure to oxygen which their circulation provides? Air and exercise have, however, been found beneficial, although not in accordance with the theory of Liebig, but most probably by the removal of acetic, and especially lactic acid, from the blood, which exist there in combination with alkaline and earthy bases. These acids are directly removed by the skin, by glandular elaboration, and indirectly by the lungs, in a much larger proportion. This observation may be doubtful as regards the acetic passing off by the lungs, so far as non-azotic food does not necessarily become acetic acid; but it does so occasionally in the intestinal tube; and therefore this acid, by whatever means introduced, together with all other organic acids taken as food, is decomposed by combustion with oxygen in the blood, and finds its exit for the most part by the lungs, in the form of water and carbonic acid. The therapeutics of Dr. Bence Jones for the uric acid precipitate are strictly in accordance with this theory, although, in a praiseworthy aversion to theories, he does not explain how the removal of carbonic acid by the skin and lungs can operate so beneficially to prevent undue acidity of urine, and check the precipitation of uric acid. His treatment, like that of most other writers, consists in the administration of alkalies, "the removal of acids by the skin, and carbonic by free respiration and exercise," the avoidance of vegetable acids, sugar, and starch, in food. Now, since it is admitted by leading physiologists of the present day that lactic acid is an ultimate phase in the digestion of non-azotic food, and also that much the larger portion of this acid becomes carbonic before it leaves the blood, we can understand why it is that this treatment so aptly strikes the nail on the head,—first, by dietary restrictions stopping the supplies of lactic acid; and then, by air and exercise, introducing an excess of oxygen into the blood to decompose or burn up the lactic acid, converting it into the carbonic, which is described as freely passing off by the lungs and the skin. Pathology and therapeutics are useful in the illustration of the subjects of physiology, and they have been referred to here for the purpose of explaining the obscure subject of uric acid. The treatment for uric acid deposits, founded on the physiology of that substance, would call rather for great moderation in diet than the avoidance of one particular class of food. The uric acid originates in azotic food, and the acid which is supplied in the greatest abundance, and which causes that excess of acidity that precipitates the uric acid, comes from non-azotic food—the lactic: one class of food tends to the formation of uric acid, and the other to its precipitation. Both classes of food are essential to life, and therefore should not be avoided, and, if used in moderation, neither uric acid nor its depositing acid will be formed in the abnormal excess that creates the evil. The elements of lactic acid—starch or sugar—are contained in every vegetable substance we eat, and cannot, therefore, be avoided. Moderation is equally necessary in azotic food also, for the reason that such food supplies to the blood the phosphoric and sulphuric acids. Oleaginous food, on the theory of its composition and digestion, would neither tend to the formation of uric or any other acid, except the carbonic. According to the foregoing theory, moderation in diet, and not the avoidance of any particular food, is called for in the treatment for the uric acid diathesis; and such a view is fully borne out by experience.

The origin and nature of the free acid of the urine is not understood: we know that it arises from one or more of the acids present in the blood, but cannot pronounce which. It cannot be the uric, for it is so feeble an acid that it scarcely reddens vegetable blues. Liebig advocates the phosphoric as the acid of urine;

and we are aware that this is a powerful acid, ever forming from the oxidation of the phosphorus of the nervous and muscular tissues. We know, also, that the sulphuric is ever ready at hand, by the oxidation of the sulphur of the tissues ; the hydrochloric, from chloride of sodium taken in with the ingesta : the hippuric we shall presently speak of. But whichever acid it is, it exists with all others in a neutral state in the blood, in combination with alkaline and earthy bases, and is separated from the blood and enters the urine by the elaborating action of the kidneys.

Hippuric acid has been discovered in human urine by Liebig, and pronounced to be one of the normal acids of the urine. Its formula, which is $C^{18}\ H^{8}\ O^{5}\ N$, resembles that of benzoic acid, and they are easily converted the one to the other. Hippuric acid supplies the place of uric in the herbivora. It exists in very small quantity in human urine, but is much more soluble than uric acid. The sulphates and the chlorides exist in urine, in combination with potash and soda, in a neutral state. The phosphates are in an acid state—the biphosphates, which is a contrary state to that in which they are found in the other animal fluids of the body, which are alkaline, from holding the tribasic phosphates. The matters in the urine that are denominated extractive, are of two kinds—alcoholic and watery. Little account can be given of them; they are organic compounds probably thrown off from the tissues in a state of change and transit from the higher forms of organisation to the lower, or inorganic. Kreatine and kreatinine are substances of this description ; they are produced from muscular tissue, though they do not exist in muscular tissue. Liebig has discovered them among the extractive matters of urine.

THE SKIN, AND ITS SECRETIONS.

The skin, besides forming an external covering and protection to the body, performs the functions of excretion and absorption, and is also an organ of touch. It consists of two layers,—the *dermis* and *epidermis*. The *dermis*, or cutis vera, is composed of condensed areolar tissue, and forms the main substance of the skin. Underneath is a loose layer of areolar tissue and fat, which abounds in the spaces and cavities formed between

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Urine.

The mean amount of fluid, by the way,
Is five and thirty ounces in the day.
Its separated solid matters hold
Urea forty-five per cent., we're told.
Touching urea, this on memory fix—
That azote's rate per cent. is forty-six.
This substance daily from the system drains
About four hundred three and thirty grains.
To gain its formula you've nought to do
But give to symbols C H O the number two,
With four to N, which does express the state
Of an ammonia, a cyanate.

Chronic Cachectic Nephrits, or "Bright's Kidney:" introduced to illustrate the changes that occur in the Urine.

Dropsy nephritic may be complicate
With chirosis, bronchitis, or struma innate.
One thousand and twenty is urine; but when
This disease is set in, 'tis a thousand and ten.

1st stage.

In the first stage the only change worthy of note
In the urine, is fat epithelium to float;
And mark in this stage what corpuscles are said
To be wanting in blood, which are only the red.
The kidney enlarged from four ounces to eight
Red spots the position of tufts indicate.

2d stage.

Next the urine albumine and hæmatine gains,
While the blood the urea and lithates retains.
The cortical substance, more swelled, now projects
In medullary portion, and tubes intersects;
Obliterates some of the tufts and the tubes,
While from others a fatty albumine exudes.
'Twixt anæmia, mingled with partial congestion,
A tubercular gland does soon settle the question.

Symptoms more or less from commencement.

The skin becomes arid, and pasty, and white;
Pale urine is voided full twice in the night;
Dyspeptic and retches, gets thinner a pace,
And the dropsy does often commence in the face.

the muscles. Besides the white and yellow fibrous elements proper to areolar tissue, the dermis contains the red contractile fibrous tissue. The white fibrous element is arranged in waving fasciculi, by which means the skin may be distended until the white bands become straight, when, in consequence of the inelastic quality of this element, no farther movement is allowed. The yellow elastic element, on being drawn out to the limits that the white bands allow it, retracts the skin to its former position, and the white bands again to their wavy state. A piece of elastic webbing well represents these two properties of the areolar tissue—the waving threads of the cloth the white fibres, and the caoutchouc the yellow. The contractile fibre contracts the skin under the influence of cold. Its effect is best seen in the nipples and scrotum. The dermis is supplied with blood-vessels, nerves, and lymphatics, and is penetrated by sudoriparous and sebaceous glands and hair-follicles. The external surface of the dermis is raised into papillæ, which are thickly supplied with nerves and capillaries, and have the sense of touch. They are conical projections distributed without regularity, except on the palmar and plantar surfaces, where they are longer, larger, and arranged in rows, which describe various curves, and give to these parts a peculiar ribbed appearance. The *epidermis* is the scarf-skin, or the external layer. By the microscope it is seen to consist of epithelium: the cells lying in contact with the dermis are nearly spherical in shape, and soft; while those towards the surface become gradually flattened, hard, and lamellated. The internal layer has been called the *rete mucosum*. In consequence of the dense structures both of the dermis and epidermis, a basement membrane has not been demonstrated between them, but, from analogy, anatomists have no doubt of its existence. Basement membrane appears to be the boundary of the blood-corpuscle. It cannot be percolated by cells, though the constituents of the blood, under other forms, pass it both by chemical and vital forces. On the same principle, epithelium may be said to be extra-vascular. The skin, like mucous and serous membranes, has a layer of areolar tissue for holding the capillaries, which is the dermis, and an external layer of epithelium. If, therefore, the basement membrane were absent, not only would analogy between the skin, mucous and serous membranes, be broken, but at least one principle of physiology would be frustrated. The dark colour of the skin among the inhabitants of tropical climates, and also darkness of complexion in Europeans, arises from the interspersement of pigment matter in the cells, and also in the nuclei: it is most apparent in the deep layer of cells called *rete mucosum*, for as the cells approach the surface the dark colour disappears. The epidermis is developed from nucleated blastema, the nuclei afterwards becoming nucleated cells, which retain their nuclei until they approach the surface, whose office is probably to attract and promote the growth of the horny matter which afterwards fills the cells and forms the scales. Desquamation proceeds as regularly from the surface as the cells make their appearance beneath. The shape of the epidermic cell is polygonal or oval; and, although it closely fits together into a *pavement epithelium*, is not impervious to exosmosis. From its surface, independently of the ducts, both water and carbonic acid gas are exosmosed, although the amount of evaporation is moderated by the epidermis. The effect of pressure, friction, or irritation, is to thicken the epidermis, but that of the palms of the hands and soles of the feet continues much thicker than any other part, though it may never be exposed to pressure. In the loose layer of areolar tissue intermixed with fat, which attaches the dermis to the parts beneath, are seated the *sudoriparous glands*. They are oval bodies, composed of a tube, convoluted, and rolled up, as it were, into a ball. The excreting tube from each penetrates the dermis, takes a spiral direction, and opens in the spaces between the papillæ. The epidermis is continued into and lines the tubes, where the epithelium undergoes a direct change in its function —from forming the gluey contents of the epidermic cells, to that of the watery fluid of the perspiration.

In the axillæ these glands are larger, as might be expected from the large amount of perspiration coming from those parts. Mr. Erasmus Wilson, who minutely describes the anatomy of the skin, estimates that there are about 3500 of these glands to every square inch of skin. By an estimate made by M. Krause, of the number of these glands, they are rated—on the forehead at 1258 to the inch; in the plantar surfaces at about 2700; soles of feet, 2680; on the back, 417. This statement explains the efficacy of a foot fomentation, and throws some light on the cause of the burning sensation that is experienced in the hands and feet when perspiration there is checked.

The solid matters of the perspiration, the acids, including the carbonic in a gaseous state, as also the ammoniacal salts included under the head nitrogenous matters, are most likely furnished by these glands; and it is to matters of low organisation, to the acids and ammoniacal salts, that the odours of perspiration are due. The skin is also supplied with another small gland, differing both in its form and in the nature of its secretion—the *sebaceous*. They are more or less distributed over the whole body. They furnish the oily secretion that prevents the epidermis from drying into one continued scale when from any cause the perspiration becomes suspended; and at all other times they confer a softness and pliability to the skin. In structure they are usually composed of two, three, or four follicles, which open into one common duct, and, together, form into an oval-shaped gland, the follicles being long and convoluted: sometimes, however, they are but a simple follicle. The ducts from some of these glands open on the surface of the epidermis, while a large portion open into the hair-follicles. The ducts of two or three glands open into one hair-follicle: this is the case as regards the hairs of the scalp, where the glands are most numerous, and secrete the oil which moistens the hair. This oily secretion from the skin is of use in protecting the epidermis from the macerating effects of the water of perspiration. Such an effect may be seen in the loose and distended state of the epidermis on the removal of a poultice that contains no oil, and on the hands of washerwomen. By this oily matter the skin is no doubt also protected from the acid reaction of the perspiration; and when we recollect that the acetic is often present in the fluid perspired, and consider how active a chemical agent this acid is upon animal structures, we shall at once see that such a protection is needed. A considerable amount of oily matter must, for these purposes, be excreted, and it consequently forms a no inconsiderable item in the elimination of hydrocarbon from the blood. The soapy matter that is frequently found collected on the skin of the fœtus is supposed to be an accumulation of the secretion from the sebaceous glands. The grounds for this belief are that it contains the three organic constituents of human fat.

Owing to the difficulty of collecting the fluid perspired from the skin in a pure state, no quantitative analysis has yet been accomplished. Several investigations have, however, been made into its qualities, from which it appears to have an acid reaction, due to the lactic which is generally, and to the acetic which is occasionally present.

It will be recollected that the acetic acid is occasionally present in the intestinal tube: in this it so far agrees with the fluid perspired. It has been ascertained by the author of this book, that the free acids of the perspiration so far synchronise with the gastric juice as gradually to diminish as this fluid is poured out in chymification: his experiments, however, have not been extensive, and require confirmation. In the meantime, this excretion may be said to be governed by the same law that regulates the periodical variations of the urine and saliva,—that the quantity of the juice excreted bears an inverse compound ratio to the amount of the acids of the urine and perspiration, and is in direct ratio to the alkalinity of the saliva. The salts found in perspiration were those of the blood, with a predominance of the alkaline chlorides; besides which, the ammoniacal salts have been detected; but it is probable that their presence depends on some trifling deviation from the standard of health. The next item in the list of constituents is perhaps of more importance than the foregoing; it is one that brings the excretory office of the skin into relation with that of the kidneys: it has passed much unnoticed by physiologists under the head of "animal matters:" it, however, is a nitrogenous matter, and as much as 100 grains is computed by Dr. Carpenter to pass daily from the skin. This extract, like most others of its class, is an intermediate product of organic matter in a state of change; and when ammoniacal salts exist in the perspiration, they are the result of the elements of some of these products having reached an inorganic state. The amount of carbonic acid gas perspired may be held to be very considerable, from the fact that an animal dies asphyxiated if this excretion from the skin is stopped by a coat of varnish; but no proof is wanted of the direct transit of carbonic acid from the skin. The amount has not been ascertained, but its mode of transit is probably by exosmosis from the general surface. The admission of oxygen into the blood by skin-absorption is by the same principle. It appears, from this account, that the skin, in secreting an adipose matter, is to that extent the excretor of hydrocarbon, the organic acids having the same constituents differently apportioned. The skin also ranks prominently as an excretor of nitrogen, and of carbon in the carbonic acid gas. The amount of fluid that passes by insensible perspiration, and by the lungs, has been ascertained by the patient labours of Seguin on the subject; the maximum of which is 5 lbs., the minimum about $1\frac{3}{4}$ lb. The difference between the two amounts is an indication of the great variations that may occur from various causes. The transpiration of watery fluid from the skin by the two sources alluded to (the glands and the general surface) is generally effected insensibly by evaporation: forces that either increase the amount or diminish the evaporating power of the air, have the effect of lodging the fluid in drops on the surface.

The *hair-follicles* are seated deeper in the subdermic tissue than the glands of the skin. The cells by which they are lined are, however, very different, both in function and appearance, from those of the epidermis. At the bottom of each follicle there is a pulpy mass of granular matter, nuclei, and cells. From this *formative pulp*, which is encircled in capillaries, the hair is produced, and this forms the *bulb*. Hair consists of a cortical sheath and medullary porous pith. The cells that become the cortex form themselves into regular-shaped oval hard scales; the bases lie on or overlap each other, and form the substance of the shaft, while the free end of the lamen projects out, the rows of which are spirally arranged, so as to give a beautiful imbricated appearance to the surface, imparting a sensation of roughness when the finger is drawn from tip to bulb. The cells which compose the pith become elongated into fibres, and form by their union this loose porous substance. The colour of hair is due to pigmentary matter, which is abundantly intermixed with both nuclei and cells, and gives a dark appearance to the bulb.

The hair appears to be penetrated by certain fluids by the force of endosmose, for in no other manner can it become daily imbued as it is with oily matter. Other fluids, also, probably traverse its substance by imbibition, which is rendered probable by the presence of the diseased excretion that mats the hair together in plica polonica. There is no other way of explaining the cause of the sudden change from its usual colour to white, which has been proved to take place in hair, except on the above principle, and that some obscure chemical agent is added to the fluid imbibed, which acts upon the pigment.

NERVOUS SYSTEM.

The Nervous System is regarded by physiologists as the machinery by which the immaterial part of man holds intercourse and relationship with the world. No idea that relates directly or indirectly to sensible things can be realised by the mind (which is the soul of man) except through the instrumentality of the nervous system. It is, besides, the principal

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Skin.

The mean amount of fluid, authors say,
Is forty ounces that transudes per day;
Of an azotic solid there has been
One hundred grains computed as the mean;
An oily matter, 'tis unknown how much,
To make it soft and pliant to the touch;
Much of carbonic acid; but the rate
Of its discharge we can't exactly state.
With these acetic acid, hydroclo-
rates of soda and ammonia flow;
The last, when azote's in excess, when well
Apportioned, salts are K Na Cl;*
The lactic acid also being free,
Gives to it a reaction sensibly.

* The chemical symbols of potassium, sodium, and chlorine.

instrument of volition and sensation, and exerts an active influence upon the nutritive, reproductive, and secretive processes, or the functions of vegetative or organic life. But, while a nervous system is essential to the existence of sensation, the exercise of volition, and a large class of ideas, it is not essential to the *existence* of the functions of organic life, either as regards secretion, or the movements, muscular or otherwise, connected therewith.

The nervous system is divided into two principal parts—the *cerebro-spinal*, and the *sympathetic* or *ganglionic* systems, which have their characteristic differences respectively. The cerebro-spinal system comprehends the cerebrum, sensory ganglia, mesocephalon, medulla oblongata (which parts are included in the term *encephalon*), and the spinal cord, together with all nerves proceeding from the above ganglia. The sympathetic or ganglionic nervous system consists principally of a chain of ganglia, which is placed on each side of the whole length of the spinal column, and the nerves proceeding from these, which intimately connect the ganglia with each other, and are distributed to the viscera of the thorax, abdomen, and pelvis, and the coats of blood-vessels. Both systems are indirectly connected with each other in their functions; but, while the cerebro-spinal system is subservient to the functions which appertain to *animal life*, the sympathetic ministers to the functions of *organic life.*

Structure of fibres of nerves.—Nerve-fibres not only constitute the principal portion of the trunks of nerves, but are thickly interspersed in the vesicular matter of the nervous centres. They consist of two kinds; one of which abounds in and characterises the cerebro-spinal nerve, and another which properly belongs to the sympathetic system, though both kinds enter the cerebro-spinal nerve. When a nerve of the cerebro-spinal kind is laid upon glass, the fibres separated with needles, and examined under a magnifying power of about 300 to 400 diameters, it is seen to consist of tubules of transparent, structureless membrane, having a double border, or to be bounded by two lines. This is occasioned by the opaque matter which lines the tubule, known as the *white substance of Schwann.*

The opaque surrounds a transparent substance, which occupies the axis of the tube, termed the *axis-cylinder of Purkinje.* A glass rod, coated with a thin layer of white wax, would give an idea of the construction of an axis-cylinder nerve-fibre ; and, if held between the eye and a strong light, would show the same double border. Before death the contents of these tubules are fluid and transparent, and it is only after death that the two substances are distinguished, in consequence of the coagulation of the white portion. The tubules are much disposed to bulge on manipulation, which gives them a beaded appearance, especially in the more delicate tubules of the nerves of special sense; and it is remarkable that in the distended parts, or even if the contents are pressed out, that the two substances still retain their relative situations, which makes it probable that there is a tendency in the *white* substance to inclose the transparent, in which we may suppose the nerve-force is seated; the white portion acting the part of insulating the transparent from other structures. It is a principle in physiology that *nerve-fibres* do not inosculate, though *nerve-trunks* inosculate by imparting branches composed of fibres to the trunks of each other. The average diameter of the axis-cylinder nerve is from 1-4000th to 1-2000th part of an inch. In the grey matter of the nervous centres they are often much smaller, having little of the white substance, and measuring only about 1-10,000th of an inch. The second kind of nerve-fibre is that which abounds principally in sympathetic nerve-trunks: they differ from the former in that the contents of their tubules are composed wholly of a grey substance, and that they are smaller, not measuring more in diameter than that of the axis-cylinder fibre in its smallest state. In nerve-centres the fibres of both kinds are so much alike that they cannot easily be distinguished apart. As nerve-fibres do not inosculate, and as the peripheries of the general fabric are thickly set with nerves, it follows that there must be as many nerve-fibres in the nervous centres as there are at the peripheries. The purpose served by the branching or inosculating of *nerve-trunks* is to concentrate the influence of several nerve-centres at one spot of the periphery, or to extend the influence of the centres. A nerve-trunk or nerve must therefore consist of many fibres: it is ensheathed in areolar tissue, which is composed mostly of the white fibrous element, and from which it derives the white pearly appearance peculiar to nerves. This tissue is interspersed between the fibres; and, besides giving a strong coat to the nerve, admits in its meshes a very fine description of capillary vessel, which also covers its surface. As the nerves approach the confines of the fabric, they separate into plexuses, and from these the several fibres diverge to their *terminations*, which are of several kinds,—1, by forming a loop; 2, by the spreading out (not dividing) of the fibres into a very fine plexus, as seen by Mr. Rainey in serous membranes; 3, in the *Pacinian* corpuscle, which consists of a body resembling a grey vesicle, surrounded by concentric layers of delicate membrane, in which the fibre terminates by a free end. This was observed by Pacini in the tactile surfaces of the hands and feet. The loop terminations were discovered by Todd and Bowman in the papillæ of the tongue, but it is not at present settled in what manner the nerves terminate in other localities.

The *vesicular nervous matter*, or that composing the substance of the nervous centres of the encephalon, spinal cord, and ganglia, is of a reddish-grey colour: it consists of vesicles or corpuscles; granular matter, interspersed among which are nerve-fibres; and a plexus of fine capillaries. The vesicles are nucleated cells filled with the same sort of soft granular matter in which they are imbedded. The nucleus, which is full ten times less than the vesicle, is generally adherent to the interior of the delicate membrane that forms the wall. The nucleus also is vesicular, and in it the microscope exhibits a nucleolus in its centre, which again is also a vesicle. The nerve-vesicle, then, is threefold vesicular; being a vesicle itself, and containing two in its interior. The grey vesicle often contains pigmentary matter: its size is worthy of notice, the average measurement being 1-800th of an inch, which is three times larger than the *white* blood-corpuscle. They are usually spherical, but often of other shapes, owing to the compression that naturally belongs to all tissues. There is another variety of these corpuscles, termed *caudate*, from the fact of their having one or more tail-like processes issuing from them. They are larger than the first described, and are of various shapes. The processes, for some little distance, contain the granular matter of the vesicle. The processes are continued with the nerve-fibres. Wagner, who has recently investigated this subject, concludes that most of the nerve-fibres of both kinds that enter ganglia become connected with the corpuscles in the manner described.

According to Vauquelin, cerebral substance consists of water, 80·00; fatty matter, 5·27; albumine, 7·00; osmazome, 1·12; phosphorus, 1·50; salts and sulphur, 5·15. According to the foregoing analysis, the albuminous and the fatty portions, which together form the main components of the brain, are in about equal proportions. From this fact, the practitioner will be enabled to estimate the cost to the system of nervous waste, in comparison of muscular waste, and will perceive that the azotic class of aliment is less required in mental than in muscular labour, and that for mental exertion the addition of the non-azotic groups is more needed. It will also seem evident that, for the purpose of getting rid of the phosphorus eliminated by the disintegration of nervous matter consequent upon mental exertion, the phosphorus, which is deleterious *per se*, must be converted into a powerful acid (the phosphoric); and hence one of the demands for oxygen in the blood, and the necessity for daily exercise *sub diu*, for the purpose of securing its introduction, and obtaining the full and unfettered powers of the brain. An equal necessity of combining muscular with mental exertion, and thus ensuring the admission of a full amount of oxygen, exists in the fact of the large quantity of carbon set free by nervous waste; for it must be recollected that, for the due activity of the nervous system, the blood must be depurated from surplus carbon: for the first effect of its retention in the blood is obtuseness of the intellect, and, where deficient, aëration of the blood is more gradual, as is the case with the inhabitants of crowded apartments, there is an inaptitude for mental and muscular exertion, and dulness of the intellectual and moral faculties, the consequence, therefore, of mental application without muscular exercise would be an accumulation in the blood of those constituents which we see in the analysis of nervous matter, in which we may detect, perhaps in equal moieties, the elements of urea and hydrocarbon.

The Functions of Nerve-fibres.—The functions both of the cerebro-spinal and sympathetic nerve-fibres are of two kinds, for which in each system two sets of fibres are provided—1st, a *centripetal*, *afferent*, or *esodic* set, which conducts impressions from the sensory surfaces and organs to the nerve-centres, which are the instruments of common sensation; 2d, a set which conducts an influence originating in the nervous centres to the periphery, and these are mostly distributed to the muscles both of animal and organic life: these are *centrifugal*, *efferent*, or *exodic*, and include the motor nerve-fibres. Although there are anatomical differences between cerebro-spinal and sympathetic nerve-fibres, and between these and nerve-fibres of special sense, there is no anatomical difference between the afferent or efferent nerve-fibres. As, therefore, the great majority of nerve-trunks are thus composed, they must be regarded as compound; and when a nerve is denominated *motor*, or sensitive, it is inferred that it contains a predominance of one or other of these fibres. In the short treatise that follows on the physiology of the nervous system, an attempt will be made to reap and combine the advantages conferred on this subject by modern writers; and we shall select three of our own countrymen—Professors Todd, Carpenter, and Dr. Marshall Hall—as representing the views of most other writers, and constituting, as a whole, an expression of the doctrines that are at present accepted on this most difficult part of physiology: we find, however, that we are in a measure defeated in this intention, for the reason that these writers have on this subject several points of difference. We shall therefore be content to accept from these authors what comes fitted to our hand, and, when driven to rest upon hypothesis, accepting that which appears the least theoretical. Although the vast amount of research that has been directed to this subject has furnished many wonderful facts, they are not generally of that nature on which it is safe to build theories. The able writers referred to suffer great disadvantage, by reason of the thick darkness that surrounds the mysteries of the nervous system. It is not, then, strange that the best efforts of the intellect should appear puny before such a subject, or that the nakedness of these authors should appear, though they be conspicuous for their attainments amongst the physiologists of Europe. The following statement will perhaps be sufficient to justify the foregoing reflection:—We are taught that a cerebro-spinal nerve-trunk is endowed, in virtue of the ganglia with which it is connected, with the following several functions:—1st, volition, or voluntary motion; 2d, common sensation of at least two distinct kinds; 3d, the function of reflecting sensations into adjacent sensitive nerves,—thus creating, in the words of Dr. Todd, "a large class of phenomena under the name of radiating sensations;" 4th, the afferent or esodic division of the diastaltic or reflex nervous arc of M. Hall, or the same division of the "physical nervous action" of Todd; 5th, the exodic or efferent division of the same arc; 6th, instinctive automatic movements; and 7th, emotional movements, both of which were dimly represented by Alison, and more clearly by Carpenter, to be centred in and reflected by the sensory ganglia; 8th, the co-ordination of muscular action by the cerebellum; added to these two distinct functions, at least in virtue of the fine fibres of the sympathetic ganglia, which are included in every cerebro-spinal nerve, making together at least ten functions that more or less belong to the cerebro-spinal nerve. The subject is sufficiently obscure; but it is not on the existence of these functions that these physiologists differ, but on the appropriation or assignment of functions to nerve-fibres.

Experiment has proved the separate existence of sensory and motor fibres, and anatomy has proved the separate existence of fibres of both systems; but at present they have gone no farther in proving the separate existence of other fibres in the cerebro-spinal nerve. But if we reject this doctrine because of the seeming physical impossibility of combining in one nerve-trunk ten sets of fibres representing the ten functions, each set being numerous enough for peripheral distribution, we are compelled to adopt the equally incomprehensible doctrine that the cerebro-spinal nerve contains only the sets of fibres experimentally and anatomically proved, and that these are implanted in, or pass transversely through, the vesicular matter of the cerebro-spinal centres with which each nerve is respectively connected, and do not pass onwards to the brain, but being connected with it by means of the continuation of the vesicular grey matter, and the commissural fibres which exist between the several segments of the cerebro-spinal axis. The several functions spoken of as originating in the encephalon are transmitted to these fibres in the cerebro-spinal centres. In support of this, it has been proved by experiment, and appears probable in anatomy, by the fibres with which it is interlaced, that grey nervous matter is capable of conducting as well as originating nervous force. The hypothesis of only two sets of fibres in the spinal cord was first enunciated by Todd and Bowman, and has since been ably supported by Dr. Todd (Cyclop. of Anat. and Phys. vol. iii. p. 722, B), and will be adopted in this place; not that either one or other can be proved, but it is more pleasing in such unfathomable subjects to admit that the several functions are the laws of God written upon nervous matter, and which is certainly earlier implied in Todd and Bowman's theory than in the separate fibre theory. We therefore hold that a cerebro-spinal nerve consists of afferent and efferent fibres; that these, in virtue of their connection with the brain, as just stated, form an essential part in the mechanism that appertains to the production of voluntary motion and sensation, but that their proper centres are the segments of the cerebro-spinal axis; and that, in the language of Dr. M. Hall, they can act independently of the brain, and constitute of themselves independent nervous arcs, as is abundantly proved when cut off from the encephalon by paralysis, and by experiments on decapitated animals. No reference has hitherto been made to the hypothesis of Dr. M. Hall, that a cerebro-spinal nerve consists of four sets of fibres, two belonging to the excito-motory *system of nerves*, and of *a true spinal cord*, the centre of reflex or diastaltic sctions; and two sets constituting the *sensori-volitional*, and being the special fibres of sensation and volition. This view demands greater attention, in consequence of the support it has received from the comparative researches of Dr. Carpenter and Mr. Newport, who assert that these four sets of fibres can be demonstrated in the Articulata. This fact has not, however, been demonstrated to the satisfaction of some other comparative anatomists; and the fact still remains that, while, in the cords of vertebrata, fibres are discerned passing transversely through the grey matter of the cord, none appear to turn upwards to the brain. If, therefore, an ascending set of fibres cannot be made visible, the hypothesis cannot be entertained in consistence with our own view, that if we admit fibres over and above those actually demonstrated, the door must be opened to the ten sets already referred to. In thus differing from Dr. M. Hall, we are not insensible to the services he has rendered the physiology of the nerves by drawing a distinct line of separation between the *excito-motory* function and the *sensori-volitional.* Such a separation is a truth in physiology, though it may not be true that there are separate fibres for each division. If Dr. M. Hall is not the true father of reflex action in this country, we are at least indebted to him for fostering, supporting, and bringing up the bantling; he has performed the part of a step-father with greater zeal in this country than Professor Müller has fulfilled the office in Germany. Our debt to him is not diminished because Professor Prochaska, of Prague, in 1784, wrote the following sentence: "Impressiones sensorius in motorias reflectit, vel animâ insciâ, vel vero animâ consciâ;" or that Unzer, of Vienna, about the same period, propounded the same doctrine; for, to the discredit of this science, as far as utility was concerned, these books were as good as dead and buried with their authors up to the time that Dr. M. Hall devoted himself to the subject; nor does it detract from his merits for having raised the subject from obscurity, that his way was in some measure prepared by Whytt, Gilbert Blane, and Le Gallois. As a labourer in his own field he stands first amongst a goodly number of names.

Although nervous force or power (vis nervosa) has of late attracted much of the attention of physiologists, it is but little understood. It is of the nature of the two great cosmic bodies, light and heat, and though it more nearly resembles electricity, it is proved by its physiology that it is totally distinct therefrom: nervous force is dynamic, and remains in a state of inaction unless aroused by its appropriate stimuli. It admits of condensation or augmentation in the nervous centres, and undue augmentation constitutes disease, or its abnormal condition. Dr. M. Hall maintains that it is capable of no exaltation in the cerebrum or cerebellum, the same being *in-excitor* and insensible on being punctured. It is, however, more probable that it admits of exaltation in these centres, or the minds of men would be generally more in a state of stationary equilibrium than is found to be the case: vital force is generated and accumulated by repose and tranquillity of the animal and organic functions, and is expended and exhausted by the exercise of these, more especially by volition or voluntary motion. It is influenced by therapeutic agents, being augmented by strychnine and opium, and diminished or nullified by the ethers and hydrocyanic acid. Irritation of a nerve, either from a wound or from teething, produces its augmentation, and shows itself in tetanus or convulsions respectively. Nervous action is induced by stimuli of various kinds—volition, or the mental stimulus, light, heat, sound, odours, electricity, irritating chemical substances, or mechanical puncturation. Excrementitious matters in the blood excite nervous action, and determine it to the part irritated, causing neuralgia or sciatica. In sensory nerves, the stimulus, or the impression, as it is usually termed, is applied at the periphery, and takes a central direction. In motor nerves it is the reverse, the impression being applied at the nerve centres; the two together, the sensory and motor, in conjunction with their centres, in nerve phraseology are termed a *nervous arc*. In morbid irritation of a portion of a nerve the stimulus may be conveyed in both directions, so far as the morbid irritation is concerned, such effects being convulsive movements, spasms, exalted sensibility, and pain; in this way a fit of epilepsy may be excited by irritation acting on the periphery of a motor nerve. At whatever part of its course a sensory nerve is stimulated, the sensation produced takes place at the periphery: this is a physiological fact, with pathological bearings, and accounts for the *cause* of pain not being always at the *seat* of pain. In accordance with the views of Dr. Todd, the power of originating nerve-force is inherent in nerve-fibres, though not in the same proportion as in the nerve centres, where it obtains the designation of dynamic force: the existence of this power in nerve-fibre is proved by the fact that when a motor nerve is cut off from its centre, the part below the section is capable of exciting muscular action: it loses, however, this power in about four days, which denotes that union with its centre is an essential condition. When a motor nerve is excited to act by the stimulus of the mind (volition), the stimulus is applied at its nervous centre: when acted on by all other stimuli, the nerve centre is excited by an impression conveyed through a sensory, afferent, or esodic nerve; the class of actions thus produced being reflected, or passing through, are termed reflex or diastaltic. Although electricity is a powerful excitor of the nervous force, the most delicate tests for electricity have failed to prove the existence of a galvanic current in the nerves. The nerves, too, are very imperfect conductors of electricity: according to Todd and Bowman they are infinitely worse conductors than copper, and are said to be four times inferior to muscle. A ligature applied to a nerve stops the course of the nervous force, but does not impede the current of electricity. If a portion is excised from the trunk of a nerve, its place cannot be effectually supplied by an electric conductor. A force very analagous to electricity is generated during the contraction of muscles (so also is heat, and in some marine animals light). This force of muscle differs from electricity only in the facts that it will readily traverse imperfect conductors of electricity, whilst it will not pass the best conductors. These important facts were lately discovered by Professor Matteucci of Pisa, who maintains that if a bared nerve of a frog's leg, still in connection with the foot, be laid across the thighs of another frog in active contraction, the force generated in the thighs will traverse the denuded nerve, and set in action the foot to which the nerve is connected. But if a piece of gold leaf (a good conductor) be made to separate the denuded nerve from the thighs, the current is intercepted. The anatomical construction of striated muscular fibre is thought to be more favourable for the conduction of electricity, than the structure of nerves, which is a continued tube, inasmuch as the fibre of muscle is a prismatic column of fibrine, encased in sarcolemma, which is impervious to vessels and nerves, and is again divided by the transverse striæ into distinct compartments ; a structure which remarkably resembles the electrical organs of the torpedo and gymnotus (Ibid. vol. iii. p. 720.) Enough has been ascertained with respect to these three forces—electricity, nerve-force, and muscle-force, to establish the fact that they are closely allied to each other, and that the main difference between them is the laws that regulate their respective modes of conduction, which are admirably and beautifully suited to their fields of action: a perfect conductor of the nervous force is a cylinder of structureless sheath, the walls of which it cannot permeate, containing albuminous matter and phosphatic fat.

There are some few facts relating to the operation of the galvanic stimulus on nerves that demand attention. It is essential that it be applied in the longitudinal direction of the nerve; for if passed transversely across the trunk, it is devoid of all power of stimulation. Contraction of muscles is produced on the completion, and on breaking the circuit, but no effect is produced when the current is passing. When the current is directed through a nerve towards the periphery, it is termed the *direct current;* when from the periphery to the centre, the *inverse current.* The continued passage of the direct current through a nerve exhausts its nervous force, although no contractions take place except on completing and breaking the circuit. On the other hand, the continuation of the inverse current augments nervous force to such a degree that tetanus may be produced by it. The word *current*, as applied to electricity, the nervous, and muscular forces, is not appropriate according to the present state of science, for nothing is absolutely transmitted. They consist essentially of a molecular change, occurring almost simultaneously through the whole length of the conducting body, and the change is a displacement and rearrangement of particles of the conductor, occurring at one end, which communicates a physical disturbance of atoms through the whole length, something after the manner of the movement of a Venetian blind, the whole length of which is opened by turning the first spar; or it may perhaps be better figured to the mind by imagining a single line of barley and wheat grains placed end to end, in the order of first a couple of barley, and then a couple of wheat. Now if it is an essential character of this line that it begins and is continued in couples, and you remove the first barleycorn, you by that means destroy the order of the couples: the first will then consist of a barley and a wheat grain, instead of two barley grains, and so in like manner through the whole line.

The atomic movement in the conducting bodies, whether of nerve or metal, is a polar change, and the galvanic or nervous force a state of polarity. The conducting power of a nerve is in direct ratio to its aptitude to undergo the change, physical or chemical, which constitutes polarity, under the influence of stimuli. These facts were first pointed out by Todd and Bowman. Electricity, magnetism, muscular and nervous force, while they are nearly allied, are essentially different; the two first are inorganic polar forces, the two latter organic polar forces, inasmuch as the media of their operation are either organic or inorganic matter.

Functions of Nervous Centres.—There are two intellectual operations that are usually assigned to the instrumentality of the cerebrum, that for their completion require more or less of the agency of all other ganglia of the nervous system: these are, perception and volition. Perception cannot be accomplished unless sensations are first conveyed to the brain from the sensory ganglia for the mind to perceive; neither can volition or voluntary motion be effected without the aid of the chain of segments of grey matter of the cerebro-spinal axis, which are the nervous centres of muscular motion, and the chief instruments in fulfilling the mandates of the will. It is also necessary for the due performance of voluntary motion that the cerebellum and the sensory ganglia lend the influence of their fibres to the process, the first for the co-ordination of our steps, and the latter that we may feel the ground on which we tread. Now, although the integrity of all these ganglia is essential to the complete performance of voluntary motion, there are a large series of actions that are performed by the instrumentality of the cerebro-spinal ganglia, and which may be effected independently of the cerebrum. This important fact is proved in various ways, and in none more strikingly than by Flourens' experiment of removing the whole cerebrum from a pigeon, by which the animal appears to be thrown into a stupor: the special senses of seeing, hearing, &c. are not injured; it swallows the food that is placed in its mouth, it walks, and, when thrown in the air, flies to the ground: the organic functions proceed as usual. All the motions exhibited by this animal are reflected by a stimulus, or impression, conveyed by afferent or exodic nerves to the central ganglia with which they are connected, and mostly the same nerves that, while in connection with the brain, were nerves of sensation. Before a reflex action can be manifested, a preliminary nervous performance is essential, in which the three members of the diastaltic nervous arc must be brought into operation:—1st, esodic or afferent nerve-fibre, to convey an impression; 2d, a nervous centre, to receive it, and to generate and transmit an impulse by, 3rd, exodic or efferent nerve-fibre, to the contracting tissue.

The same class of movements may be better contemplated in cold-blooded animals, when those seated in the spinal column are called into action, and when the cord is separated from the medulla oblongata by decapitation. After some convulsive movement dependent on the operation has passed off, the animal lies motionless, totally unable to stir: if, however, the surface of the body be irritated, movement is produced; if a toe be pricked, the limb is instantly drawn up. The same movements may be produced in man when the spinal cord has been separated from the encephalon by disease or accident, and all voluntary movement suspended; and of this class, also, are the movements of anencephalic fœtuses. Every segment of the spinal cord is probably a centre of motions of this kind, and which are denominated reflex or diastaltic. Although the whole class of these actions are essentially independent of the will (cerebrum), most of them are guided and aided by voluntary effort; and the more they are carried on without the aid of the will, so much the more are they sustained without the fatigue and exhaustion that attends voluntary motion. Although both classes of actions, voluntary and reflex, each require a stimulus for their production, there is this notable difference between them,—that the mind, which is the only stimulus for the production of voluntary motion, acts directly on the cerebrum, while the other class are produced by their respective stimuli, through the mediation of afferent or esodic nerves.

We have already stated that nervous force is generated in the grey vesicular matter of the great mass of nerve centres; the impulses or impressions that cause muscular movement, and by which the organic functions are guided, regulated, and governed, are issued from these centres; but it is probable that nervous force, in whatever centre it exists, is at all times passive and inoperative, unless aroused by stimuli. In no case is it spontaneous. The mind is its only stimulus in the cerebral convolutions: no diastaltic or reflex movement can proceed without an impression brought to the nervous centre of such movement by the esodic or afferent division of the diastaltic arc with which it is connected. Respiration is stationary, unless an impression is conveyed to its nervous centre, of carbonic acid in the blood, by the pulmonary branches of the vagus, some nerves of the skin, or by fibres between the centre of respiration and the brain, in which the impression becomes a sensation. The rhythmical pulsations of the heart, the nervous centres of which are supposed to be located in its substance, are excited by nerves conveying to these ganglia the impression of blood in the ventricles. The sympathetic ganglia of the intestinal tube issue no motory impulse to the intestines unless they first receive the impression of matters contained in the tube by nerves destined for that purpose; and the decapitated animal remains immoveable until movement is excited by impressions conveyed to the nervous centres of the cord, and which are manifested by the transmission of the motor impulse.

It is well known that the spinal cord possesses the power of reflecting sensations. The pain in the knee that is experienced in the incipient stage of hip-disease is an illustration of this fact, so also is pain in the right shoulder reflected by the spinal centre of the phrenic nerve from the cause of irritation in the liver. It may be repeated here, that the spinal nerves act the part of nerves of sensation, in virtue of their connection with the brain and sensory ganglia; that the axis-cylinder fibres of a cerebro-spinal nerve consist essentially of two sets of fibres, afferent or efferent; that volition and sensation are imparted through the encephalonic connection, and stand in the relation of subjective or adjunct qualities, while there are other functions of the same nerve-trunk, belonging to its afferent and efferent fibres, which may be considered absolute and integral qualities—diastaltic or reflex action. Not only have cerebro-spinal centres the power of reflecting muscular action through afferent nerves, and sensation from sensory nerve to sensory nerve, but it is also observed that muscular action may be reflected from motor nerve to motor nerve. A familiar illustration of this is the involuntary movements that are sometimes excited in the legs by passing the catheter: the irritation applied to one paralysed limb may also produce movements in another. This principle is witnessed extensively in the pathology of the nerves: a motor nerve in a state of irritation from injury, by accumulating abnormal polar force in its centre, may communicate the same to other centres, and become the cause

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Diastaltic or reflex action.

Oft-times doth will, oft doth sensation guide
Motions reflex, that in the spine reside;
The question, though, no longer's in suspense,
That reflex power is free of will and sense;
'Tis like the horse, and, push the notion wider,
Volition takes the office of the rider.
The horse is diastalsis, we presume,
Volition takes the reins, as doth the groom;
Though respiration needs this guidance, still
It moves in independence of the will.
But few exceptions to this rule we wot,
One is, that the heart's action needs it not;
That diastaltic action, deglutition,
Is peristaltic,* and free of volition.

* Peristaltic in lower half of œsophagus.

of tetanus. Softening of the brain is apt to communicate excitement to the cord, and occasion incessant restlessness of muscle, or an inclination to move about; and irritating matters in the intestinal canal, and teething, produce epilepsy, by diffusing irritation through the whole chain of centres of the cord. These are said to be *indirect* causes of epilepsy; direct causes are more or less connected with the corpora striata, which bodies have especial motor relations with every segment of the cord. All these cases instance the transmission of abnormal motor power, or polar force, from one nerve-centre to another. The concentration of blood to certain parts of the surface, such as stationary redness of the face, or the more transient effect of blushing, is occasioned by a determination of nervous force to the part; and this is also the *primum mobile* of the increased action that attends the generative function, and erection of the penis. All such nervous operations are reflex, requiring the double arrangement of nerve-fibres and a nerve-centre.

Structure of the Spinal Cord.—The physiology of the spinal cord requires that a general account of its anatomy should be first given. Beginning at the termination of the medulla oblongata, it is continued to the first or second lumbar vertebra. Its form is a flattened cylinder, presenting two enlargements in its course: the uppermost corresponds with the nerves going to the upper extremities, constituting the *cervical bulb;* and the lower, opposite the origin of the nerves given off for the lower limbs, the *lumbar bulb.* It exhibits two principal fissures, an anterior and a posterior; these divide the cord into two lateral halves, except where the anterior terminates in the white, and the posterior in the grey commissure of the cord. Each of the two halves of the cord is divided by anatomists into three columns by slight indentations or sulci on its surface, from which sulci the anterior and posterior roots of the nerves take their origin: the grey matter of the interior approaches the posterior sulcus, and by the sulci the halves are apportioned into anterior, lateral, and posterior columns. The fissures, sulci, and columns, may be better understood by placing the three first fingers of each hand together, and allowing the divisions between the two first to represent the anterior fissure, that between the two third fingers the posterior fissure; the anterior sulcus, the crevice between the first and second fingers; the posterior sulcus by the crevice between the second and third fingers; and the fingers to represent the columns: the first finger the anterior, the second the lateral, and the third the posterior columns. The fibrous matter of the cord is external, and forms its larger portion. The form of the grey vesicular matter in the interior of the cord resembles two crescents joined at their convex surfaces. The horns of the moon correspond to the origin of the nerves. At or near their origin, the anterior lateral sulcus, the anterior, motor, or efferent roots of the spinal nerves, join the cord; at the posterior lateral sulcus, the posterior sensitive or afferent nerve, roots are attached, the *posterior* being the largest, and having ganglia upon them in the intervertebral foramina, which having cleared, they unite with the anterior roots, no longer retaining the name of *roots*, and, on dividing into an anterior and a posterior branch, become *spinal nerves*, of which the *anterior*, with the exception of the first pair, are the largest, and these only receive branches from the sympathetic ganglia.

Functions of Roots of Spinal Nerves.—The anterior roots of the spinal nerves have been demonstrated to be motor, and the posterior sensory: no action of an esodic or afferent kind distinct from sensation has as yet been discovered in the posterior roots by experiment, so lông as their connection with the brain has remained entire. This is taken to be an indirect proof that the spinal nerves send no fibres directly to the brain. Section of the anterior roots produces paralysis of motion; section of the posterior roots, paralysis of sensation: but diastaltic or reflex action has not been caused by irritating the posterior roots with a view of exciting the anterior or motor roots through the cord. All that anatomy teaches regarding the entrance of the nerve-fibres into the cord, is, that they make their approach to the grey matter obliquely upwards, penetrating it a little higher than the point of entrance, as best seen in the anterior roots. The white fibrous portion, it is true, may be separated into concentric laminæ; the fibres, however, run transversely in the layers. The size and relative proportions of the grey and white portions in the cord in its different localities are important, as bearing on the question of the separate fibre theory of the cerebro-spinal nerves. If, as we suppose, the fibres of these nerves terminate in the several segments of grey matter of the spinal column, it is but a fair corollary that the communication between the nervous centres of the encephalon and the spinal nerves is effected by means of the white fibrous matter of the cord, and the fibres that are known to interlace the vesicles within the grey matter; and, moreover, that a less number of fibres come from the brain to engraft the nerves with volition and sensation, than the number of fibres constituting the trunks of the cerebro-spinal nerves. It it were not so, but, on the contrary, that volition and sensation were represented by a system of fibres that go on to the brain, it is plain that, as the pairs of nerves severally join the cord, its bulk must increase with every additional pair. It is admitted that the lumbar bulb of the cord is fuller of grey matter, has a less quantity of the fibrous portion, and is altogether smaller than the cervical bulb; but, on examining the cord, up to the latter bulb the fibrous matter is found to decrease in the dorsal portion, and a very notable diminution of fibrous matter takes place between the cervical bulb and that part just below the decussation of the pyramids. The bulbous enlargements of the cord, both of the grey and fibrous portions, that take place at the parts where the trunks of nerves are bulky in proportion of the extent of the tissues they supply, favour the deduction that the nerves arise directly from the cord, and are not continued on to the brain. The stellate grey vesicles seen to exist in all parts of the grey matter of the cord by Wagner and others, add probability to the same conclusion. The following results obtained by Volckmann by weighing and measuring different parts of the spinal cord of a horse, add considerable testimony to the correctness of the above view. The weight of four portions, of equal length, taken from below the 2d, the 8th, the 19th, and the 30th pair of nerves, were, in the above order, 219, 293, 163, and 281 grains. The areas of the transverse section of the grey matter in these portions were, in the same order, 13, 25, 11, and 25 square lines; and those of the white matter 109, 142, 89, and 121 square lines. By this it appears that the quantity of grey (as also of white) is less at the cervical than at the lowest part of the lumbar portion, and consequently it is impossible that all the fibres that enter the cord can pass on to the brain.

Functions of the Spinal Cord.—The following may be stated as propositions generally accepted in the physiology of the spinal cord:—1st. That the spinal cord is an essential instrument in the manifestation of common sensation and voluntary motion in the trunk and extremities; albeit the more physical motions that directly belong to the cord are independent of their functions, though more or less guided, aided, and governed by them. 2. That section of the cord in animals, in whatever part it takes place, occasions paralysis of common sensation and voluntary motion in all parts below the division. 3. If a partial transverse division only takes place, paralysis is perceived *on the same side* as the injury. 4. If the two halves of the cord are separated a few inches longitudinally, no paralysis occurs, though a disturbance of functions is the result.

Healthy muscles at all times, even though in perfect repose, maintain a certain amount of contraction. This principle has been named *tension* by Dr. Carpenter, and requires particular notice, that it may not be confused with *tone* (see Tone); there being an essential difference, inasmuch as tension is described as a property of nervous centres, while tone is an inherent property of muscular fibre. Dr. M. Hall first pointed out the dependence of tension upon the spinal cord, and Dr. Carpenter distinguished it from tone, and made the whole subject intelligible. A striking illustration of the power of tension is the loss of balance that occurs in the muscles of the face when the facial nerve of one side is paralysed; the sound muscles draw the paralysed muscles towards them, for the reason that they have lost their support. When the spinal cord of a rabbit is broken up, the limbs become relaxed, the sphincters lose form and resistance, and the muscles generally have not the firmness of those of another animal killed by the removal of the head. It is by this passive contraction that muscles at once adapt themselves to the various lengths into which they are thrown when the limbs of a person are moved against his will, or whenever movement takes place without the agency of regular muscular contraction. The action of the sphincter ani, so much of it as is ordinarily exerted, and not under the control of the will, is usually assigned to the influence of the nervous centres, or reflex action. The result of experiments on which this statement is founded is not sufficiently conclusive. Dr. Todd maintains that ordinary contraction of the sphincter ani is due only to *tone*, or inherent contractility. He thus differs, not only from Dr. M. Hall, but from the text on this subject as given in the works on physiology of Dr. Carpenter and Dr. Kirkes. Dr. Todd rests the force of his argument on the fact that when the cord is divided, and the irritation consequent upon the operation is subsided, the sphincter is paralysed, and no reflex action can be excited by stimulating the anus; and that paralysis of the sphincter is frequent from disease of the brain when the cord is otherwise healthy, and other reflex action in full force. That it is not a greater amount of contraction than may fairly be attributed to tone, may be gathered from the fact that when the stomach of an animal that has been killed during the process of chymification is removed, the sphincter of the pylorus is usually found sufficiently contracted, by the same inherent force of muscle, to prevent the escape of the contents of the stomach through the pyloric orifice. On the other hand, it may be asked, how does it happen that the sphincter can be so paralysed as to offer *no* resistance if its *ordinary* contraction is out of the reach of paralysis, by being of the nature of *tone*,—unless, indeed, muscular irritability is paralysed also. And again, if the antagonistic contraction of muscles is due to *tone*, which is asserted by Dr. Todd (Ibid. p. 721), whence is it that this inherent property of muscle can be suspended by paralysis of the facial nerve? It is impossible in this place to do justice to the arguments of either Dr. Carpenter or Dr. Todd, who have each gone fully into the subject; and to do so would not further the question, for experiment has not yet been carried far enough for its elucidation. One source of confusion in the results of experiments on the spinal cord is, that the effect anticipated from its division has been that all nerve-force from centres above the section being cut off, the centres below should exhibit the full amount of nerve-force that belongs to them as independent centres; the fact being lost sight of, that the effect on the centres below may depend on the manner in which the cord has been divided; for it is probable that if a portion of it is crushed, instead of at once severed, not only may all reflex action centred in the lower segments be impaired or destroyed, but the two distinct vital properties that are independent of nervous systems—muscular irritability and tone, or passive contraction—may suffer in like manner, and to such an extent that that last manifestation of tone, rigor mortis, may not appear in the muscles after death,—effects that are also witnessed in sudden shocks to the nervous system, as from blows on the head, or on the cœliac plexus through the medium of a full stomach, or in deaths from lightning. The fish-woman is practically acquainted with these facts, we may suppose, by the method she takes to kill an eel, not by dividing the cord, but by crushing a portion of it.

The different outlets of the body, it is most probable, are under the unceasing guardianship of the spinal centres; these are warders that never sleep, and, in the ordinary office of keeping the gates closed, they are neither aided by the will nor sensation. The will is the supreme governor of the fortress, over-riding subordinate power; and sensation, or the sensory ganglia, may be said to work the telegraph by which the extraordinary interference of volition is summoned when needed.

The ordinary contraction of the sphincters differs from usual reflex action in being in constant operation: the amount of this ordinary contraction is not more than enough to prevent the escape of the contents of the rectum or bladder when impelled only by gravity: when the expelling force of defecation or urination is superadded, ordinary contraction altogether fails to restrain the discharge, unless the aid of the will is summoned to its assistance. The operation of the will is an active agent in the work of these sphincters, and paralysis of the voluntary control of them should be distinguished from that total paralysis in which the sphincter is completely relaxed. In the first case, no escape of matter will take place except by peristaltic or diastaltic expulsive force, exercised in the coats of the intestines or walls of the abdomen. In complete paralysis an escape will take place constanter by force of gravity. In both these cases the action of egestion and sphincters are paralysed to the will, and therefore involuntary; and the question proposed is as to the extent of paralysis,—whether the spinal centres are so far affected as to cause paralysis of reflex or diastaltic action, and so as totally to relax the sphincters. In such complete paralysis it is probable that the rectum and bladder become emptied by the peristaltic efforts of their muscular coats, and get no assistance from the diastaltic action of the abdominal walls. The contents of the intestinal tube are moved onwards by peristaltic action (vis insita), which is considered to be directly independent of nerves, but indirectly influenced by them. In this influence the spinal nerves take their share. The acts of urination and defecation are peristaltic as regards the action of the muscular coats of each viscus, and a combination of diastaltic and voluntary action as regards the contraction of the abdominal muscles; the glottis being closed, the diaphragm contracted, and the cardiac sphincter shut. The expulsory action of parturition is usually considered reflex. The supply of nerves to the uterus, in its impregnated state, are very few: while there is a large muscular and vascular growth in its substance, there is no increase of nervous structure, and as it is well known that parturition may take place when the spine has been diseased or divided, and that the inhalation of ether, which so neutralises nervous force, does not in any way diminish the power of uterine contraction, it is probable that nearly all the contractile force of the uterus is connate with the organ, while that of the numerous muscles that assist, which have been enumerated, in defecation, are reflex spinal, and at once out of the pale of volition, though aided by it.

The muscular contractions that take place during emissio seminis are reflex, and, like deglutition, uninfluenced by volition except in the preliminary act. It has been proved that the high degree of sensation that accompanies the excitor or afferent division of this nervous performance is not absolutely essential to its accomplishment; for it has been known to take place when sensation has been annihilated by dividing the cord. Erection of the penis will take place under the same circumstances, and is so far a reflection from spinal centres; but mental emotion is the ordinary excitor.

Alkalescent urine, in which abound mucus and the triple phosphate, is common in affections of the spinal cord. The first cause of these symptoms is the paralysis of the bladder and the lodgment of the urine, by which decomposition of the urine is effected and ammonia produced, which, in its turn, irritates the coats of the viscus, and causes a discharge of mucus or pus. It is not uncommon, both in disease of the brain and also in cases of over-exertion of this organ, or other exhausting drain upon the nervous system, that the urine becomes alkalescent and phosphatic: an explanation may be found in the large amount of phosphorus that in both these cases is liberated in the blood by the undue disintegration and waste of nervous matter, that, arising from cerebral disease, may owe its origin to the weakened powers of vitality and the exaltation of chemical forces that more or less prevails in all diseases.

Office of the Columns of the Spinal Cord.—Anatomy does not afford much insight into the subject of the especial office of the columns of the spinal cord. The anterior roots of the spinal nerves are implanted into the anterior sulcus, and they can be traced transversely and obliquely upwards towards the grey matter, which appears to be proper to the anterior and lateral columns. This is not the case with regard to the posterior roots; for, on entering the posterior sulcus, their fibres, though taking the same upward direction as the anterior towards the grey matter, yet it can be seen that the whole of their fibres penetrate the lateral columns. The anterior and lateral columns, it appears then, receive both anterior and posterior nerve-roots; they also are in connection with the principal ganglia *en route* to the cerebrum,—the corpora striata, and thalami optici, through the olivary bodies and both anterior and posterior pyramids. To this may be added what farther is gathered from anatomy, human and comparative. In man, the two bulbous enlargements of the cord appear to be formed out of the anterior and lateral columns; and by comparison it is found that in those animals that have larger bulbs in the spinal cord, in accordance with the multiplied function of the organ in their respective cases, that in these columns only is the enlargement developed. Neither pathology nor experiment give much aid in disclosing the functions of the spinal columns,—the difficulty of approach, the delicacy of structure, and proximity of the undoubted instruments of sensation, the posterior roots of the spinal nerves, present almost insurmountable obstacles: lesion of the anterior and lateral columns, from disease or injury, impairs both the motor and sensory functions of the cord, though motion is of the two the more easily affected. Experiments tell us that motion resides in these columns, but can give no conclusive evidence as to sensation,—probably from the nearness of the posterior nerve-roots. For this reason, also, no satisfactory information can be obtained from experiments on the functions of the posterior columns; but their anatomy, especially their connection with the cerebellum, and the large part they take in the formation of the nerves of the lower extremities, makes it probable, as pointed out by Dr. Todd, that they are intimately connected with the functions of the cerebellum: pathology adds probability to this view, and gives negative evidence that they are not otherwise connected with the great mental and physical operations in which the spinal cord is concerned.

Structure of Medulla Oblongata.—The medulla oblongata forms a continuation of the spinal cord, being about an inch in length, more bulky, and rather conical. The three fingers of each hand placed together will help to recall to mind the general scheme of the structure of the medulla oblongata. The fore-fingers will represent the *corpora pyramidalia*, or anterior pyramids; the second pair, the *corpora olivaria;* and the third, the *corpora restiformia:* the fissures and sulci retaining the same relative position as in the spinal cord. A large part of the fibres of the anterior pyramids decussate at the lower end, and not only change sides, but also pass backwards into the lateral columns of the cord, or pass from the fore-finger of one hand into the middle finger of the other. The fibres that do not decussate are embodied in the anterior columns of the cord. The olivary bodies occupy the position of the middle fingers: in the centre of each is its ganglion, the corpus dentatum. The fibres pass downwards into the anterior column of the cord, taking their course from the middle to the fore-finger without changing hands or decussating. Above, the fibres of both the pyramids and olivary bodies pass between the transverse layers of the pons Varolii, and are continued in the crura cerebri, through the optic thalami and corpora striata, to the hemispheres, the fibres of the olivary bodies being the lower. The restiform bodies, by diverging into the cerebellum, become the processi à cerebello ad medullam oblongatam. There is an essential particular to be observed in reference to the anterior pyramids: they send a band of fibres with the restiform bodies to the cerebellum (the aciform fibres of Solly), which, on coming off, divide, and inclose the olivary body on each side. It is also important to observe that the restiform bodies send up a small column of fibres on each side the posterior fissure to the cerebrum. In the medulla oblongata these columns are marked off from the restiform by a slight indentation. They are termed the *posterior pyramids:* they pass up to the brain in connection with the processes connecting the cerebellum to the cerebrum. By raising the anterior portion of the pons Varolii, the *motor tract* is exposed, descending from the corpora striata to the anterior pyramids: from this tract arise all the motor nerves. By turning aside the corpora restiformia on the posterior aspect, the sensory tract is exposed: there are the fibres of the olivary bodies and posterior pyramids passing up to the thalami optici in the posterior layer of the crura.

Functions of Medulla Oblongata.—It is found that disease or lesion seated on one side of the medulla oblongata, or in one side of its fibres, as they are continued in the crura cerebri within the pons, will produce paralysis of the opposite side: this is owing to the decussation of the pyramids, and accounts for cross paralysis; but no results have been obtained from the pathology of the medulla oblongata itself, or from experiment, owing to the liability there is of the sound side to become involved in the experiment, or to partake of the disease: mechanical irritation of the medulla oblongata produces irregular and spasmodic breathing, and difficult deglutition, in consequence of the nearness of the nervous centres of these important functions, which consist of portions of vesicular matter. The brain may be removed, and so also the spinal marrow; the medulla oblongata also may be cut away to within a few lines of the origin of the pneumogastric nerves, without destroying life: the power of deglutition will continue in such a case, and respiration will proceed,—weakened, indeed, from various causes, such as the withdrawal of the aid respiration obtains from volition, the shock the nervous system has received from the mutilation, and especially from the circumstance that, though the centre of respiration is left entire, the centres of the movements of respiration have been nearly all removed with the spinal column. If, however, the spot spoken of in the medulla is invaded, and the brain, spinal cord, and other parts, are untouched, so that the nerve-centres of the muscular movements of respiration are preserved in their integrity, yet this particle of vesicular matter being disorganised, there will be no impression of the "necessity of breathing," and respiration will immediately cease.

Although the centre of respiration is not the nervous centre of the respiratory movements, it is the source of the rhythm and regularity with which they take place, both as to the periods of intermission, and the combining a number of muscles together in simultaneous contraction. The principal nerves that, in connection with the centre of respiration, form the afferent or excitor division of the nervous arc (without which, and a motor division, no diastaltic or reflex action can be complete), are the pneumogastric. Experiments on the roots of these nerves give negative evidence of their functions. Such irritation appears to produce motion and sensation only in a slight degree. Positive evidence of its function is, however, obtained in the respiratory movements that the irritation occasions, which are not thought to be due to motor fibres of the vagus, but to a reflected action from the centre of respiration to the several centres of motor nerves of respiration. The fibres of this nerve that convey to the centre of respiration the impression that ends in respiration, are those contained in its pulmonary branches, and are called afferent or esodic; and as the nerve-centre is not endowed with common sensation, neither are these fibres. The impression spoken of is supposed to be due to the presence of carbonic acid in the blood of the capillaries of the lungs, and imparted to the vagus through the intermediate agency of the sympathetic, which is the proper nerve of blood-vessels: it may be that the sympathetic ganglion at the origin of the vagus imparts this power to the nerve-fibres. This impression is not necessarily appreciable to common sensation, though we shall see that common sensation is an acknowledged excitor of respiration. Section of the vagi on both sides causes a diminution of the respiratory movement to at least one-half; and the removal of the cerebrum takes about the same effect. The peculiar and somewhat difficult character of the respirations during sleep is explained by the aid that respiration obtains from volition being withdrawn at that season; and the voluntary sigh with which ordinary respiration is interspersed at short intervals, declares the fact that respiration would flag and be insufficient for complete aëration of the blood, but for the impulse conferred upon it by volition. The stertorous breathing of apoplexy arises from an extension of the injury to the centre of respiration. It has been ascertained that the division of both vagi, together with the cerebrum, does not entirely suspend respiration. Dr. M. Hall observed that these operations reduced the respiratory movements to four in the minute; but, by the application of cold air and water to the animal, he succeeded in producing from twenty to thirty respirations in the same time, and thereby added an interesting proof of the efficacy of cold as an excitor of the process, and that the sensory nerves generally on the surface are the agents. Although the physical impression of the necessity of breathing is not ordinarily attended with sensation, it gives rise to sensations of great distress when the impression is intense: it is in this way that the physical impression becomes instrumental in summoning the voluntary efforts in the process of respiration; and from the fact that an impression may thus become a sensation, and the fact, also, that some mucous membranes that are normally the seat of nervous impressions, and not sensations, do, under excitement and inflammation, become painful, we are led to adopt it as a principle in physiology, that esodic impressions become sensations under certain aberrations from their normal condition. The nerves that act as the physical excitors of respiration (which produce the impression and not the sensation) are by far the most energetic excitors of the process. This may be inferred from the fact that man passes a third of his time in sleep, during which period respiration is carried on by the physical excitors. The motor nerves that are called into operation by the stimulus generated by the centre of respiration, and transmitted to their respective motor centres, are the portio dura, the spinal accessory, the inferior laryngeal (the motor nerve of the larynx), the phrenic, and the intercostal nerves. The actions of *sighing*, *yawning*, *laughing*, *crying*, and *hiccup*, are reflex movements from the centres of respiration, sensation, or emotion, according to the causes from which they proceed,—whether, for instance, from the sense of pain, the feeling of emotion, or whether they are a modification of respiration. Hiccup is of the latter description, attended with a sudden contraction of the diaphragm, and a sudden closing of the glottis. Laughing is a succession of expiratory movements with the glottis open: the same is also the case in crying.

Coughing and *sneezing* are expulsive efforts to rid the air-passages from offending matters: they are produced by first filling the chest by an inspiration, closing the glottis, and then expiring or blowing out till the glottis is forced open. Blowing the nose is a representation of these actions: the sides of the nostrils are pinched together and obstructed until the *vis à tergo* is enough to force them asunder. In sneezing, the velum is brought against the root of the tongue, which, closing the passage through the mouth, directs the air through the nostrils.

Almost all the muscles of the body are brought into co-operation in attacks of dyspnœa and violent coughing; and at such times the muscles of the face, neck, shoulders, chest, and abdomen, will respond indifferently to the physical or the mental stimulus that calls them into action.

The nervous centre of *deglutition* is in the medulla oblongata: the pharyngeal stage of it, which is the reception of food by the pharynx, and its transmission into the œsophagus, is entirely a physical, reflex, or diastaltic action. Without the aid of a morsel of food, fluid or solid, it is impossible to set the machinery of deglutition in motion by any effort of the will. It is, moreover, performed when all influence of the will has been suspended, in apoplectic cases, and also in anencephalous infants. The excitor impressions are principally conveyed to the centre of deglutition by the glosso-pharyngeal nerve—a nerve distinguished by its negative attributes, in possessing few or no fibres of motion or common sensation, excepting, at least, those fibres that are distributed to the back of the tongue, which supply that part with the special sense of taste, and which is nearly allied to common sensation. The other excitors are probably the gustatory and the superior laryngeal. The motor part of the arc is supplied, according to Dr. J. Reid, by the pharyngeal, the hypoglossal, the inferior laryngeal, some motor branches of the fifth, the portio dura of the seventh, and descendens noni. The centres of this list of nerves are variously placed in the cerebro-spinal axis, and indifferently respond to the mental stimulus of volition in their vocation as instruments of voluntary motion, or to the physical stimulus from the centre of deglutition, which also supplies that co-ordination and adaptation that secures the rhythmical and combined action of the numerous muscles engaged in the process. The mucous membrane of the pharynx is highly susceptive of its proper physical impression: the touch of a feather produces the act of deglutition, but the presence of the feather in contact with the pharynx is scarcely perceived by touch or common sensation.

The *mesocephalon*, or *pons Varolii*, claims little attention with regard to its functions, farther than being commissural, and that it effects that union between the two hemispheres of the cerebellum which is necessary for consentaneous action; connecting, also, the anterior pyramids and olivary bodies with the cerebrum. It is worthy of notice, however, that a large portion of vesicular matter is irregularly placed amongst its fibres, which causes it to be ranked amongst the tract of nervous centres of this region. The *crura cerebri* are layers of commissural matter inclosing a semilunar portion of grey matter, from which the third nerve arises; and the fourth winds around both, which are motor.

The *corpora striata* and *thalami optici* have certain anatomical characteristics which not only denote that they exert an influence on all fibres by which they are traversed, but also that they differ from each other essentially in the offices which they perform: they do not consist merely of a centre of vesicular matter, with an external coating of the fibrous, but there is in their structure such an intimate mixture of the two substances, that the whole is tinted with a greyish colour, the corpora striata having the deeper tint. A great portion of these fibres, according to Todd and Bowman, originate or terminate in the ganglion, but are so multitudinous and thickly set that the caudate unions with the vesicles cannot be distinguished. In the corpora striata the fibres are partly collected in bundles, whence their striated appearance. There is also an extensive commissural connection between the two bodies, and each has its special connections with the medulla oblongata. The fibres from the corpora striata mostly form the lower layer of fibres in the crura cerebri, and thence pass to the anterior pyramids of the medulla and lateral columns of the cord. The fact that paralysis is a certain effect of lesion of the corpora striata, or even of extravasation of blood in their vicinity, is held to be strong evidence of their motor function. Experiments on animals do not throw much light on the nature of the functions of either of these bodies, for the gradual removal of the corpus striatum does not invariably produce either paralysis or convulsion; nor does the cutting away the optic thalamus produce any great disturbance of common sensation. The fibres of the optic thalamus may be traced into the upper layer of the crus, having the locus niger between the two layers;

thence passing to the olivary bodies, and downwards to the anterior columns of the cord. If we add to this latter tract the posterior horns of grey matter of the cord, and also the posterior roots of the spinal nerves, we have the whole sensory tract complete, with the exception of this chasm in the account, that owing to the difficulty attending vivisections of the cord the functions of the columns have not been determined. From this tract the sensory nerves, common and special, either directly take their origin or can be traced to it. Although some fibres of the optic tract may be traced into the thalami, it does not appear that they exercise any influence on the special sense of vision. According to Flourens and others, the removal of one thalamus is followed by a rotary movement in the animal, but no paralysis. These are effects similar to those attending the loss of one crus cerebri: but, though these bodies appear to be placed at the heads of the respective departments of motion and sensation, still it must be borne in mind that they are not the centres of these functions; the centres of motion being in the segments of the cord. But of the parts that are assigned to these bodies in the functions of sensation and motion, we cannot speak particularly, except that, if they do not form integral parts, they are at least important adjuncts to the machinery of these functions; bearing in mind also that Dr. Carpenter has satisfactorily shown that, between the seat of the involuntary and physical actions that are proper to the spinal cord, and between the seat of the higher emanations of the brain, are a tract of centres intermediate in character, of which these two form part, in which are centred the emotions, and from which, we would add, is furnished the stimulus for other actions termed consensual, automatic, and emotional; that these, being without the pale of the cerebrum, and of a higher order than those proper to spinal centres, are in some way represented by the corpora striata and optic thalami, composed as they are of a large quantity of vesicular and fibrous matter, the arrangement of which stamps upon them the characters of organs for producing and dispensing dynamic force; the *rationale* of whose action could not be explained but by this hypothesis. This doctrine may be said now to be placed among the maxims of physiology, and for the correct classification of these actions, and the localising their centres, the science is indebted to Dr. Carpenter; but the existence of such actions—that they are dependent on sensation and independent of volition—was previously enforced by Dr. Alison. Of the nervous mechanism of these actions, the theory of Todd and Bowman has been adopted here in preference to that of Dr. Carpenter, who assigns to them separate fibres. The movements of locomotion, although almost inoperative without the exciting stimulus of the will, are virtually independent of it, the nervous centres of which are in the spinal cord. The independent part of locomotion is rude and objectless without the sensory ganglia to convey to the cerebrum a sensation of touch in every muscle (muscular sensation)—the cerebellum to arrange the order of movement, and the cerebrum to furnish the ideas on which volition is grounded. Nevertheless, if the cerebellum and sensory ganglia keep their posts, the influence of the cerebrum may be occasionally withdrawn, and locomotion will proceed orderly and rhythmically. This is exemplified when deeply engrossed in thought: we walk beyond the place of our destination, and totally withdraw all guidance from our steps; or when we find ourselves reading, our thoughts being entirely occupied in another direction. These movements are called by Dr. Carpenter *automatic*. That such movements are independent of the cerebrum is shown by the fact that locomotion is continued in animals (especially in insects) after decapitation, and the same in animals from whom the cerebrum has been removed. By frequent repetition, actions that are at first voluntary become involuntary, and assume the characters of the foregoing class: this constitutes the force of habit. Some permanent change appears to take place in the cord,—the nervous centres of locomotion by which they respond to another stimulus than the mental, and that stimulus making its approach in the way of an afferent or esodic impression by the sensory ganglia. Dr. Carpenter has given the name of *consensual* to a group of actions which, in man and some of the higher vertebrata, are generally performed under the direction of the will. These are the instinctive movements of animals, of which the bird's nest and the spider's web afford good examples. There are some movements of a like nature in man; but, before further alluding to them, it will be well to state that the nervous centre of these movements we presume to be the spinal cord, the common centre of all locomotion. The usual stimulus that acts on the nervous force that produces locomotion has been already pointed out to be the mental stimulus—volition; but, in the movements in question, we have not this stimulus, nor have we the usual stimulus that sets on foot ordinary reflex action through its appointed channel, the afferent or esodic nerve-fibres. Now the class of movements in question are supposed to have the esodic or afferent division of the diastaltic arc accomplished through impressions received by the sensory ganglia, the centres of sensation and emotion; and we would add that in these centres is generated the stimulus which is issued to the centres of locomotion in the spinal column, that respectively command the various muscular actions that come into operation in the manifestation of the whole of this class of movements. The movements that physically demonstrate *emotion* are shown to be independent of volition by the fact that, in paralysis of the facial nerve, the muscles that are not controlled by the will are moved by emotion. Emotional movements may be excited by the mind, though, being excited, they are physical and involuntary. An idea may produce such an effect, or an hysterical paroxysm may be called forth by the stimulus of emotion. Dr. Carpenter is the discoverer of the *locale* of the nervous centre of emotion. By a train of reasoning that has brought Dr. Todd to his opinion (Ibid. p. 722), he has placed it in the entire region of the sensory ganglia, especially the corpora quadrigemina. This region is connected to the spinal column by the sensory tract, the thalami; the anterior pyramids passing backwards to the lateral columns of the cord, and probably thus joining the posterior roots of the spinal nerves. Dr. Carpenter not only claims emotion for these centres, but the muscular actions that accompany them. This he does in accordance to the usage that sanctions the same rule as regards the nervous centres of respiration and deglutition. It would greatly simplify the subject, and infringe nothing on the acknowledged boundaries of these hypotheses, if we separate in language, as it is in fact, the *impression* that produces the muscular action, from the action itself. Thus, in respiration, the impression of the *necessity of breathing* is the only impulse that is centred in the medulla oblongata, and constitutes the centre of respiration. The centres of muscular motion that make up the mechanical part of the performance are not in the centre of respiration: though some are near it, others are in the spinal nerves. The centre of respiration is the organ in which the impression of the necessity of breathing is quickened and becomes effective, and which issues the stimulus and the rhythm of action to the centres of the muscles of respiration. We obtain a better view of the whole subject by bearing in mind the fact that no nervous force can produce muscular contraction without a stimulus: the principal source of stimulus is the mind, which, by being furnished with ideas of sensible things by the cerebrum, generates volition therefrom, and thence guides and controls the muscular movements of animal life by stimulating the nervous centres of such movements, in virtue of the fibrous or vesicular connection between the brain and those centres. The movements of respiration, deglutition, emotion, &c., being independent of the brain, do not depend on that chief of ganglions for a stimulus, but are provided with it by ganglions of their own—their respective centres. The centres of muscular action are the same in all, whether voluntary, diastaltic, emotional, automatic, &c., and are seated in the cerebro-spinal axis; and there is in all a fibrous or vesicular connection between the ganglions furnishing the stimulus and the nervous centres of motion. For a correct description, then, of the mechanism of the diastaltic or reflex nervous arc, the usual account of the afferent or esodic division need not be disturbed; but to the efferent or esodic division should be added the commissural connection between the centre furnishing the motor stimulus, and the centres of motion; and this may be done without rudely interfering with the present theory.

The muscular movements that physically illustrate the emotion of grief by sobs, horror by a shudder, joy by a thrill, surprise by a scream, enthusiasm by action, or those movements of agitation which caused laughter to be seen "holding both his sides," require the co-operation of many motor nerves to accomplish; chiefly those coming from the medulla oblongata, as the fifth, the portio dura, the glosso-pharyngeal, and the par-vagum, the spinal nerves, and those especially of respiration. We suppose that the movements in question are seated in the centres of these nerves, and that the stimulus by which the nerve-force is furnished (all nerve-force requiring such a stimulus) is by the sensory ganglia, somewhere in which the centre of emotion is seated. The organs of sense, or the mind, variously supply the esodic division of the arc by their connections with the centre of emotion, and the motor stimulus issuing therefrom, and the cerebro-spinal centres referred to the efferent or exodic division. The centre of emotion, constituted as it is of a portion, more or less, of grey vesicular matter, is supposed to be localised in the tract of ganglia at the base of the cerebrum, that, by their influence and commissural fibres, emotion may be fully developed; intelligence is close over-head to appreciate the influence transmitted; the organs of special sense stand round to produce their single or conjoint effect; common sensation forms the chair on which she is seated, which, with the aid of the centres of motion underneath, make up the complement of her handmaidens, having those of the latter stationed in readiness at her feet that supply the tear and the smile—the fifth and the portio dura. Besides generating the nerve-force of emotion itself, and the stimulus for the physical movements of emotion, this nerve-centre tinges and colours the character of every individual, and, as the character of emotions may predominate or be encouraged, makes the difference between the sombre and the gay, the morose and the benevolent,—a subject well treated by Dr. Carpenter. It is not meant to be inferred that the mental stimulus which ends in voluntary motion, and the stimulus to muscular action that is furnished by the centre of emotion, may not act together. On the contrary, we are all aware that the one is strengthened by the other, and that the muscular efforts of combatants, which are perhaps at first only the result of volition, are much increased in energy when aided by the emotions of anger and revenge.

The *corpora quadrigemina* are the centres in which are realised and brought into existence the impressions of vision conveyed to them by the optic nerves. The removal of the corpora from animals not only produces stone-blindness, but causes, also, paralysis of the irides. From this latter circumstance it is inferred that these ganglia, besides being centres of vision, furnish the stimulus of action to the nervous centre of the third nerves, by which the irides are moved. There is a reversion of the order of muscular action in the iris; at least in the circular fibres it dilates instead of contracts under stimulus, which modification of its action is attributed to an influence imparted to its motor nerves whilst traversing the ophthalmic (sympathetic) ganglion. The removal of one tubercle causes blindness to the opposite side; but in this case it is observed that light admitted to the sound eye causes the iris of both eyes to contract simultaneously by sympathy. They are supposed to contain more vesicular matter than is necessary for the purposes of vision. Comparative dissections confirm this opinion, by supplying the fact that in animals that have very diminutive eyes these bodies are not small in proportion; and the centre of emotion is said to be wholly or partly there.

Cerebellum.—Experiments on the cerebellum have been undertaken by Flourens, Longet, Magendie, Budge, Hertwig, and Bouillaud, with nearly uniform results. Flourens reports that the gradual removal of the organ from guinea-pigs and birds produced, in the first part of the operation, a slight irregularity in walking and standing; and, as the operation proceeded, the animals exhibited the want of order in motion rather than the want of strength which is observed in the staggering of drunkenness. When the animal fell, its efforts to rise were powerful, but misapplied. When the entire portion was removed it could no longer stand, or, when down, regain the erect position; and a bird so mutilated, on being thrown in the air, could not even fly to the ground, though, when there, it could struggle apparently with every muscle. The movements appeared the effect of volition, and not of convulsion; for neither special nor common sensation seemed paralysed. It both saw and avoided the coming blow, and felt the effect of it when inflicted; nor was the sense of hearing impaired. The above phenomena physiologists infer to be the loss of the co-ordination of the actions of muscles, or the absence of the faculty of combining the action of muscles in sets or groups; and although in these animals the muscles may have acted in groups, so as to produce the flexion or extension of a limb, the order of action between the limbs was lost. Neither pain nor convulsive movement were produced by cutting into the cerebellum; but it is worthy of remark that the animals became restless during the process,—a fact that claims the more attention in consequence of a restlessness being a prominent symptom in certain pathological states of the organ. It is maintained that the foregoing phenomena are not the effects arising from the disturbance to the nervous centres that such an operation would be likely to occasion, for the reason that the removal of the cerebrum in the same species of animal does not occasion the loss of equilibrium and such want of combined actions. The pathology of the cerebellum affords evidence in support of this view of its functions, but being so generally complicated with disease of the other parts of the encephalon, the evidence deduced is rather of a negative than a positive character. The tables of M. Sèvres, which give a comparative view of four classes of vertebrate animals, show that those whose movements require the associated action of the largest number of muscles are the most developed in the cerebellum. There is a variety of common sensation which is proper to the muscles, by which a knowledge of the position of the body and all its parts is conveyed to the mind. Although the cerebellum, like the cerebrum, is shown to be without sensation, it is maintained that the cerebellum is the seat of this muscular sensation. The combination and co-ordination of the action of muscles may be of a higher order than is comprehended in the mere sense of position; but still, a sense of the position of muscles seems as requisite to the grouping process as the knowledge of the position of every regiment is necessary to a general officer in the day of battle. The function is independent of the will, and the influence exercised is in its nature automatic: take away the sense or the impression of distance seated in the cerebellum, and, though the muscles of each leg may be properly grouped in their movements, the length of the step could not be determined. We sometimes become confused in the order of moving the legs in descending a staircase: this would seem to arise from a withdrawal of that control of the cerebellum which gives the rhythmical sequence to the action of the groups of muscles concerned in moving the legs. Drunkenness appears attended with a particular disorder of this co-ordinating faculty. A man may be stronger in muscular power under the excitement of alcohol, and yet be unable to walk in a straight line. No one doubts the energy with which such persons can vociferate, and yet that they have no power of rightly adjusting the length of the vocal cords is proved by the drawl and the clipping of the words that such irregular action of the muscles of the larynx produces. The senses and volition are not usually affected unless the intoxication is profound. It has been humorously said, that the senses do not become extinct in the positive nor the comparative degrees of drunkenness, but only in the superlative; and, as a proof that the cerebellum is more affected than the cerebrum, there is a proverbial saying, that "a man is never so drunk but that he can lay on his back and call for a cab." M. Longet observes, that a pigeon from which half the cerebellum has been removed "exhibits the unsteady and faltering gait of drunkenness." It may therefore be admitted amongst the principles of physiology, that while ether exercises a signal effect upon the functions of the cerebrum, alcohol principally affects the functions of the cerebellum. Dr. Todd points out that the anatomical relations of the cerebellum support the co-ordinating hypothesis by the fact of its large connections with the posterior column of the cord, and the greater relative proportion of fibres in this column. While the anterior and lateral are the especial columns of the cerebrum, the posterior column has been shown by Dr. Todd to be that of the cerebellum. He has also well observed, that there is a special connection between the cerebellum and the centre of common sensation, as if for the purpose of combining sensation with the co-ordination of movements. The connection alluded to is the processus à cerebello ad testes, and the column of fibres that is sent up from the posterior column of the cord to the optic thalamus in the shape of the posterior pyramids, and forms part of the processus à cerebello ad testes.

The development of the functions of the cerebellum, like those of the cerebrum, and sensation common and special, is effected by the gradual process of growth. In the early period of human life, it is observed that the grey vesicular matter of the cerebrum and cerebellum is very imperfectly formed: so, also, are the functions of these organs. With this direct ratio between the proportions of nervous matter and dynamic power in infancy, there is also a remarkable correspondence between the two as the respective structures progress towards maturity; maturity of function in each being accompanied with the full growth of the convolutions, and a consequent vast extension of the layer of grey vesicular matter on the surface. Although the cerebellum is equally as powerless as the cerebrum in early life,—which may be gathered by the unmeaning and ill-directed movements of a new-born infant,—it is held by physiologists that the cerebellum becomes mostly developed in childhood, or at that period of life in which the nice adjustment of the contraction of sets of muscles in all their intricate proportions is acquired, and, as it were, stamped upon the memory by means of muscular sensation. The hypothesis that the cerebellum is the nervous centre of the sexual appetite not being generally considered to be founded on sufficient data, and at most a questio vexata, is not here introduced.

The Cerebrum.—There are a few leading characteristics of the structure of the cerebrum that it will be desirable to notice before we proceed to the subject of its physiology. Both this organ and the cerebellum form exceptions to the plan of arrangement of the two elements of nervous matter, as usually

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The Cerebellum.

The cerebellum regulates the action,
And sets in order muscles for contraction,
Exerting on their motion no control
Save to adjust and harmonise the whole.

observed in ganglions:—1st. vesicular being placed on the exterior, and 2nd. in the depth and perfection of the convolutions of which their surfaces are formed. The objects gained by these deviations appear to be mechanical, being the best of all methods of arranging and disposing in the smallest space a very large surface of vesicular matter (which when spread out is in the shape of a pancake,) into a hollow sphere; regard also being had to the following special provisions,—that fibres from every part of this expanse proceed in the direction of one common opening, and that also an intimate commissural connection of fibres is established between all its parts; the vesicular portion being potential, and the fibrous being internuntial in their offices. Amongst the fibres are observed four principal sets in connection with the grey matter. A descending motor set, to convey nervous force to the corpora striata; an ascending set, conveying common and special sensations and emotions from the optic thalami; and two sets of commissural fibres, one transverse connecting opposite sides, and one for connecting all parts of the same side. Not least amongst the prominent features of the cerebral structure is the fact that the whole of these fibres, and also the vesicular matter, are totally insensible to all stimuli except their own—the mental; for neither irritation, not even the galvanic, nor cutting into the substance of the cerebrum or cerebellum, produces either motion or sensation. It is therefore obvious that a striking difference exists between the fibres proper to these hemispheres and those of the cerebro-spinal system, and unquestionable proof is here given, not only that the veritable fibres contained in the spinal nerves are not continued directly to the cerebral hemispheres, but that the connection is indirect and commissural. As a general proposition, it may be stated that the size of the head and the depth and perfection of the convolutions, taken together, are in direct ratio to the intelligence both of man and of animals. Fifty ounces is the average weight of the entire brain in the human male; about five ounces should be deducted for the female, and by adding or deducting fifteen ounces from either of the foregoing numbers of ounces, we arrive at the maximum and minimum weights; and, if the weight of the brain does not come within these numbers, it will be evidence of disease or idiotcy. While the average weight of the brain, as compared with the whole body, is about 1 to 35, one sixth of the entire volume of the blood is circulated in the brain. Provision is made to avoid pressure of blood on the brain, that might otherwise be occasioned by the unyielding walls of the cranium, by the tortuosity of the trunks of its arteries, and also by the protection that one of its arteries (the vertebral) receives in its approach to the brain, in the bony foramina of the spinal column. Protection is also afforded by the *cerebro-spinal fluid*, which is contained in spaces formed between the arachnoid and pia mater, both in the cranium and spine. This fluid amounts to about two ounces, and probably the whole admits of being pressed down into the spinal cavities; upon occasion requiring it to act as a safety valve. The brain is the instrument of intelligence. The word *instrument*, so applied by Dr. Carpenter, is better than the word *centre:* however essential the cerebrum may be to enable the soul of man to hold communication with the world, it rests on physiological evidence sufficiently good, if such were necessary to support the truth of revelation, that the functions of the cerebrum are subordinate to the operations by which we demonstrate the existence of soul,—such operations being volition, perception, thought, &c. The term *centre* of intelligence, as applied to other ganglia, would not therefore be applicable to the cerebrum. The health and integrity of the cerebrum is indeed essential to the soul, in bringing volition, thought, and perception, to bear on things of sense, and there is doubtless an

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Brain.

The brain *tout en masse*, physiologists say,
One-fortieth part of the body doth weigh;
Much then from the blood vis nervosa must drain,
Since a sixth of its volume is sent to the brain;
One half is composed of albuminous matter,
The other a fat, and for centage of latter,
Give oxygen twenty, give hydrogen ten,
Give phosphorus two, and give two nitrogen,
Give carbon the balance, and do not refrain
To own you have cerebric acid of brain.

unfathomable union or connection between the two, which will not be understood.

That the cerebrum has an operation independent of the indestructible part of human nature is seen in the lower animals; and that the cerebrum is the organ of intelligence is proved by the fact that the whole organ may be removed from animals, with the result of a loss merely of psychical powers. The animals, according to Longet, though plunged into a sleepy stupor, appeared to preserve sensation in all its varieties, but lost the power of making sensations available by grounding ideas upon them. The whole of one hemisphere has been removed, with no result except a little weakness of the opposite side of the body. As regards pathology, some cases have occurred in which one hemisphere has been almost wholly destroyed by disease, yet without injury to the mental faculties. A sudden and slight effusion or lesion will sometimes cause severe symptoms, when a chronic alteration of the same kind and amount would be innocuous. If convulsions are present in complaints of the brain, it is inferred that parts as low down as the corpora quadrigemina are in some way involved in the mischief. An accelerated circulation of blood in the brain, by increasing nutrition and growth, stimulates the functions of the cerebrum, and promotes a corresponding growth of ideas, or a fruitful pabulum for the *occasions* from which they arise: if with this is accompanied a general fulness of the system, the lower ganglia will partake of the plethora; ideas, the rank produce of the emotions, will crowd upon the already excited mind, and a state likened in Scripture to "fed horses in the morning" will need to be restrained and governed. If nutrition is so active in the brain as to assume the characters of inflammation, the balance and consentaneous action between cerebrum and mind is destroyed, and ideas come in such confusion before the mind that it can no longer take them in order. Ideas furnished, by the immediate presentation of objects to the mind, by the ganglia of sense, are confounded with ideas from former impressions made by the same ganglia that have been transferred to the memory; and *vice versâ*. If with this state the nervous or polar force is augmented and exalted in the centre of volition, this part also will be disturbed in its functions (the centre of volition comprehending the segments of grey matter from the corpora striata through the spinal column); then will the patient not only mentally rave, but probably require to be physically restrained. If, instead of this state, or during this state, the brain becomes compressed and condensed, from an undue quantity of blood, or other cause, the nutritive process is checked, no occasions of ideas are furnished, the balance between mind and organization is upset, and the patient is either stupified, or lies in profound coma, according to the extent of the pressure. Insanity is a disorder of the vesicular portion of the cerebrum; in the confirmed states of this disease this portion of the brain becomes more or less softened, and altered in colour, or in an opposite state of consistence, the arachnoid and pia mater being opaque and thickened.

The cerebrum is the only medium of approach by which a knowledge of the qualities of the material world can reach the mind of man. The manner in which this is accomplished philosophers have not been able to determine, and since the time of Mr. Locke no advance has been made in the knowledge of this obscure subject, unless the retrograde movement can be considered in this light,—that of rejecting Mr. Locke's hypothesis of ideas as the origin of our knowledge. Mr. Locke's doctrine embraced two great classes of ideas, one having its foundation in the attributes and qualities of matter, such as ideas of colours, of sounds, of hardness, of motion, or of extension, and these finding admission to the brain by means of sensations, and the other being ideas of our own mental operations, those for example of memory, of imagination, of pleasure, or of pain. The first class of ideas, according to this doctrine, is received by the mind through the medium of material organization—the cerebrum and organs of sense; and two objections have been raised against it,—first that it deals with ideas too much in the matter-of-fact manner of materials in chemical experiment, or like some daguerreotype process by which the notions of sounds, colours, and other sensible materials, can be transferred to the substance of the brain; and 2ndly, that an unwarrantable use has been often made of it to support the arguments of sceptical writers. Dr. Reid was the first to strip from this subject the artificial clothing placed upon it by Mr. Locke, and by so doing he robbed it of a perspicuity that made it simple and intelligible, and most acceptable at the period of its enunciation, when the subject was not only encumbered with speculative hypotheses, but when knowledge had not been analysed into elementary principles, and for which this doctrine formed an easy method. The subject, so denuded, and reduced to its primitive obscurity by Dr. Reid, is thus stated by Mr. Stewart:—" The mind is so formed, that certain impressions produced on our organs of sense by external objects are followed by correspondent sensations, and that these sensations are followed by a perception of the existence and qualities of bodies by which the impressions are made; that all the steps of this process are equally incomprehensible, and that the consideration of these sensations, which are attributes of mind, can throw no light on the manner in which we acquire our knowledge of the existence and qualities of body." From this view of the subject it follows, that it is the external objects themselves, and not any species or images (ideas) of these objects that the mind perceives, and that, although by the constitution of our nature, sensations are the constant antecedents of our perceptions (a perception being the act of the mind perceiving a sensation), yet it is just as difficult to explain how our perceptions are obtained by their means, as it would be on the supposition that the mind were all at once inspired without any concomitant sensations whatever."—Elements of the Philosophy of the Mind, p. 69.

We are equally in the dark concerning the intrinsic nature of sensation: it is said to be an impression of the qualities of matter conveyed to the mind, but neither it nor the thing conveyed resemble the qualities of matter any more than the names of things resemble the things they represent. We have no grounds for concluding that a class of ideas is furnished by, or is the product of, an organised structure; the most we can say is, that by certain impressions made upon the organs of sense, and the ganglia connected therewith, that the mind (which is another word for the imperishable soul), by laws relating to its own constitution, and by medium of the cerebrum, forms ideas or notions of the qualities of the material universe, and which qualities become the subject matter on which the mind afterwards exerts its powers of composition, abstraction, generalisation, &c. Of the first class of ideas, those derived from sensible things, or the qualities of matter, some are termed *simple*, and others *complex :* the occasions on which the simple ideas of colours and sound are formed in the mind are by sight and hearing; extension and figure, both by sight and touch; the perception of the changes that take place in the states and modes of matter suggests the simple idea of a cause. Complex ideas are those which convey to the mind something more than elementary notions of the qualities of matter: for instance, the ringing of a bell conveys the idea of a bell as well as the simple idea of sound. Perception is the act of the mind perceiving sensations through the medium of the cerebrum. The sensory ganglia occasionally receive sensations that are not perceived by the mind, the cerebrum having as it were forsaken its post. This is inferred by the fact that sleepers in church are awakened if the preacher stops suddenly in his discourse, or the miller is aroused if his mill ceases to grind. A clock may strike in the same room with us without our perceiving it, and yet it cannot be doubted that the sense of hearing was at the time in perfect operation. There are two classes of perceptions, the *acquired* and the *intuitive :* the movements of the human infant need to be regulated by the gradual *acquirement* of the perceptions of the relations and qualities of matter, such as notions of distance, solidity, &c., which is accomplished by the medium of the cerebrum, and is necessary in addition to the co-ordinating faculty conferred by the cerebellum. The intuitive class is principally seen in the young of the lower animals, which enables them, by intuitive ideas of the qualities of matter, at once to procure their food. Such ideas are therefore connate, and the nervous centre of the actions that result therefrom—the instinctive—is in the sensory ganglia.

The memory is supposed to be a function of the cerebrum by which ideas are retained as it were in a dormant state, in readiness for the mind to recur to, either accidentally, or by a direct mental effort to reproduce them. Reasoning is the exercise of mental operations upon the ideas, and so far as the ideas are complicated with the sensible qualities of matter, so far they are dependent on the functions of the cerebrum to carry these operations into effect; the mind is therefore incapable of obtaining knowledge of external things, or education, except by means of the cerebrum. The reasoning operations referred to, are, first, *composition*, which is the aggregation and collocation, or the combining the simple ideas which most objects convey, into a representation or general expression of the object. *Abstraction* is the separation of the various qualities and components of complex ideas. *Comparison* is the perceiving the relations and bearings by which ideas reciprocate. *Generalisation* is the general application of comparison to a number of ideas. *Conceptions* are lively ideas of sensible things, whether according to truth or exaggerated. *Imagination* is the power of modifying our conceptions by combining the parts of different ones together, so as to form new wholes of our own creation. We demonstrate the separate and independent existence of mind by such qualities as perception, thought, and volition; it has been shown how the material universe supplies in a large degree the subjects on which these powers act. We receive from God a soul pregnant with the above powers: we receive also a material organization by which these powers are called forth,—the qualities of the material mass by which this is accomplished bear no analogy to the qualities of soul: matter can produce vital phenomena, but to attribute to it mental phenomena is to confound the flower with the sod on which it grows. The latent and inherent qualities of mind may be likened to the latent varieties of species that are stored up in the seed of the wild flower; the soil, and the cultivation that brings them into existence, may be compared to the subordinate media of the brain, and education, in enabling the mind to exercise the various operations which we have enumerated—perception, composition, &c., on the ideas. Perception, &c., have therefore the above relation to the brain, but it is no more the product of the brain than the rose is the product of the ground instead of the wild thorn. The foregoing comparison applies chiefly to the operation of the mind upon the first class of ideas, or those from sensible objects. The second class are generally mixed with the former, but there are some so free both from the taint of material things conferred by the cerebrum, or the taint of emotions and passions, the growth of still lower organization,—so free, as Mr. Locke expresses it, from the "tang of the cask,"—that they are termed fundamental principles of thought, in which are included belief in personal existence and identity, ideas of conscience, responsibility, right and wrong, &c. "Although," observes Dr. Alison, "each conception (a conception being an idea matured by mental operation) is involuntarily presented to the mind, yet we are conscious of a voluntary power of retaining it in the attention, or of letting it pass off, which leads us to believe that it has no existence independent of the mind." An impartial consideration of the phenomena of mind is sufficient to show, in the words of the same writer, "that the only foundation of much of our belief, and the only source of much of our knowledge, is to be found in the constitution of our own minds." The term volition, as used by writers on the philosophy of the mind, and by writers on the physiology of the brain, has different significations; in physiology, the centre of volition means the nervous centres of voluntary motion, or the machinery through which the volition or the will of mental philosophy acts: the true centre of volition is not in the cerebro-spinal centres, but is a quality or operation of mind. It cannot act on matter or sensible things, except first by the agency of the cerebrum, which furnishes its proper stimulus, termed the mental stimulus, which in the next place sets in motion the tract of centres from the corpora striata downwards, described as constituting the centre of volition or voluntary motion.

It is admitted by all parties that the second class of ideas, or those called by Mr. Locke ideas of reflection, do not necessarily arise in the mind by the operation of the organs of sense. These are said to be ideas that are suggested by the subjects of our own consciousness: they are thought, however, to have an indirect relation to the things of sense, inasmuch as, without the impressions furnished by the organs of sense, we should never arrive at the knowledge of the possession of our faculties. Ideas of responsibility, conscience, and right and wrong, &c. are truly said to originate in the mind, in virtue of the original qualities of mind by which they are produced: but it is difficult to imagine how they could be called forth, unless the impression of sensible things received by the organs of sense had not previously furnished occasions whereby the ideas of the meaning of the verb πράττω had arisen in the mind; for the exercise of these ideas refers to conduct or action, and action implies a knowledge of matter to be acted upon. At the same time, it is an undisputed axiom in the schools that notions of the operations of mind, or the subjects of our own consciousness, are not *necessarily subsequent* to the knowledge of the qualities, or even the existence of matter. The admission of this connection between the second class of ideas (such as those of the moral discernment of right and wrong, and matters of conscience) and the organs of sense does not involve the admission that the mind cannot be exercised with these ideas independently of the operation of organised structure. There are grounds for supposing, both from anatomy and pathology, that no disintegration or waste of nervous matter takes place during these genuine operations of the mind. It is observed that the grey vesicles of the convolutions of the cerebrum are of their smallest size on their external surface, where they are in contact with the vascular membrane by which they are nourished, and that few are seen to be of their full dimensions except those in contact with the fibrous portions on the internal surface of the vesicular matter. It is argued from thence, that the vesicles traverse from the outer to the inner surface; that it is here that disintegration of the vesicle takes place, and that the operations of the cerebrum are carried on; and that these operations are here manifestly connected with all other ganglia of the body—a state of facts which points to the conclusion that the brain is the mechanism whereby mind is brought to bear upon matter. In regard to pathology, it is commonly observed that the failure of the bodily powers does not impede the progress of thought. It is admitted on all hands that mental application, the nature of which requires incessant communication between sense and mind, is most exhausting to the animal frame: and the fact that one-sixth of the whole volume of the blood is circulated through the brain, and therefore necessary for the generation of the various nervous forces, strengthens such an opinion; and at those seasons of trial when the powers of life are on the wane, nervous force keeps pace with the decline of the other phenomena of life, and the perusal of half a page of printing would be found too great an effort for the dying man. But the pure energies of the mind seem to outlive the victory of chemistry over the powers of organization, and the mind is frequently seen to be unimpaired at the very threshold of the tomb. When those contemplations that arise from the second class of ideas are attended with bodily exhaustion, it is probable that they are not unmixed with the first class of ideas, or those of sensible things, and from which, in fact, they are seldom entirely separate. The fact that the mind is singular, and the cerebral hemispheres plural, furnishes an inference that mind does not originate in matter. Much has been written on the subject of the *duality* of mind; but man cannot entertain such a proposition, although he has no proof to the contrary, excepting that he is told that the contrary is the fact by a dictum from the pure operation of mind,—a connate conviction that he is one being; and as so vast a preponderance of the vesicular matter is doubly arranged, and the smaller mesial portion having a commissural function, it is fair to conclude that the two hemispheres are two servants acting in concert, and not one master occupying the seat of original power.

Sleep.—In sleep, the cerebrum, cerebellum, the sensory ganglia, and those centres of the cerebro-spinal axis which are concerned in the maintenance of the movements of animal life, are in a state of inaction; while those centres which guide and influence the movements of organic life, together with the ganglia of the organic functions (the sympathetic), continue in their usual activity. The augmentation of the nervous forces that influence organic life, and the diminution of the nerve-force that is proper to the centres of animal life, observe an inverse ratio to each other in the production of sleep. This proposition is aptly verified by the comfortable drowsiness that succeeds a long walk, and calls for a nap after dinner; the exhausting effect of great exertion on animal life, and the stimulating effect of nutrition on organic life, both conducing to the same result in inverse proportions. The average duration of sleep in man is from six to eight hours, at which season the consumption of oxygen, the production of carbon, and general waste of the tissues, are all diminished. If the body is exposed to a low temperature, profound sleep is produced; and from 34° to 36° Fah. produces the periodical sleep in hybernating animals, when animal heat is not generated, hunger and thirst cease, and digestion is suspended. The cerebrum being at rest during sleep, the ordinary amount of blood is not needed in the brain. The circulation there is adjusted by the same provision that withdraws the drowsy will from its wonted office in the respiratory process; the respirations become less frequent, the general circulation receives a check, and arterial action is consequently diminished in the brain; the expenditure of polar nervous force is arrested, and at the same time accumulates by the general growth of the grey vesicles that is promoted by nutrition. In sleep the pupil is contracted and the straight fibres of the iris relaxed; the eye is covered by the lid for protection, and the ball drawn upwards by the inferior oblique muscle. In dreaming, the mind and cerebrum are partially awake, but not the cerebellum, sensory ganglia, or the centres of voluntary motion. In somnambulism the centres of voluntary action and the cerebellum are also awake, and the senses partially so. Nightmare is probably the consequence of the ineffectual efforts of volition to arouse the nervous centres of voluntary motion, volition being a quality of mind manifested on sensible objects by the cerebrum.

The following quotation of a few lines from the writings of Dr. Holland will express the opinion of himself, and also of Dr. Todd (who also quotes the passage), on the present position of *Phrenology*:—"In the present state of our knowledge of the brain, and of its relation to the mental functions, an impartial view of phrenology requires, not that the doctrine should be put aside altogether, but that great abatement should be made of its pretensions as a system. To say the least, it is chargeable with what Lord Bacon has called an 'over-early and peremptory reduction into acts and methods,' and with the adoption of various conclusions not warranted by any sufficient evidence. But on a subject thus obscure in all its parts, and where our actual knowledge is still limited to detached facts or presumptions, there is enough to justify the opinion being kept before us, as one of the outlines to which future observations may apply, not fettered, as they now are, by the trammels of a premature arrangement."

Unprofitable disquisitions on the nature of mind and the doctrines of materialism have received a greater check by the fact, which is now admitted, that the nature of mind is incomprehensible, and that the proposition—that the mind is the product of material organisation—is unphilosophical and puerile, than by all the arguments which go to prove that the conclusions of materialism are false. We are acquainted with mind through certain mental operations of which we are conscious,—such as thought and volition; and we are acquainted with matter by its qualities of figure, solidity, extension, &c. From the phenomena exhibited by mind and matter we cannot positively determine the existence of either. We receive certain sensations of figure, colour, &c., and we suppose the existence of matter, and from the operations of mind we argue the existence of mind. Concerning the *nature* or essence of matter or of mind, or the *causes* by which the phenomena which attach to each are produced, we are equally in the dark; they form subjects of metaphysics especially uninviting in an age in which the physical sciences furnish the favourite subject-matter for education, as well as the arena for the display of the best efforts of national intellect; in an age, too, in which experiment is the end and boundary of knowledge, and metaphysics are generally distasteful and at a discount. They belong, indeed, to a large class of facts which form the end of all physical investigation, and which the physical philosopher is so accustomed to see attached to matter that he views them as an integral part of matter. The metaphysician has, however, no such faith; he believes that the qualities that matter exhibits are adjunctive, and not original *in* matter; and he views in these facts, barriers or doors of entrance to a vast world of knowledge, very inaccessible to himself, but which are altogether unsuitable to the tenor of the mind of him who is wholly occupied with physics.

But although the nature of the qualities of matter is not understood, they serve to demonstrate both the existence of matter and the existence of mind, with equal claims to human belief; and to deny it in either case is to strike at the conclusions of common sense; and "to destroy," as observed by Mr. Stewart, "the foundations of mathematical science as completely as if you were to deny the axioms of Euclid." If, then, natural philosophers content themselves with the examination of the phenomena which matter exhibits, and the laws by which these phenomena are governed, and have abandoned, as vain and useless, questions concerning the nature and essence of matter, and the causes of the phenomena by which it is distinguished, we may fairly expect that the same questions on the nature of mind and its attributes should meet with the same treatment; and while we keep in abeyance the like questions as regards mind, and at the same time give that prominence among the sciences to the study of its phenomena which is justly claimed by the "philosophy of mind," we shall, by the same rule, on seeing the proposition propounded—that mind is the product of animal organization, place it on the same footing, and adjudge it to imply the same absurdity as the proposition—that matter is the product of mind. It is utterly impossible to conceive how matter can produce mental phenomena: the fact also contradicts the supposition, that while our bodies undergo thorough change (at least those parts in which mind has been said to reside), our personal identity remains. The motive which has led to this exposition of the futility of our knowledge concerning the essence of matter and mind, and the causes of the phenomena which they display, is the double one of furnishing a clue to the student by which he may detect visionary speculations on the subject of mind, however they may be garnished with the garb and appliances of science, and also prominently to enforce the truth, founded in physics as well as in revelation, that the existence of the soul can be demonstrated with as much certainty as the existence of matter; and by the same laws of physics, the qualities by which we prove its existence bespeak it to be imperishable, not being, like matter, subject to fermentation and decay.

Having finished the consideration of the physiology of the cerebrum, a few observations made in the same spirit, and with an object equally good, on the baneful consequences of excluding metaphysics from medical education, and of solely exercising the mind with the physical sciences, may not be misplaced. There is such an exclusion in a great majority of the medical schools, both foreign and indigenous; and the evil will not be removed so long as teachers count it sufficient to supply to the public the highly finished medical practitioner, without regard to the high finish which in all ages has distinguished the man of letters—the polish that is only derived from metaphysical learning. It is more than a mere speculation the assertion that the physical sciences, while they eminently adorn the man, fail to give him those qualifications that emphatically belong to and distinguish the gentleman. Physics consist essentially of the aggregation and assortment of a number of facts; the study consists in tracing out those simple and wonderful laws that regulate and govern the qualities of matter; the effect of physics is to raise these subjects that are involved in a supernatural mystery into natural light, and to show that such mysteries are governed by universal laws: the nature of these facts physical science does not attempt to discover, and the study and contemplation of them is the business of the metaphysician. The attainment of these ultimate facts is a great triumph for the physical inquirer; he looks back on the darkness that he has turned into light, and it is not within the range of his occupation to notice the line that fences in the narrow circle of his knowledge. His dealing is with the discovery of the fact, and every step increases his power, and supplies the fuel for his pride; but his calling is not to observe the boundary line, or to look beyond it. He is not necessarily aware of ought beyond the confines of his narrow field; he must go to the metaphysician for the fact that in the regions beyond his puny range is laid the foundation for the doctrines of natural theology and moral philosophy. He cannot attain to the humbling truths, that the laws that attach to and characterize matter, are qualities that cannot belong *to* matter; that it is not intrinsically in matter that the effect follows the cause; that the phenomena that matter exhibits are adjuncts, and not its integral constituents. The profound discovery of gravitation to be a law in physics by which the course of the planets is ordered, might well engender pride in the mind of the discoverer, if metaphysics had not reminded him that while he beheld its operation, he had no power to reveal the nature of the treasure he had found, and brought with it the humiliating reflection that his faculties were insufficient to penetrate the real arcana of the universe in the present infant state of our being. He saw the law of gravitation written upon matter, but he stood aghast when contemplating the mighty hand that had written it there. The continual application to experiment, and the systematic disregard of every proposition that cannot be demonstrated thereby, which it is the part of the physical student to observe, does not *soften the manners;* while his occupation is to unfold the beauties of nature, it gives him no power to appreciate them. The senses and perceptive faculties which more especially belong to organization are chiefly engaged in his researches; and the higher operations of the reasoning faculties, comparison and generalization, are not so much called into exercise as is necessary for the metaphysical studies of intellectual philosophy, natural theology, and ethics. While engaged observing the movements of the planets, his forte is not to listen to their music, or hear them sing together. He can tell of the orders and classification of flowers, and their organic and inorganic constituents; but he does not understand the language which they speak. He may obtain the thanks of an audience for delivering a learned lecture; but cannot realize the fact that the best beauties of language consist in the metaphysics by which it may be adorned. Not ranging beyond the hard and matter-of-fact tenor of his own language, he cannot demonstrate from the language of Shakspeare that he was a great moral philosopher: he can astonish you by unfolding the qualities of matter, but he is essentially ignorant of the qualities of taste—the governing principles of true art, harmony, simplicity, and truth. The foregoing arguments may not carry conviction, but the truth cannot be gainsaid, since it is proclaimed by the public voice. Why is it, it may be asked, that more weight, respect, and consideration are given by the public to a degree in arts, than to medical diplomas generally, and which require the largest amount of learning to obtain? Is it not the mortifying fact, that the public can distinguish something which generally characterises the man in the former which is absent in the latter; and that the latent virtue is in the metaphysics which so eminently characterise the classics in the dead languages?

The Cerebral Nerves.—Twelve pairs of nerves take their origin at the base of the brain, and issue from the skull by various foramina provided for them. Willis's classification, in which two pairs are apportioned to the seventh, and three to the eighth, is generally preferred. Some of these nerves will be found to resemble the spinal nerves in having ganglia seated upon the roots or trunks of their sensory fibres, and to differ from them in a more distinct separation of the sensory and motor fibres in their main branches. The nerves of special sense are included in the number which it is customary to describe with their respective ganglia.

The *third* nerve, or motor oculi, is the common motor nerve of the eye, being distributed to all the muscles except the superior oblique and external rectus. It arises from the dark vesicular matter of the crus cerebri close upon the ganglia of the optic nerves; it supplies motion to the levator palpebræ muscle; it is connected to the sympathetic system by means of the *short root* of the ophthalmic ganglion, through which it supplies the iris with motor fibres. The trunk of this nerve is said to contain some fibres of common sensation, which is grounded on the fact that when it is irritated at its origin in rabbits, they give signs of suffering. The same irritation occasions contraction of all the muscles alluded to, and the division of its trunk produces their paralysis, and ptosis or falling of the upper eyelid. The effect of this division upon the iris, according to Valentin, is first the energetic contraction of the pupils of both eyes, followed by a total paralysis of the iris of the corresponding side. The esodic division of the diastaltic nervous arc, of which this nerve forms the exodic or motor portion, is the optic nerve ; for it is ascertained that diastaltic or reflex movements are produced in the muscles which this nerve supplies by irritating the optic nerve. The action of the iris is more decidedly a diastaltic act than that of the muscles alluded to. The fibres that supply the movements of the iris, not being under the mental stimulus, those movements are involuntary, for which the centre of the nerve responds to a stimulus generated for it expressly by corpora quadrigemina or the centres of vision. The influence given to this nerve by its sympathetic connection is probably to remove the iris from the influence of volition; to reverse the order of its action by causing the straight fibres to dilate instead of to contract under the stimulus of light; to effect the symmetrical movements of the eyes, and to bring those movements into relation with the lachrymal glands and blood-vessels. Besides the mental stimulus for the voluntary movements of the muscles, and the stimulus for the movements of the irides from the centres of vision, the centres of the third nerves are also supplied with motor stimulus by the centre of emotion; for the muscles in question aid in the involuntary movements that express the emotions and passions.

The *fourth pair*, *trochlearis seu patheticus*, which is the motor nerve of the superior oblique muscle, and the *sixth, abducens*, the motor of the external rectus muscle, are not found to contain sensory fibres: the movements supplied are partly diastaltic, receiving the motor stimulus for such movements from the centre of emotion. The fourth nerve, by causing the eyeball to project, and turning it slightly downwards and inwards, expresses the emotions of surprise, terror, joy, &c. The sixth, or abducens, by acting in conjunction with the recti, and retracting the ball, or turning it outwards, is said to express suspicion, anger, jealousy, and envy.

The *fifth* pair, *trifacial* or *trigeminal*, commences its course from the pons: each nerve consists of a large sensory portion of fibres, which is posterior, having a ganglion upon them (the

Casserian), and a small anterior motor division which does not enter the ganglion. So far this arrangement of structure resembles the spinal nerves, but not farther, for the fibres of each root do not intermingle at this point. The larger or sensory portion may be traced backwards from the pons into the olivary and restiform bodies. When this portion of the nerve is divided, the animal evinces great suffering, and the operation over, the following parts are deprived of sensation: the skin of the temples, forehead, ear, eyelids, nose, lips, and mouth—the mucous membranes of conjunctivæ and nasal fossæ, the roof of the mouth, the anterior portion of the tongue, teeth, and gums. When the anterior portion of the nerve is galvanized in an animal shortly after death, powerful masticatory movements are excited, and the teeth are firmly ground together. When divided in the living animal these muscles are paralysed, and the jaw drops, or loses parallelism, if the nerve of one side only is divided. This nerve takes no part in the movements of the cheeks, the lips, or soft palate. Three main branches are formed from the two kinds of fibres existing in the roots,—the ophthalmic and superior maxillary, which are wholly of sensory fibres, and the inferior maxillary, which is mixed. The gustatory branch of the third main division supplies the anterior and lateral portions of the tongue with the special sense of taste.

The *fifth* is the nerve of common sensation to the eye, nose, ear, and lips, and a branch from the second division supplies the mucous membrane of the hard palate with an acute degree of common sensation which aids in the special sense of taste. By this portion of the nerve the more pungent matters that enter the food are tasted, and it seems to confer some special influence on the proper nerves of taste (the gustatory branch of this nerve, and the glosso-pharyngeal); for it is well known that when common sensation and smell are arrested in the Schneiderian membrane by a cold, that the sense of taste is impaired or wholly prevented, The nasal branch of the first division seems to confer a like influence on the special sense of smell, by detecting the pungent and irritating matters that are mixed with the respired air. Division of this nerve produces the following effects upon the iris in cats and dogs: the pupil contracts and dilates rapidly, and then becomes immoveably contracted. The nasal branch is connected with the iris by its ciliary branches, and also by the long root of the ophthalmic ganglion. How these effects are produced is unexplained. This nerve fulfils the esodic or afferent part of the diastaltic arc of the emotions of fear, rage, &c., either in producing the flushing of the face, or in the pallor of the countenance. On division of this nerve certain changes take place in the nutritive processes with which it is connected: the secretion of tears is suppressed, and inflammation of the eye commences, which usually ends in ulceration and destruction of the organ: encrustations are formed on the lips and nose, and the tongue is covered with a thick fur. It is a principle in physiology that the nervous system, though not essential to, aids and controls nutrition: there is another principle, equally well based in facts, that the capillary movement is principally promoted by the chemical or vital changes that the blood undergoes in its capillary transit. It is by these laws, and by the fact that congestion and inflammation are the results of section of the pneumogastric nerves in the organs they supply, occasioned by the withdrawal of nervous influence, that we may find a reason for the inflammation and disorganization that follows in the globe of the eye after section of the fifth nerve: bearing in mind, also, that the cause to which it is usually attributed, the loss of tears, and the friction to which the conjunctiva is exposed, is an exciting cause of inflammation, though not sufficient to produce so large an amount of mischief. The 5th appears to be the nerve of nutrition to the organs of special sense.

The *facial nerve, portio dura of the seventh*, is the motor nerve of all the muscles of the face; not, however, of the muscles of mastication, which are supplied by the third division of the fifth. When the root of the facial is galvanised, the following muscles actively contract: frontalis, buccinator, orbicularis palpebrarum et oris, the muscles of the external ear, the posterior portion of the digastricus, the stylo-hyoideus, and platysma. By this nerve are performed the movements of the countenance that give external expression to the passions and emotions (excepting the movements of the eyes). This nerve constitutes the exodic division of the nervous arc; the fifth, the exodic or afferent division in those movements. As to the influence that this nerve has on the muscles of the soft palate, reports are at issue. In paralysis of this nerve, and in those unfortunate sufferers from neuralgia who in their treatment mistakingly had this nerve divided at the styloid foramen, the skin of the forehead could not be moved; the eyelids could not be completely closed; the nostrils were partially collapsed; spitting and sneezing were prevented; the lower lip fell away from the jaw, and the saliva escaped from sunken corners of the mouth. The countenance in such cases is devoid of expression; but sensibility is unimpaired, except in the same ratio that hearing, smell, and taste, are affected from paralysis of some of the muscles belonging to the organs of these senses. The muscles of the eye-ball being unaffected, and the movements of the eye not synchronising with the movements of the countenance, a peculiar vacant stare is communicated to the eyes.

The glosso-pharyngeal communicates at its origin with the pneumogastric, the spinal accessory, and the sympathetic; and near its origin it has a ganglion (Andersch) through which the whole of its fibres pass. It is distributed, as its name implies, to the tongue and to the pharynx. It supplies the mucous surfaces of the following parts: the base of the tongue to about as far forwards as the centre, and also the edges and under surface up to the tip, the fauces and tonsils, the Eustachian tube, and upper part of the pharynx. The latest experiments of Biffi and Morganti confirm the previous reports, that this nerve contains no motor fibres in its roots: movement is caused by irritation of its trunk in the muscles of the pharynx and palate, which is due to fibres imparted by the spinal accessory nerve. By dividing the nerve within the cranium, and irritating the cranial portion, it has been ascertained that some movement in the muscles of the palate and pharynx took place, and as these are muscles of deglutition it is probable that the movements were diastaltic or reflex through the centre of deglutition. No movement could be produced at the distal portion unless the irritation was applied after the addition to the trunk of the fibres from the spinal accessory. The animals operated upon give indications of suffering pain; from whence it is inferred that fibres of common sensation are present: this is not surprising, since it confers on the part of the tongue it supplies,—the soft palate, uvula, and anterior palatine arch,—the special sense of taste which is nearly allied to common sensation. It is argued to possess taste in a more acute degree than the gustatory branch of the fifth that supplies the anterior portion of the tongue with the same function. This nerve is much engaged as the esodic or afferent excitor of the centre of deglutition, in the very parts (the fauces and back of the tongue) to which it imparts the sense of taste it receives and conveys to the centre of deglutition,—that impression which is occasioned by contact of the food to be swallowed, and which impression, in that centre, originates the stimulus that impels to action the nervous centres of the muscles of deglutition. As an esodic or afferent nerve in the machinery of deglutition, this nerve has a prominent function; but the quantity of motor fibres derived from the accessory, and giving it direct motor functions, are insignificant compared with its other fibres: this is inferred by the fact that its fibres take a course to, and are distributed upon, the mucous membranes. It is not, however, the only esodic nerve of deglutition; for, when these nerves are divided on both sides, deglutition may be excited at the lower part of the pharynx by food forced into it: this is effected through the esodic influence of the superior laryngeal which partly supplies the pharynx. The glosso-pharyngeal is one amongst the numerous esodic nerves connected with the centre of vomiting, by transmitting impressions to that centre of the nauseating tastes of substances taken into the stomach.

The *pneumogastric* nerves, or *par vagum*, have well merited the latter name, from the wandering course they pursue, and a still better title to the appellation of *par varium* from their various functions; for we find them ministering indifferently to the organic functions of the heart, the lungs, and the stomach. Experiment indicates that the vagus is a mixed nerve from its origin, deriving a portion of its motor fibres from the internal branch of the spinal accessory; it receives communicating branches from the facial, glosso-pharyngeal, spinal accessory, sympathetic, and hypo-glossal, all of which enter the proper ganglion of this nerve, and afterwards become a plexus, which contains vesicular matter. The branches of the pneumogastric are as follows:—the pharyngeal, which is the principal motor nerve of the muscles of the pharynx. The superior laryngeal, distributed to the mucous membrane of the larynx, the glottis, the epiglottis, and pharynx; by this nerve the glottis and larynx are endowed with that exquisite sensation that these parts are known to possess, and that detects pungent and deleterious impregnations in the respired air; the fibres supplied to the pharynx are almost devoid of sensation, and the impressions they convey resemble those of the glosso-pharyngeal in this part. The *external* branch of this nerve, according to Mr. Hilton, is the motor nerve of the inferior constrictor and crico-thyroid muscles. The *recurrent,* or inferior laryngeal, is the motor nerve of the larynx and lower part of the pharynx; this nerve joins with the superior laryngeal in forming the diastaltic arc for the movements of closing the glottis against the admission of foreign bodies, and executing those intricate contractions of the muscles of the larynx that are called forth in vocalism. Some of these movements are performed under the influence of the mental stimulus, or volition; those that are diastaltic or reflex depend on this nerve for the esodic, and on the superior laryngeal for the exodic mechanism of the nervous arc. The pulmonary branches have at least a two-fold function, supplying motor fibres to the muscular tissue of the bronchial tubes as well as the impression of the necessity of breathing to the medulla oblongata. The cardiac branches enter the great cardiac plexus, and represent the cerebro-spinal system of nerves in the structure of the heart, and maintain, together with the sympathetic, the connection between this organ and the intellectual and emotional centres. Those to the œsophagus supply both motion to the muscles and the property to the mucous membrane of receiving the esodic impression which they transmit to the centre of deglutition: these branches principally exert their influence on the upper half of the œsophagus.

The terminal branches of the par vagum are the gastric;

they enter largely the solar plexus, and supply the viscera contained in the epigastric and hypochondrial regions. By division of the vagi on both sides, the animal is placed in imminent danger of suffocation, occasioned by paralysis of the recurrent branches, and the consequent falling together of the arytenoid cartilages, which makes it necessary, in young animals, to introduce the tracheal tube. Respiratory movements, by this operation, diminish to about one half in a given time; and of those animals that escape suffocation at least two-thirds die from pneumonia in a chronic form. Such were the results of Dr. J. Reid's well-known experiments. The primary effect on the pulmonary tissue was the sero-sanguineous infiltration peculiar to the first stage of pneumonia. The explanation given for this phenomenon is the congestion of the capillary circulation in the lungs, which is the lawful result of diminished respiration and imperfect aëration of the blood, and that it becomes sero-sanguineous as the due result of exalted formative powers co-existent with inflammation. It will be seen, on reference to the laws that regulate the circulation in the capillaries, that the chief amongst them is that which relates to the change that the blood undergoes in its passage through them; and that whatever retards secretion, nutrition, or other vital phenomena, conduces to a stagnation in the capillary circulation. We know, also, that pulmonary congestion is one of the effects of asphyxia. The total loss of appetite, vomiting, and the imperfect digestion of food, that follows the section of these nerves, makes it probable that similar changes are taking place in the capillary circulation of the stomach and organs concerned in digestion, to which we have referred, occasioned by the withdrawal of nervous influence; with this difference in the common result, that these organs, not being so eminently essential to the manifestation of the vital phenomena as are the lungs, their aberrations from the healthy standard are not so destructive to life as those of the latter organ. The vagus, it will be seen, has an indirect agency on the sense of hunger, but seems to have a direct agency in communicating the sense of satiety; for after the section of these nerves in puppies, they continue to suck till they are enormously distended with milk.

When the roots of the *spinal accessory* nerve are irritated, the animal gives some indication of feeling pain, and active contractions of the sterno-mastoid and trapezius muscles, to which the external or principal branch of the nerve is distributed, are the result. It appears, from experiments, that the pneumogastrics derive but a small portion of their motor fibres from this nerve. Irritation at the origin has done little to determine the point, but the direct section of the roots, including the fibres to the pneumogastric, has shown that the principal effect produced on the functions of the vagi was confined to the laryngeal nerves, indicated by hoarseness and aphonia; Arnold, and several others, having previously affirmed from pathology that the accessory is the vocal nerve, or rather the fibres that it supplies to the vagus. The external branch to the trapezius and sterno-mastoid, or rather its nervous centre, indifferently responds to the mental stimulus both in ordinary voluntary movements, and in the respiratory movements, so far as they are voluntary, and also to the motor stimulus furnished by the centre of respiration, as the consequence of the physical impression transmitted to that centre by the esodic excitor nerves of respiration. We cannot hope to distinguish this nerve clearly from the vagus in physiology, observes Professor Paget, till we can distinguish the two anatomically.

On section of both *hypoglossal* nerves, the tongue is imme-

The Physiology of the Eighth Pair of Nerves.

When retching does from nauseous taste ensue
The glosso-pharyngeal gives the cue,
And with the gustatory branch we find
It shares the sense of taste, though not combined;
In deglutition 'tis the esodic nerve,
While pharyngeals do for motion serve.
Superior laryngeals test the air;
Recurrents say there's no admission there:
One gives of hunger sated the sensation,
One makes the blood cry out for aëration,
Stirs heart and lungs in rhythm; and no question,
They rule the stomach's functions in digestion.

diately paralysed, while special and common sensation remain unimpaired. In mastication after this double section, the tongue exhibits the extraordinary phenomenon of possessing all the refined sensation comprehended in taste, and yet so dead to motor impulse as not to escape continual laceration from the teeth in mastication. Experiment shows it to be almost entirely the motor nerve of the muscles of the tongue, though indications of pain on irritating the trunk make it probable that some few sensory fibres from its connections with the cervical plexus may pass into it. Although this nerve may be paralysed on one side in hemiplegia, it sometimes happens that the paralysis cannot be detected in the movements of the tongue: this may be, perhaps, explained by the peculiar action of these muscles, inasmuch as, not acting on levers, like most other muscles, with short arms of power and long arms of resistance, they compensate for freedom from that mechanical disadvantage by the strength and perfection of their movements, which is shown by the apparent completeness of the action of the muscles of one side of the tongue when the antagonistic support of the other side is withdrawn. In consequence of the few sensory fibres that this nerve contains, it is thought to resemble the anterior roots of the spinal nerves: the propriety of this opinion is strengthened by the fact that in many mammalia, not only does it arise by a double root, but a ganglion is observed on the posterior.

SYMPATHETIC SYSTEM.

The *sympathetic system* of nerves we have before referred to, and have already dwelt on the morphology of the nerve-fibre that is included in this system. Notice has also been taken of the structure and site of the ganglia, to which the name of *ganglionic nervous system* has been applied. In these ganglia are included those placed on or near cerebral nerves, and those on the posterior roots of the spinal nerves. The physiology of the whole of this system is involved in so much conjecture that it is scarcely safe to go farther than a mere statement of facts. Told as we are by anatomists of the existence of the respective centres of the cerebro-spinal and the sympathetic nerves, we look to the anatomy of the several ganglia to disclose to us the origin of the nerve-fibres peculiar to each system of centres. From this source of information, however, we obtain nothing that can fix the origin of the nerve-fibres to the ganglia to which they are assigned. Both kinds of fibre are seen not only to interlace the vesicles of both kinds of ganglia, but also to originate from caudate vesicles in the same ganglia if not from the same vesicle. The fine fibres abound most in the sympathetic ganglia, characterising the same with a darker hue, and *vice versâ*. It is worthy of notice that the ganglia on the spinal nerves are on the sensory fibres, and those on or near the cerebral nerves are connected with fibres whose function is chiefly the same—the 5th and the 8th. It has been elsewhere observed, that the fine fibre in question is found not only in the nerve-centres of both systems, but also in all the cerebro-spinal nerves: from this it follows that they must be contained in the brain, and its fibrous connections with other ganglia; and so it is. It must also be stated that the axis-cylinder nerve-fibre is to be found traversing sympathetic ganglia, and the trunks from these ganglia that are sent to the viscera of the thorax and abdomen. When, therefore, it is recollected that there is no perceptible anatomical difference between the fine fibre and the axis-cylinder fibre, when the latter is divested of the white substance of Schwann, we may cease to look to anatomy to disclose the separate function of the fine nerve-fibre. Comparative anatomy lends no aid to the elucidation of the question, but rather opposes the doctrine of a separate function; for in the cyclostomes among fishes the par vagum supplies the want of a ganglionic nerve to the viscera, and in serpents the spinal nerves pass directly to the viscera.

Although it may be possible that there is a difference of function in the two fibres, and also that the axis-cylinder fibre reaches the organic structures, of which there can be little doubt, though more sparingly than the fine fibres, yet there can be no doubt that the function of the axis-cylinder nerve-fibre is essentially modified in its transit through the ganglia of the sympathetic. As a general principle, the few cerebro-spinal nerve-fibres, whether sensory or motor, that can be traced to an organ, become there altered in their functions. The sensory fibre is devoid of common sensation, and no longer can transmit the sensation of pain, unless under the effects of inflammation or some special exciting cause: the motor fibre is not only removed from the control of volition, but imparts that movement to muscle that characterises the muscular fibre of organic life, together with all that is conveyed in the physiological words of *rhythm* and *adaptation*. It cannot be said that such qualities of motion are seated in the unstriped muscular fibre, for the striped fibre is found in the heart and upper part of the œsophagus, where the same movements are observed. An apparent exception to the above statement, and one that affords much matter for thought, is, the nervous connections of the mammary glands. It is well known that the heart, œsophagus, and intestinal canal, when removed from the body, and galvanized, exhibit these movements with their several peculiarities. This is fully in accordance with the principle that these movements are peristaltic; but, though independent of nerve-centres, they are controlled, guided, and supplied with motor stimulus and rhythm by nervous centres; and the continuation of such nervous influence in the movements in question, after removal from the body, may be attributed to the small ganglia that are well known to exist in the structure of the heart, and are said to have been discovered in the mesentery. Ocular proof of the influence of the ganglionic system on the movements of the intestines may be obtained readily, and with great facility, by the experiment of John Müller,—that of opening an animal quickly after death, and touching the cœliac ganglion with a solution of caustic potash: the farther interesting fact, that the modified nervous action is independent of the cerebro-spinal centres, may be demonstrated by removing the intestines with the mesentery, applying the potash to the nervous branches in the mesentery, and witnessing a repetition of the movements thus produced. Although organs whose nerves are thus modified by the influence of sympathetic ganglia become thus altered, and almost insensible to pain, pathology discloses to us that the reverse is frequently the case in the abnormal conditions of inflammation or irritation—of which the pains of colic, stones in the bladder, ureters, &c. will afford us ample conviction. It appears, also, that when one of these ganglia is first irritated, no pain is felt; but if the irritation is continued, the animal soon exhibits the signs of suffering. While the foregoing statements authorise no conclusions as to a difference of function of the nerve-fibre of the two systems, there is enough to justify the inference that the various phenomena that appear to become proper to the two kinds of nerve-fibres on their entrance into organic structures, are conferred upon them in the ganglionic centres of the sympathetic. There can be no doubt that the two kinds of nerve-fibres, after leaving the sympathetic ganglia, exercise a notable influence on the functions of organic life, both in their movement and secretions: we cannot, however, determine the power that belongs to each fibre: we know that the functions of the cerebro-spinal nerve are changed in these organs, and that a cerebro-spinal nerve is a compound of both kinds of fibres both on entering and quitting the ganglia. We believe, also, that all ganglia are centres for the production of dynamic force, and we should in no wise forget that this dynamic character is sustained mainly by the fact that a large portion of fibres originate in them: but whether these original fibres are the media only of original power in producing the phenomena that secretion exhibits, how the action of the cerebro-spinal nerve becomes altered, or what part they take in bringing the organic functions into relation with the emotions and intellect, we are, in the present extent of our knowledge, unable to affirm. This we may conclude,—that in the muscular movements that take place in organs *ex corpore*, so much of them as depend on nervous centres must be due to an original power seated in the ganglia in their structure, and cannot be a modified power derived from the cerebro-spinal centres.

MOTION.

There are two kinds of muscular tissue, differing alike in their physiology and anatomy; one of which the muscles of animal life are composed, and the other belonging to muscles of organic life. The anatomical distinction resides in the fibre. A muscular fibre of either kind is too small to be seen by the unassisted eye, but is readily distinguished by a lens: it is composed of a number of fibrillæ, contained in a transparent structureless sheath, termed by Mr. Erasmus Wilson, *myolemma*. A muscle is constructed of fibres held together by areolar tissue, which encases a number of fibres in a bundle or fasciculus, arranged side by side. This fasciculus may be seen by the unaided eye, and is penetrated by vessels and nerves, which is not the case with the myolemma sheath. The bundle of fibres, or fasciculus, thus inclosed is in contact with a number of others, which are again enveloped in a common sheath of areolar tissue, which process is again and again repeated; the effect being the construction of a delicate framework of areolar tissue in various-sized compartments, which, after inclosing the first fasciculus of fibres, is, by means of the after-investments, dispersed through the whole substance of the muscle; thus communicating to muscle the physical properties of strength and elasticity that belong to that amount of areolar tissue. The muscular fibre of *animal life* is so named from entering the structure of muscles that are mostly concerned in the animal functions. It is also met with in the heart, the pharynx, and upper half of the œsophagus, and also in the sphincter ani, where both sorts are blended. A muscular fibre is a collection of fibrillæ, or fine filaments of contractile tissue encased in a sheath of myolemma; the fibrillæ are placed in parallel lines, which imprint the surface of the fibre with *longitudinal* striæ, which are more distinct in animal life. The colour of a fibre is a pale yellow. That of animal life, besides the longitudinal, is distinguished by *transverse* striæ arranged at equal distances, which, together with the longitudinal, give the surface of a fibre an appearance of an inlaying in squares alternately dark and light, the dark projecting. The fibre of animal life is also known by its polygonal shape, and its larger though variable size. The average size of this fibre, according to Mr. Bowman, in man, is 1-352th of an inch; in woman, 1-454th; the mean of the two being 1-403th. Both Dr. Carpenter and Dr. Sharpey agree that the spaces marked out by the striæ are squared with a distinctness almost inconceivable in so small an object. The fibrillæ which give to the fibre the checkered appearance amount to several hundred in each fibre, and have a diameter of 1-18,000th of an inch. It is ascertained that the contractile force of the muscle of animal life is seated in the squares that are marked out on the fibrillæ of fibres; and it is perceptible that, on contraction, the planes of the squares that face transversely approximate, producing a widening of the spaces transversely, and narrowing longitudinally, and consequent thickening of the fibre. No explanation can be given of the dark and light squares formed in the fibrillæ, except that there are two kinds of sarcous matter, or the same kind arranged differently. The dark square is said by Mr. Dobie to be crossed by a light bar, dividing it transversely, and the light square by a dark bar. The fibre of *organic life* is flat, having no transverse striæ, is not marked in squares, and is about one-third smaller. The structure of the fibrillæ composing the fibre does not appear to differ from *contractile fibrous tissue*, except that they have nuclei, which cause the fibril to swell out at certain distances; and from the nuclei dark lines extend, which is an indication that the nuclei are either in a state of development or disintegration. Muscular fibres of organic life are sometimes arranged tortuously instead of in parallel lines. They constitute the muscular coat of arteries of the intestinal canal, the urinary and gall bladders, vesiculæ seminales, and uterus. The fibrillæ of both kinds of fibres have a tendency to separate from each other; and it is remarkable that the fibre of animal life, which is the most energetic, and capable of exerting the greatest force, has the same tendency to separate in the transverse direction. The tendency to transverse separation in the animal fibre, and also that of the position of the nuclei in the organic fibre, which are at considerable intervals, makes it probable that the dark appearance of the squares in the animal fibre is not occasioned by nuclei, as some suppose, but by a definite arrangement of the molecules of the sarcal substance. Mr. Bowman has contributed to us our knowledge of the mode of contraction of muscle, which is, by the approximation of the transverse lines in the fibrillæ, producing a general thickening of its substance. The zigzag direction into which muscles are sometimes thrown during their action is the result of an irregular relaxation after contraction. The modes of action in the two kinds of muscle are very different: that of animal life is rapid and energetic, and, when irritated mechanically, the part touched only moves: the movements of muscles of organic life are slower, less powerful, and move in rhythmic waves: on irritation, the movement is transferred onward to adjoining fibres, attended with alternate contractions and relaxations, which continue after the irritation has ceased. The same movements are produced by a continued stream of electricity directed to this muscle. The heart forms an exception in its behaviour under mechanical stimulus: it appears to combine the actions peculiar to each fibre. On being touched with the point of an instrument it contracts with the energy of a striated muscle, repeating the pulsations in rhythmical order, after the manner of a non-striated muscle. The muscular fibres of the heart are indistinctly striated, and differ from the fibres of animal life also in their arrangement: they take a waving direction, instead of the usual straight parallel position of animal fibres. A continued stream of electricity applied to a muscle of animal life throws it into a fixed state of contraction. The nerves that supply muscles of animal life are mostly from the cerebro-spinal system, and chiefly motor. Sensation derived from muscle is peculiar: it differs from common sensation, and is peculiar in conveying to the mind an accurate knowledge of the position of the muscles. Such sensation differs from touch: by this sense we have knowledge that a muscle is in a state of contraction—that a limb is extended or at rest. It appears to be of a more refined and subtle nature than touch; for we derive from it that wonderfully accurate knowledge of distance that apportions the exact amount of contraction of muscles to the effects produced. The perfection of this sense constitutes execution on musical instruments played by the hand, and the still more astonishing power of rightly adjusting the contraction of the muscles that regulates the length of the chordæ vocales. Not only does this sensation determine the exact amount of contraction necessary to produce given effects, but the position of the muscles in their endless variety is so associated with their effects in the mind, and so distinctly registered in the memory, that, so soon as the mind conceives the tones to be uttered, the muscles readily fall into the positions necessary for their production. Such movements, which, in the first place, derive their motor stimulus from the brain,—volition, at length become *habitual*, and are then sustained by motor stimulus issuing from the centre of sensation. This hypothesis, advocated by Dr. Carpenter, is enforced in the writings of Dr. Alison on this subject. Heat is generated by energetic muscular contraction to the amount of about two degrees, which would be greater but for the fact that the circulation of blood, which is accelerated by muscular action, tends to its equalisation.

The muscular fibre of organic life is but sparingly supplied with nerves: these are found to consist of both the axis-cylinder and the fine nerve-fibre. The influence of nerves upon the muscular fibre of organic life is peculiar, and merits particular attention. There is an original power of action inherent in muscular fibre—irritability: the stimulus to action is supplied by nerve-centres. The difference which exists between the action of the two kinds of muscular fibres, and which is peculiar to that of organic life, is probably dependent on nerves; and the same may be said of the rhythm—an objective adaptation which is observed in the movements of the muscular tissue of organic life: for instance, the tendency of the action of the heart to empty the ventricles simultaneously, or that of the intestinal tube to move onwards the contained matter. Such movements differ from those ordinarily produced by cerebro-spinal nerves, and are considered to be either due to a modification of action with which they appear to become endowed in their transit through the sympathetic ganglia, or to an original power generated in these ganglia in virtue of their characters as seats of dynamic nervous force, and communicated to the muscular tissue by means of that portion of the fine nerve-fibres that are known to take their origin from vesicles within the ganglia.

The following is Professor Playfair's analysis of ox flesh, which does not materially differ from that of Bœckmann, C 51·83; H 7·57; N 15·01; O 21·37; Ashes, 4·23.

The vital phenomenon that especially distinguishes muscular tissue is called *irritability*, that of becoming contracted or relaxed under stimuli applied immediately to the muscle by contact, or mediately through nerves. This property is considered to be inherent in muscular tissue, and independent of nerves: such belief rests mainly on the facts that a similar contractile power is observed in certain tissues of the vegetable kingdom, and that it is maintained in muscles when they are removed from all connection with nervous centres; so far as such can be done by dividing the nerves, or by means of paralysing their influence by etherization. The existence of a vis insita in muscular tissue rests on indirect rather than direct proof, from the difficulty of detaching muscle from nerve: and Dr. J. Reid's notorious experiments of dividing the nerves of the lower extremities of frogs, and daily exercising one of the limbs by galvanism, were more valuable in proving that nutrition ceases on the disuse of muscles, than in settling the question whether irritability is dependent on nervous centres, for in these experiments the sympathetic had free access to the capillaries of the limbs, being conducted thither on the coats of the arteries,—a fact that has been hitherto overlooked by physiologists. Paralysed muscles gradually lose their irritability, together with every other vital or physical property, as a consequence of their disuse: the change in structure observed is the adipification or degeneration of their tissue into fatty matter. This is explained by the cessation of that disintegration which is the constant attendant on their action, and the consequent cessation of the deposition of nuclear matter from the blood, on which the nutrition of muscle depends. Irritability of muscle also ceases if a due supply of oxygen is not transmitted to it by means of arterial blood: the effect, however, is very tardy, and differs altogether from the instantaneous effect of the withholding of oxygen from nervous matter, as is exemplified by the sudden insensibility that arises when the circulation through the brain ceases, as in fainting. In fainting, voluntary and involuntary motion, or the physical action of muscle, ceases, as the result of inaction of the nervous systems, but muscular irritability is not suspended; it is, however, diminished. The same effect is produced by the undue circulation of carbonic acid in the blood, which is supposed to occasion, in some degree, the cessation of the action of the heart in asphyxia. In accordance with this observation, it is found that in death from asphyxia irritability leaves the muscles earlier than usual.

Severe shocks to the nervous centres will sometimes instantly extinguish muscular irritability: this is the case when the brain and spinal cord are suddenly crushed in experiments, and is not observed when the same parts are gradually removed. Cases of sudden death, whether arising from a shock given to the cerebro-spinal system, as by a blow on the head, or to the ganglionic centres, as on the cœliac plexus, by a blow received on a full stomach, is attended with a sudden diminution of irritability. The shock given to the nervous centres by extensive burns, or the electric-like effect of the absorption of prussic acid, have similar effects on muscular fibre. The usual symptoms that precede death from prussic acid harmonise with this assertion; there is an indication of the paralysis of irritability by the general absence of convulsive movements, except one or two slight convulsive inspirations.

In deaths from lightning, or from excessive muscular exertion, as in over-ridden horses, irritability is found to have forsaken the muscles; and a marked diminution is the consequence of the introduction of certain animal poisons into the blood: as in scarlatina maligna, puerperal fever, &c. An especial absence of oxygen, and presence of carbon, characterise all such blood, and the panting, the usual attendant on over-exertion, is the effort to obtain oxygen to effect the chemical change which is the essential condition of muscular action. Disease of the heart or lungs, or an atmosphere deficient in oxygen, will for obvious reasons produce a loss of muscular power, and inaptitude for muscular exercise.

Dr. Marshall Hall observes that *every act of respiration, every act of volition, and every meal, diminishes irritability.* The meal lessens its amount by an expenditure in nervous and muscular action, in chymification and digestion, but it is augmented and restored by nutrition and sleep. It may be advanced as a principle in physiology, that the intensity of muscular contraction is in compound ratio to the irritability of the muscular tissue, and to the excitability or polar force of the centre of volition. Irritability, again, is in direct ratio to volume, health, and nutrition of the muscular tissue. The action of muscles so commonly respond to both the mental and physical stimuli, or to the various nerve centres in which motor stimulus is generated, that no correct classification can be made of them, as into the voluntary and involuntary. The exclusively involuntary muscles are few, and are not necessarily composed of one kind of fibre.

Tonicity, like irritability, is an original quality of both kinds of muscular tissue. It is this property that in amputations causes both the cut muscles to recede from the blade of the knife, and the divided arteries to retract and close upon their contents. This power is continually exerted in muscles during life, and is a force sufficient to claim particular notice. At the period of death, tone ceases from the muscles, but makes its last appearance again, in the form of rigor mortis, in about six hours from dissolution. The phenomenon of passive contraction (tone) does not reappear until that of active contraction (irritability) has departed, which continues up to this period. We have enumerated many conditions of the body which are conducive to the diminution of irritability, and its early departure after death; tone appears to be guided by the same laws, and seems to wait only for the exit of irritability to take its last hold upon the animal fabric. It is first observed in the muscles of the face and neck, proceeding downwards, and leaving by the same order. The period of the duration of this stiffness is from twenty to thirty hours. Even in persons dying in a healthy state of body, as from accidents, death stiffness is occasionally uncertain in the time of its commencement and duration. The heart, during rigor mortis, is so firmly contracted, and the ventricles so much obliterated, as to give to the unobservant an appearance of disease.

Ciliary Motion.—Cilia are transparent filaments placed in regular rows, flattened, and so constant in shape as to be described as leaflets. The length of these bodies is most variable—from 1-500th or 1-5000th part of an inch. They usually appear upon the cylinder, though they are seen also on the pavement-epithelium; and their size may be imagined by the fact that six or eight cilia are placed on the summit of each cell. They have been observed in the following situations:—the upper part of the pharynx, eustachian tube, larynx, trachea, bronchi, cervix uteri, fallopian tubes up to the fimbriæ, the nasal cavities and sinuses, palpebral conjunctiva, all the cavities of the brain, and the soft palate. The movement is of two kinds —a bending forwards, thus making a curve at the base, and then straightening; or the circular movement around the base, at which point the cilia is fixed. The movements of cilia are so orderly as to give the appearance of a waving surface; and when an epithelium is detached having its cilia still adherent, they move rapidly in the fluid, and move bodies before them of great comparative size with great velocity. The movement continues for a long time after death in cold-blooded animals, but in man and warm-blooded vertebrata it ceases in a few hours, or as soon as the body is cold: in some amphibia it has been observed after putrefaction has commenced. It is not influenced by any of the laws that regulate nervous force. Hydrocyanic acid or strychnine exert no effect upon it. Water appears to retard the movement, while blood, milk, and albumine, increase the vibrations, and continue them for hours. These bodies have a growth as rapid as the epithelium on which they are produced: for obtaining a view of them, a little mucus from the nose or other part may be moistened and placed on an object-glass. The action of cilia is towards the external outlet of the cavity in which they are seated; and, judging from the force with which they are seen to propel fluids under the microscope, they must take an active part in moving onwards the secretions with which they are in contact. It is said that in both their movements the flat surface of the cilium is brought to face the outlet, while the thin edge faces in other directions; and it is by working of this complicated movement only that the onward impulse could be given (see Bowman, Philosophical Transactions, 1843; Professor Sharpey, Cyclopædia of Anat. and Phys., article Cilia).

ABSORPTION.

Absorption is the act by which living beings in some way imbibe, and make penetrate into the mass of their humours, the substances which surround them. If the body of a frog be plunged in water, so that none of this liquid can enter the mouth of the animal, nevertheless at the end of a certain time its weight is found to have been augmented. Now this increase, which under favourable circumstances amounts to a third of the total weight of the animal, can evidently depend only upon the absorption of the water by the external surface of the body. If a known quantity of water be introduced into the stomach of a dog, and, by the aid of two ligatures, all the openings by which the cavity of this organ communicates with other parts be closed, the liquid will yet disappear at the end of a little while; for it will be absorbed by the walls of the stomach, and thus be mingled with the blood. And yet there do not exist on the surface of the skin or stomach any pores or openings conducting directly to the blood-vessels, and which may serve for a passage to the liquids absorbed; but the tissues which form these organs, as well as those of all other parts of the body, have a structure somewhat spongy, and are more or less permeable to fluids. In the living as well as the dead body these tissues always imbibe the fluids which bathe them, and allow themselves to be traversed with more or less facility.

Thus, if a current of acidulated water be made to traverse a portion of a vein, the external surface of the vessel being in contact with a solution of tournesol, the colour of the latter liquid will soon be changed to red by the action of the acid which has passed through the walls of the vein: in the dead body, consequently, these parts are permeable to liquids. Now if we expose a vein in the living animal, perfectly isolate the vessel, and apply upon its exterior surface the extract of nux vomica, this violent poison will soon penetrate the membranous walls of the vein, mingle with the blood, and occasion the terrible symptoms which are observed whenever it is directly injected into the blood-vessels. It is, then, evident that during life, as well as after death, the veins are permeable to liquids. Capillary attraction contributes powerfully to produce this imbibition; but it is not the only force which so operates; and, to form an exact idea of the mechanism by means of which liquids penetrate the substance of the organic tissues, we must understand a very curious phenomenon discovered by M. Dutrochet, and named by him *endosmosis* and *exosmosis.* This physiologist has proved that, if a solution of gum or neutral salt be inclosed in a small membranous sac surmounted by a tube, and the sac be placed in a shallow vessel containing pure water, the latter liquid will penetrate into the interior of the apparatus, and ascend in the tube to a considerable height: this is *endosmosis.* If, on the contrary, gum or sugar and water be placed without the membranous sac, and pure water in its interior, the passage takes place inversely, and the sac, instead of filling, is emptied: this is *exosmosis.*

This phenomenon is very analogous to the absorption which takes place in living beings; and the explanation is easily given. We have seen that the organic membranes, as well as all the spongy and porous tissues, may be traversed by liquids; but the facility of this transport varies with the fluidity of these liquids, and the ease which they imbibe the filtrations. If the two liquids placed in the interior and upon the exterior of the membranous sac could traverse equally well the walls of this cavity, they would mingle, and the same level be established upon either side; but if the exterior liquid traverse more readily the walls of the sac than the interior, the current from without inward will be more rapid than the current in a contrary direction, and the liquid will accumulate in the interior of the apparatus. Now this takes place in endosmosis: the water surrounding the sac which contains the gum-water filtrates easily through the walls of this cavity; and when it has reached the interior it unites with the gum, and thus forms a new liquid, the passage of which through these walls is difficult in proportion to the quantity of gum ; it must then accumulate and ascend in the vertical tube, which communicates with the membranous reservoir.

The organised bodies, which absorb the liquids by which they are surrounded, are placed in the same conditions with the membranous sac, of which we have now spoken. The presumption, then, is, that in all these cases the same effects arise from analogous causes, and that the principal force, which occasions the passage of the absorbed substances through the living membranes, is the same with that which produces the phenomena of endosmosis.

The forces that operate to produce endosmosis and exosmosis are—first, capillary attraction. We see this in operation in the force with which a damp sponge will attract water into its pores ; and, as this force bears an inverse ratio to the diameter of the capillary tubes, it must exert great power in the minute pores of organic membranes. We have seen that capillary tubes select one fluid in preference to another ; and this, as a general rule, is the thin and light fluid, in preference to the dense. Another power to be noticed exists in the liquids themselves—a *tendency to mix*. Such a tendency causes a solution of a salt to diffuse itself when added to pure water, and produces the thirst which we feel when we have rendered the blood too saline by eating salt provisions. The absorption by veins is as easily proved in animals with a system of lymphatic vessels as in those without. The following experiment can leave no doubt in this respect :—Messrs. Magendie and Delille having stupefied a dog with opium, to render it insensible to the pain occasioned by a laborious operation, amputated one of his thighs, leaving the artery and vein to maintain the communication between the limb and the rest of the body by means of quills introduced into the vessels, and they deposited within the paw thus separated a violent poison (*Upas Tieuté*). The effects of the poison were manifested with the same promptitude and intensity as if the limb had not been severed from the body, and the animal perished in a few minutes. It has been proved by experiments equally conclusive that poisons are absorbed by the lacteals and lymphatics very tardily, and in some instances not at all.

The first condition of all absorption being the permeability of the tissues interposed between the substance to be absorbed, and the liquids which are to effect its transport, it is evident that, other things being equal, this phenomenon will be rapid in proportion to the lax and spongy texture of this tissue itself, and the degree of vascularity which is the seat of it.

In truth, the lax and spongy texture of the organic solids is of all the physical properties that which most facilitates imbibition; and with regard to the veins, since by them principally the absorbed substances are diffused in the economy, the influence of their number and size is too evident to require any comments. In the majority of cases these two laws will explain to us the great diversity observed in the rapidity with which absorption is effected in the various parts of the body: we might even anticipate this difference from the sole consideration of the anatomical disposition of our organs.

Thus the lungs are of all parts of the economy those in which the structure is most spongy, and the vascular system most developed. It follows, that absorption must be more rapid in these organs than elsewhere, and to this result does experiment lead. Areolar tissue is also very permeable to liquids, but possesses far fewer blood-vessels than the tissue of the lungs; therefore absorption, although very rapid, takes place less rapidly than in these organs.

The skin presents, on the contrary, a very dense texture, and its surface is covered by the epidermic epithelium; and, as might be expected from this anatomical disposition, absorption takes place with great difficulty. By raising the epidermis, imbibition is considerably facilitated, and consequently absorption is rendered more easy: finally, when we do not confine ourselves to simply stripping the dermis, but also excite its vascular system (by the irritation of a blister, for example), this function is rendered yet more active, by thus adding to those physical conditions that are favourable to absorption.

Another circumstance, which also exercises a great influence on the rapidity of absorption, is the state of plethora of the animal. The quantity of liquid which may be contained in the body of a living animal has limits, as well as the degree of desiccation, compatible with life. Now, the nearer the body approaches to its point of saturation, the greater difficulty do the liquids experience in reaching its interior.

Thus, if to two dogs equal doses of a poison be administered, the effects of which are not manifested till after absorption; and if previous to this operation the mass of humours in one of these animals be diminished by a copious bleeding, while in the other the volume of liquids contained in the body be increased by the injection of a certain quantity of water into the veins, the effects of the poison will take place sooner in the former than in ordinary cases, and in the latter those symptoms which denote the absorption of the poison will not appear for a much longer time. These results are more important to be known, as they meet with constant application in the healing art, and show how much the functions of living beings are subject to the ordinary laws of physics.

The various medicinal applications usually applied to the skin are introduced into the blood by capillary absorption, which is effected by the physical forces enumerated, aided in some instances by the more obscure operations of chemistry, of which the power of albumine, of holding certain metallic oxides in solution, is remarkable.

The Structure of Lymphatic Vessels.—In structure, the lymphatic vessels have a general resemblance to arteries and veins, having an external coat of areolar tissue, in which predominates the yellow element; and next, a layer which, according to Kölliker, is composed of a mixture of this tissue and muscular fibres. The muscular fibres have a circular arrangement; and, like arteries, mostly abound in the smaller vessels. On this layer comes the basement membrane, covered with tesselated epithelium. The lymphatics are supplied with valves which so effectually prevent the regression of their contents as to cause an accumulation at the site of every pair of valves, and so produces a bulging of the vessel, from which they derive their characteristic beaded appearance. The lacteals of the intestinal canal are of the same construction as the lymphatics, and join one common trunk,—the thoracic duct, which opens into the left subclavian vein at its junction with the internal jugular vein of the same side ; others, collected from the right side of the body, form a smaller trunk, which enters the vein of the opposite side. Lymphatics are met with in all parts of the body except the brain, ganglia, cartilage, tendon, bone, and the eye, and form in general a superficial and a deep plane of vessels. During their course they freely anastomose, and are seen to traverse little organs,—the lymphatic and the mesenteric glands, which are respectively situated in axilla, groin, neck, chest, and abdomen. The forces that move onwards the contents of these vessels are the elasticity of their coats, the contractility of the layer of muscular fibres, and the various pressures that all animal tissues encounter, either from the atmosphere, the action of muscles, or that arising from occasional contact of one part of the body against another. There is no doubt that the muscular fibres exercise an important agency in the furtherance of this object, although their contraction has not been made visible by stimuli; but it is observed that the lymphatics, like the arteries, are generally empty after death; and as the effects of rigor mortis are distinctly seen in them, it is probable that, being liable to this form of passive contraction, they are not deficient in the more active properties of muscular fibre. The *lymph-hearts* of reptiles, which are portions of the vessels dilated into a sac, the muscular fibres of which are endowed with rhythmic pulsation, adds comparative evidence to the proposition that the muscular fibres are not inert in human lymphatics.

The villi are prolongations of the mucous membrane of the small intestines: they are never present in the stomach, and very sparingly so in the duodenum or large intestines. They are fringed with epithelium at their edges, and being about the length of the pile of velvet, have a soft velvety feel. According to Dr. Handfield Jones,* their contents are a semi-transparent granular matter and nuclear corpuscles. This granular basis not only fills the villi, but is seen in the fibrous layer of the mu-

* Lancet, Nov. 17th, 1848.

cous membrane subjacent to its basement, and is continued through the whole course of the walls of the intestinal canal. During the active periods of the villi, their contents are opaque from the oil they contain; in a state of emulsion the nuclear corpuscles are indistinct, and a full-formed cell is rarely to be seen. It is probable, therefore, that *nuclear attraction*, and not cell-growth, is the means by which the chyle is introduced into the lacteals. This granular matter is not found in the coats of the stomach. In the large intestines Dr. H. Jones supposes it to be the seat of the black discolouration so common to certain diseased states of those membranes. It doubtless fills an important office in the functions of the intestinal tube; for, in the diarrhœas that so often attend failing vitality, which are the effect of increased efforts to rid the blood from the immense waste that at such a time is poured in from the tissues, this granular substratum becomes thickened with an abundant growth of cells and nucleated blastema; and to such an extent is it carried, that the basement membrane no longer adheres in patches, and ulceration is the consequence. It appears probable, from the general absence of cells in this layer of granular matter, that nuclear matter may perform an active agency in the animal economy without progressing to perfect cell-growth; the perfect cell is usually the tenant of a more permanent formation than the chyle, which is in this part of its progress in a more active state of change than the blood. The function of the villi is more one of separation and absorption than elaboration; and nuclear corpuscles have the power of attracting matters to themselves in almost every tissue, and which is particularly observable in the cartilaginous stage of bone development. The villi are covered with cylindrical epithelium, which have more the character of cells than the interior of the villi. Such epithelium becomes filled during digestion with the chyle, and bursting on the surface, their contents thus prepared is taken into the villus by the attracting power of its nuclear contents. Capillary blood-vessels and lacteals are thickly distributed within the villi, and pervade also the walls of the intestines, especially the small. The capillaries are mostly distributed immediately beneath the basement membrane, spreading out in a fine net-work. The lacteals, on the other hand, lie deeper in the granular substance ; and the lymphatics generally lie deeper in the tissues than the capillaries, which affords some explanation for the ready entrance of certain fluids into the veins, and for the comparatively slow process we have described by which the lacteals receive their contents. It may also account for the other differences between absorption by veins, and that under consideration. It is evident that absorption, accomplished by lacteals and lymphatics, is a much more complicated process than absorption by veins ; the first is confined to the selection of those matters that are found in lymph and chyle, and the rejection of all others. It has been proved by Tiedemann and Gmelin, that neutral and metallic salts, alcohol, the turpentines, odoriferous and colouring matters, find no admission into the lacteals ; and ferrocyanate of potash, absorbed by the lungs, reaches the left side of the heart earlier than the right—a proof that it is absorbed by the capillaries, and transported thither, mixed with the blood of the pulmonary veins, and consequently not taken up by the lymphatics, which would have taken it the round of the thoracic duct to the right side of the heart. The office of lymphatics is to collect nutritious matters of the type of lymph, and return them into the blood. It is supposed that some of the matters that are liberated in the disintegration and waste of the tissues are of this type. It may be that one office of the lymphatics is to prevent albuminous matter from escaping from the body by insensible perspiration: we know that albumine does traverse the blood-vessels, and forms a normal deposit in areolar tissue. The office of lymphatics being thus confined to the absorption of lymph, they do not operate towards the removal of extravasations, diseased formations, and exuberant growths, which is generally effected by veins.

Chyle has been ascertained by experiment to contain the essential constituents of the blood in a different state of organization ; on reference to the analysis, it will be seen to contain two ingredients in remarkable quantity—albumine and fatty matter. The chyle of mammals, whether carnivorous or herbivorous, is not found to differ materially, inasmuch as there is no difference in the essential constituents of their food. Chyle taken from the lacteals is milky, in consequence of the emulsive state of the fatty matter, which, under the microscope, is found, like milk, to contain a molecular base of very fine globules. The globules are supposed to consist of the fatty material. The exterior envelope of these minute bodies is merely a coating of albumine. Fine nuclei are also seen, which constitute all that can be discovered in chyle in this part of its course to the blood. It is of about the consistence of the serum of the blood, and coagulates very slowly, and scarcely can be said to become solid. When chyle is taken from the other side of the mesenteric glands it contains more fibrine, and gives a firmer coagulum; and chyle-corpuscles, which, when matured, cannot be distinguished from the white corpuscle of the blood, appear to be in course of formation, and of various sizes. In this stage the chyle has a creamy appearance, from a pink tinge given to the corpuscles, which is still more distinct as it advances in the thoracic duct.

With such a striking resemblance to the blood in composition which this fluid exhibits, the colour of the blood, which it seems on the verge of assuming, and the large amount that daily traverses the thoracic duct, we must admit the claim that the chyle has to be considered a fundamental pabulum for the generation of the vital fluid. Another very important source of the blood we have seen to be in the portal blood, as it returns from the coats of the intestines (the same lacteal district) to be circulated through the liver. Research has not yet determined whether both kinds of the blood-corpuscle are furnished from each of these sources; but as we have ample reason to suppose that the veins are capable of absorbing both azotic and non-azotic principles of aliment, it seems probable that the portal blood should not come behind the chyle in furnishing all the constituents of blood. The physiology of veins in some animals supports such a conclusion, from the fact that by them is the whole amount of nutriment absorbed into the blood. The salts of the chyle are the same as those of the blood, and its alkaline character is also the same. Lymph is essentially diluted chyle, minus the fatty material. The progressive formation of cells appears also to be carried on in the lymph. The following analysis of chyle and lymph, obtained from a young ass, by Dr. Owen Rees, is thus given :—

	Chyle.	Lymph.
Water	902·37	965·36
Albuminous matter	35·16	12·00
Fibrine	3·70	1·20
Alcoholic extractive	3·32	2·40
Aqueous extractive	12·33	13·19
Fatty matter	36·01	a trace.
Salts	7·11	5·85
	1000·00	1000·00

The amount of lymph and chyle that daily passes into the blood has been computed from experiments to be nearly equal to the whole volume of the blood. The relative proportions of each have not been ascertained. The large quantity of solid matters contained in the blood makes it probable that they are not replaced under several days.

THE SPECIAL SENSES.

The nerves of special sense enjoy but in a very limited degree the sense of touch or common sensation. The optic nerve may be pinched or cut without producing pain. The organs of special sense are supplied with common sensation by

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Chyle.

The chyle's constitution is founded, you know,
On fat and albumine ; we also can show,
That from these chyle-corpuscles, and fibrine indeed,
In gradations are formed as they onward proceed ;
Some little extractive 'tis said to contain ;
The salts are the same as the blood o'er again.

Human Milk.

The milk's composition is stated with ease :
Three organic compounds—fat, sugar, and cheese ;
Two ternaries first, the latter quatern :
The salts are the same as the blood you discern ;
With this special difference—a truth, though in rhyme—
It holds in solution more phosphate of lime.

the fifth pair. These different modifications of the faculty of sensation constitute the five senses by which we acquire all our ideas of external objects.

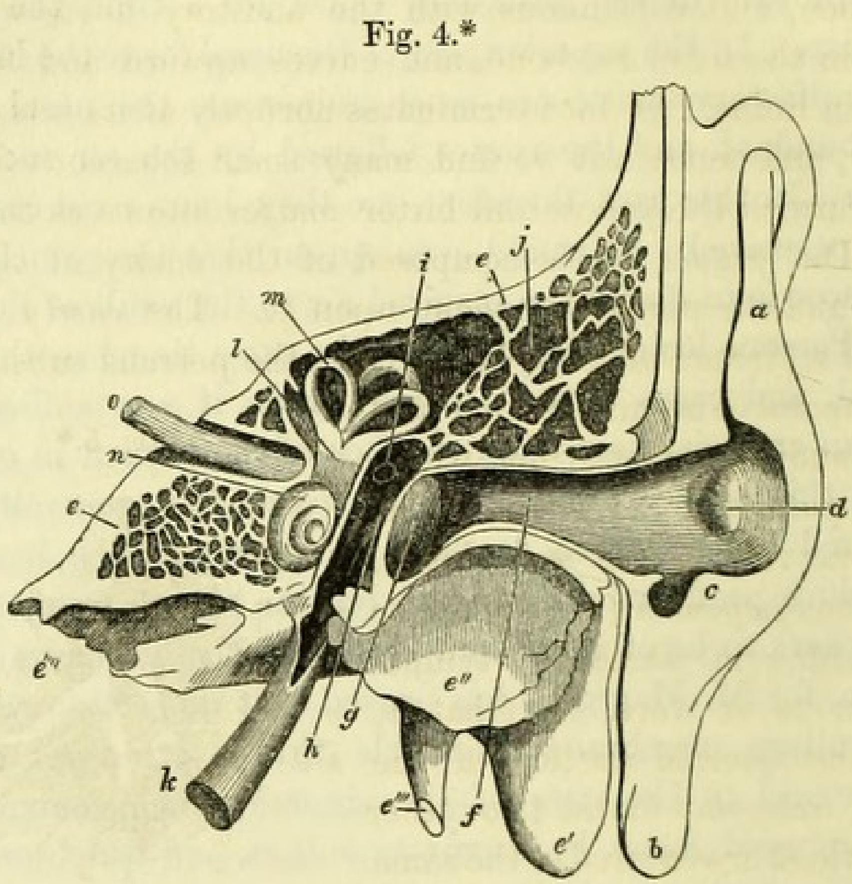
SENSE OF SMELL.

Certain bodies possess the peculiarity of exciting in us sensations of a peculiar nature, which cannot be perceived by the aid of the sense of touch or taste, and which depend upon the odour they exhale. Odours are produced by particles of an extreme tenuity, which escape from odoriferous bodies, and are diffused in the atmosphere as vapours. The quantity of matter thus diffused in the air, to produce even the strongest odours, is extremely small. A particle of musk, for example, may perfume the air of an apartment for a long time without any sensible change of weight. A multitude of bodies, such as water, clothing, &c., may imbibe these vapours, and in their turn become odoriferous; but other substances, such as glass, completely oppose their passage. To arouse our olfactory sense, odoriferous particles, emanating from bodies, must arrive in contact with the organ destined to receive them. And in this the mechanism of smell is analogous to taste and touch; while with sight and hearing, as we shall soon see, it is quite otherwise. The air is called the vehicle of odours: by this fluid they are transported to a distance, so as to reach us. It is, then, plain that the organ destined to perceive them must always be placed so as to receive their contact; and experience teaches us, that for the proper discharge of its functions, the membrane touched by the odours must be continually moistened and covered by a liquid proper to absorb the odoriferous particles, and to fix them for a certain time upon its olfactory surface. If this surface were exterior, the former of these conditions would be fulfilled, but not the latter; the odours would strike it, but it would soon dry up, and become insensible to their contact. Smell must consequently reside in the walls of a cavity within the body, communicating freely externally; and the more rapidly and regularly the air conveying to us the odours is renewed, the more favourable are the conditions to the exercise of this sense. This actually takes place, not merely in man, but also in all the other mammiferæ; in birds and reptiles, also, the sense of smell has its seat in the nasal fossæ, and these cavities are constantly traversed by the air going to the lungs to supply the requisitions of the respiration. They communicate outwardly by the nostrils, and open posteriorly into the pharynx, at a short distance from the glottis. Thus, whenever the mouth is shut, the air must pass through them to reach the latter opening, and they may be considered as the anterior portion of the aërial tube. The nasal fossæ are separated from each other by a vertical partition, directed from before backward, and occupying the median line of the face; their walls are formed by various bones of the face, and by the cartilages of the nose; and their extent is very considerable. Upon the external surface may be remarked three projecting plates curved upon themselves, and called the *ossa turbinata.* They increase the surface of this wall, and are separated from one another by a longitudinal furrow, called a *meatus.* Lastly, these fossæ communicate with *sinuses* hollowed out in the os frontis, ossa maxillaria superiora, &c. The mucous membrane lining the nasal fossæ is called the *pituitary membrane;* it is thick, and prolonged beyond the borders of the ossa turbinata, so that the air can traverse the olfactory cavities only by narrow and long routes; and the least swelling of this membrane renders the passage of this fluid difficult, or even impossible. The surface of the pituitary membrane presents many little projections, which give it a velvety aspect; lastly, it is continually lubricated by a liquid more or less viscous, called the *nasal mucus,* which appears to be formed in a great measure in the sinuses already mentioned; and it receives a very great number of nervous filaments,—some from the fifth pair, and others from the olfactory, or first pair. The mechanism of smell is very simple; it is only necessary that the nasal mucus should imbibe the odoriferous particles diffused in the air traversing the nasal fossæ, and that these particles should be thus arrested upon that part of the pituitary membrane which receives the filaments of the olfactory nerve. From this it can easily be conceived how important is the nasal mucus to the sense of smell, and how the changes in the nature of this liquid which take place during coryza or cold in the head, may cause, for a time, the loss of this sense. In the superior part of the nasal fossæ the branches of the olfactory nerve are most numerous, the nasal mucus most abundant, and the routes followed by the air most contracted. In this part, therefore, are the odours most easily and vividly perceived. It would even appear that the principal use of the nose is to direct the inspired air to the vault of the nasal fossæ. Persons losing this organ at the same time lose the sense of smell, and cases have occurred where it was sufficient to adjust an artificial nose upon the face of the patient in order to restore this sense. The olfactory nerve has generally been considered as the nerve destined to convey to the brain the impressions produced by odours; but the branch from the fifth pair appears to be of important service in the discharge of this function, for M. Magendie has proved that its section rendered the pituitary membrane insensible to the strongest odours. With regard to the uses of the sinuses which communicate with the nasal fossæ by narrow openings, and which are lined by a thin membrane, nothing positive is known. It has been remarked, however, that animals in whom these cavities are more vast are also those in whom the sense of smell is the most delicate.

SENSE OF HEARING.

Hearing is the function which makes us acquainted with the sounds produced by vibrating bodies. The apparatus of hearing is very complicated; the different parts of which it is composed are, for the most part, extremely small; thus it occupies but a very small space, and is almost entirely contained in the interior of a bony prominence, which, from either side of the head, advances into the interior of the cranium, and constitutes that part of the temporal bone called, from its hardness, the *petrous portion* (fig. 4, *e*). It may be divided into three portions—namely, the external, middle, and internal ear. The external ear is composed of the pavilion of the ear, and auditory canal. The pavilion of the ear

Fig. 4.*

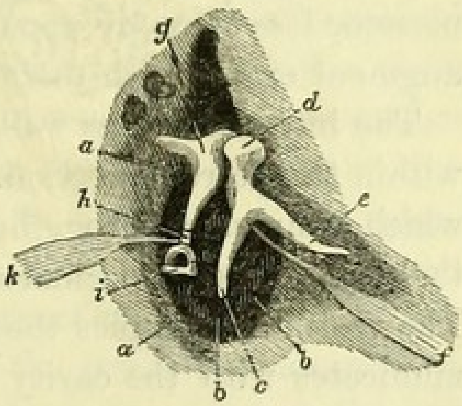


(*a*) is a fibro-cartilaginous plate, supple and elastic, which is perfectly free in the greater part of its extent, and which adheres to the edge of the auditory canal. The skin covering it is thin, dry, and very tense; its surface turns in several ways, and presents various eminences and depressions, the most con-

* This figure represents a vertical section of the auditory apparatus, with the interior parts slightly magnified, that they may be better seen. *a*, Pavilion of the ear; *b*, Lobule of the pavilion; *c*, Small eminence called the *antitragus; d*, Concha, the bottom of which is continuous with the auditory duct; *e*, *e*, Portion of the temporal bone, called *the petrous*, in which is lodged the auditory apparatus; *e'*, Mastoid portion of the temporal bone; *e''*, Portion of the glenoid fossa in which the lower jaw is articulated; *e'''*, Styloid process of the temporal, serving for the insertion of the muscles and ligaments of the os hyoides; *e''''*, Extremity of the canal traversed by the internal carotid artery before entering the cavity of the cranium; *f*, Auditory duct; *g*, Tympanum; *h*, Cavity from which has been taken the chain of bones; *i*, Openings from the cavity of the tympanum into the cells (*j*) of the petrous portion—on the internal wall of the cavity we find two openings, *fenestra ovalis* and *rotunda; k*, The Eustachian tube, conducting from the cavity to the summit of the pharynx; *l*, Vestibule; *m*, Semicircular canals; *n*, Cochlea; *o*, Acoustic nerve.

siderable of which is the concha (*d*). It forms a sort of tunnel, very open, and continuous with the auditory duct, which is buried in the temporal bone, and curves upward and forward. The skin lining this duct terminates abruptly at its internal extremity, and beneath it we find many small sebaceous follicles, which furnish the yellow and bitter matter known as the *cerumen*. The *middle ear* is composed of the cavity of the tympanum and the parts dependent upon it. The *cavity* (fig. 5, *h*), is of an irregular form, hollowed in the petrous substance of the temporal bone, and making part of the auditory duct, from which it is separated by a membranous partition, very tense and elastic, called the *tympanum* (*b*). Opposite the opening in which the tympanum is, as it were, set (that is, upon the internal portion of the cavity), may be found two other holes, which are covered in the same manner by a tense membrane; they are called, from their form, *the oval* and *the round fenestra*. Upon the posterior wall of the cavity is a hole conducting to the cells of the mastoid portion of the temporal bone, and on its inferior wall may be seen the opening of the eustachian tube, a long and narrow duct, with an outlet to the posterior part of the nasal fossæ, and which thus establishes a communication between the cavity of the tympanum and the external air. Finally, this cavity is tra-

Fig. 5.*

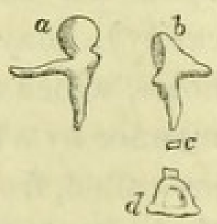


* This figure represents the external wall of the cavity, the tympanum, the bones of the ear, and their muscles, all enlarged. *a a*, Frame of the tympanum; *b*, Tympanum; *c*, Handle of the mallet, its end resting upon the middle of the tympanum; *d*, Head of the mallet articulating with the anvil; *e*, Process which springs from below the neck of the mallet, and buries itself in the glenoidal fissure of the temporal bone; its extremity gives attachment to the anterior muscle of the mallet; *f*, Internal muscle of the mallet; *g*, Anvil, a vertical branch of which rests upon the walls of the cavity, and a vertical branch articulates with the os orbiculare (*h*); *i*, Stirrup, the summit of which articulates with the os orbiculare, and the base of which rests upon the membrane of the fenestra ovalis; *k*, Muscle of the stirrup.

versed by a chain of little bones, which extends from the tympanum to the membrane of the fenestra ovalis, and which leans, by means of a branch directed to the side, upon the posterior wall of the cavity. (Fig. 5). These bones are four in number, and are called the mallet, or malleus (fig. 6, *a*), the anvil, or incus (*b*), os lenticulare (*c*), and stirrup, or stapes (*d*). A small stalk, which may be compared to the handle, and which belong to the malleus, rests against the tympanum, and the base of the stapes thus reposes upon the membrane of the fenestra ovalis. Finally, little muscles fixed to these bones impress upon them movements by means of which they press more or less strongly upon these membranes, and consequently augment or diminish their degree of tension.

The internal ear, as well as the middle, is entirely contained within the petrous portion. It is composed of several cavities which communicate together, and which are called the vestibule, semicircular canals, and the cochlea. The vestibule occupies the middle part, and communicates with the cavity by the fenestra ovalis. The semicircular canals project upon the superior and posterior part of the vestibule; they are three in number, and have the form of rounded canals swelled at one extremity, like a flask. Lastly, the cochlea is a very singular organ, spirally twisted like the shell of the animal whence it takes its name. Its cavity is divided into two parts by a longitudinal partition, semi-osseous, semi-membranous; it communicates with the interior of the vestibule, and is separated from the cavity only by the membrane of the fenestra rotunda. This latter cavity is filled with air; the internal ear, on the contrary, is filled with an aqueous liquid, and the membrane lining the vestibule, as well as the semicircular canals, is not applied to the bony walls of the cavity, but is in a manner suspended in their interior. The portio mollis of the seventh pair, which arises from the medulla oblongata near the restiform body, and which

Fig. 6.*



* Bones of the ear separated; *a*, Malleus or mallet; *b*, Incus or anvil; *c*, Os orbiculare; *d*, Stapes or stirrup.

departs from the encephalon between the peduncle of the cerebellum and the annular protuberance, enters the petrous portion through a bony passage called the internal auditory canal, and terminates in the interior of the membranous sacs of the vestibule and semi-circular canals, and also in the cochlea. Upon it depends the special sense of hearing, and therefore it is called the acoustic nerve. Such are the principal parts of the auditory apparatus. Let us now see the part taken by each in the exercise of the sense of hearing. Hearing, we have said, is to make us acquainted with sounds. Sound results from a very rapid vibratory motion of the particles of sonorous bodies. To be assured of this, it will suffice merely to sprinkle some fine sand upon a plate of glass, or the table of a violin, and to produce on this plate or instrument any sound whatever. The grains of sand are at once agitated, and thrown into the air with a force proportioned to the intensity of the sound. The undulations experienced by the sonorous body are communicated to the air in contact with its surface, as they were communicated to the grains of sand in the preceding experiment; and thus from step to step are sounds propagated to a distance. To perceive these sounds, the vibrations now spoken of must reach the internal ear, and by their influence the liquid, which immediately bathes the acoustic nerve, will itself be thrown into undulation. To point out the rationale of the mechanism of hearing, we must then follow the course of these undulatory motions through the various parts of the auditory apparatus interposed between the external air and the acoustic nerve. The sonorous vibrations of the air first strike the pavilion of the ear. In animals, where this part has the form of a horn, it serves to reflect the vibrations, and to augment the intensity of the sounds at its contracted extremity, as experiment easily proves. Every body knows that persons a little deaf hear with much more facility when they use a similar horn, and if a thin membrane be stretched over the open summit of a paper cone, and its surface be sprinkled with fine sand, the movements of the sand will be found much more intense when the sound arrives at the membrane by the broad outlet of the tunnel, than when coming from the opposite side. In man, the concha and the auditory duct discharge the same functions; but the other parts of the pavilion are not so arranged as to reflect sounds to the tympanum, and they also appear to have other uses. When sonorous vibrations fall perpendicularly upon an elastic surface, the undulatory motions excited in the latter are much more intense than when the sound arrives obliquely; and it may be concluded, that the varied directions of the surface of the pavilion of the ear are destined to present to the sonorous waves, whatever be the direction in which they strike us, a plane thus arranged, and, consequently, they serve to augment the vibratory action of this elastic appendage. The pavilion of the ear is not, however, of very great utility, and the loss of it does not much affect the hearing. The vibrations thus excited in the pavilion of the ear are communicated to the walls of the auditory duct, and thence to the deeper-seated parts of the apparatus of hearing; but these movements can only be very weak, and principally by the intervention of the air contained in this duct the sounds penetrate into the interior of the ear. Thus, if the tube be plugged with cotton or any other soft body which opposes their passage, the perception of them is rendered indistinct. The tympanum serves principally to facilitate the transmission of sonorous vibrations from the external air to the acoustic nerve. The experiments of a skilful physiologist, M. Savart, prove that sounds, by striking upon a thin and moderately tense membrane, excite in it, very easily, vibrations. If a leaf of paper be stretched upon a frame, and its surface powdered with sand, the latter is readily agitated, and collected so as to form varied lines, as soon as a sonorous body in vibration is brought near. If the same experiment be made with a plane of wood, or a leaf of paper, no such movement will result, unless the sound employed be extremely intense. But if to these latter bodies there be adapted a membranous disc, similar to the tympanum, they will readily vibrate under the influence of sounds which before would have produced no appreciable effect. It is plain, then, that the tympanum must readily vibrate when sounds strike upon it, and that its presence must augment the facility with which the other parts of the auditory apparatus experience similar motions. The vibrations are transmitted from the membrane of the tympanum to the bones of the ear, to the walls of the cavity, and especially to the air with which this cavity is filled: they thus arrive at the posterior wall of the cavity, where there are membranes stretched upon openings conducting to the internal ear, nearly as the tympanum is stretched between the auditory duct and the cavity. These membranes must act in the same manner as the latter; that is, easily be made to vibrate, and transmit these motions to the neighbouring parts. The posterior face of these membranous discs is in contact with the aqueous liquid which fills the internal ear, and in this liquid are suspended the membranous sacs,* which, in their turn, are distended by another liquid, into which are plunged the terminal filaments of the acoustic nerve. The vibrations executed by these membranes must then be transmitted to this liquid, afterwards be communicated to the membranous sac of the vestibule, and finally arrive at the nerve upon which their action produces the sensation of sound.

From the preceding observations it will be seen that the air contained in the cavity plays a very important part in the mechanism of hearing: now, if this cavity did not communicate externally, this air would soon be absorbed and disappear, and the vibrations of the tympanum could be transmitted to the internal ear only by the osseous walls of the cavity, and then with difficulty. This accounts for the use of the eustachian tube, and explains to us in what way the obstruction of this duct may become a cause of deafness. The tympanum is not indispensable to hearing, for when this membrane is torn the vibrations of the air contained in the auditory duct are communicated without interruption to the air of the cavity, and

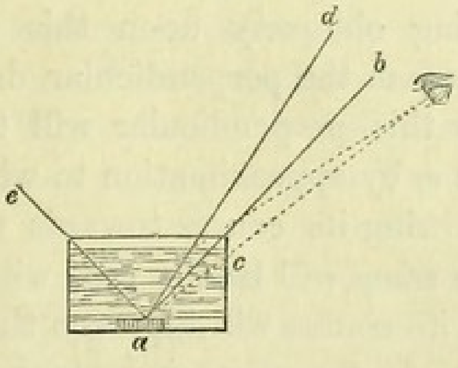
* They are called the membrane of the vestibule, and the tubes of the semicircular canals, according as they occupy the vestibule or the semicircular canals; in the cochlea there is nothing similar, and the liquid by which it is filled is the same which bathes the membrane of the vestibule.

thus arrive at the membranes of the fenestra ovalis and rotunda. It might then be asked, what is the use of this, and what disadvantage could arise, if, the cavity not existing, the membranes of the fenestra ovalis and rotunda were placed externally? To reply to this question it must be borne in mind that the manner in which the membranes vibrate under the influence of the same sound varies with their degree of dryness or humidity, their temperature, &c. Now it is probable that two sounds make upon us the same impression whenever they cause the liquid in which the acoustic nerve terminates to vibrate in the same manner; and, consequently, in order that the same sound may always act upon us in an identical manner, the membranes which communicate directly their vibrations to this liquid must consequently be at the same temperature and the same degree of dryness; and this is precisely the case with the membranes of the fenestræ of the internal ear. The air of the cavity being renewed but very gradually, is always completely charged with moisture, and at the same temperature, while if the cavity did not exist, or had free external communication, the condition of these membranes would be changed at every instant, according as they were exposed to the action of air, hot or cold, dry or moist. This also explains to us why the eustachian duct is long and narrow in all warm-blooded animals, while in the cold-blooded, such as the lizards, it is short and very large. In the former the air must have time to ascend to the temperature of the body, before penetrating the cavity, while in the latter, this temperature being the same with the atmosphere, the speedy renewal of the air contained in the cavity has no bad results. We learn, therefore, that the chain of bones traversing the cavity, and which rests upon the tympanum and the membrane of the fenestra ovalis, may execute certain movements by means of which the pressure it exercises upon these membranes may be increased or diminished. The utility of this arrangement is easily understood: if sand be sprinkled upon a membrane made tense by a frame, and a sonorous body in vibration be approximated to it, it will be found, that without in the least changing the intensity of the sound, the violence with which the sand is thrown into the air will be increased or diminished as the tension of the membrane is increased or diminished. In the former case it will execute under the influence of a sound of the same intensity, vibratory movements much more extensive than when the tension is increased. From this we may infer, that the pressure, more or less strong, of the malleus upon the tympanum, and of the stapes upon the membrane of the fenestra ovalis, will prevent these membranes from vibrating too strongly under the influence of very intense sounds, without depriving them of the faculty of vibrating when a feeble sound strikes them. The pressure exercised upon the membrane of the fenestra ovalis is thus communicated to the membrane of the fenestra rotunda by the intervention of the liquid with which the internal ear is filled; and the result is, that the bones of the organ of hearing, by leaning upon the two membranes to which they are fixed, prevent the sonorous vibrations arriving at the acoustic nerve from being so intense as to injure this delicate organ. The loss of the malleus, incus, or os orbiculare, diminishes the hearing, but does not destroy it; that of the stapes is, on the contrary, followed by deafness, for this bone, adhering to the membrane of the fenestra ovalis, by its fall tears the partition, and thus the liquid contained in the vestibulum being lost, the acoustic nerve can no longer discharge its functions. We see, then, that all the parts composing the external and middle ear serve to perfect the hearing, without however being absolutely necessary to the exercise of this sense. Thus they gradually disappear as we depart from man, and study the structure of the ear in animals gradually descending in the scale of beings. In birds there is no pavilion of the ear; in reptiles the external auditory duct is also wanting, the tympanum becomes external, and the structure of the cavity is simplified; finally, in most fishes there is neither concha, external nor middle ear. In animals placed yet lower in the series of beings, it is the same with the cochlea and the semicircular canals, parts the uses of which are not well known; but the membranous vestibule is an organ never wanting; wherever there exists an auditory apparatus, there is always found a small membranous sac filled with liquid, in which the acoustic nerve terminates, and this vestibule is always an instrument indispensable to the exercise of the sense of hearing.

VISION.

Sight is that faculty that makes us sensible of the action of light, and which acquaints us, through this agent, with the form of bodies, their colour, size, and position. The globe of the eye, with which we shall first be occupied, is a hollow sphere, a little prejecting in front, and filled with humours more or less fluid. Its exterior envelope is composed of two very distinct parts, one strong, opaque, and fibrous, called the *sclerotica :* the other transparent and similar to a plate of horn, therefore called the *cornea.* The latter occupies the front of the eye, and is, as it were, set in a circular opening of the sclerotica. Its external surface is more rounded than that of the latter membrane, and it resembles a watch-glass applied upon a sphere, and projecting beyond its surface. At a short distance behind the cornea, in the interior of the eye, is a membranous partition, which is stretched transversely, and fixed to the anterior border of the sclerotica, quite around the cornea. This kind of diaphragm, which varies in colour with the individual, is called the *iris,* and presents in its middle a circular opening named the *pupil.* Muscular fibres may be detected in the tissue of this organ, directed like rays from the edge of the pupil towards the circumference of the iris, and other fibres of the same nature, which are circular, and surround this opening like a ring. When the former contract, the pupil dilates ; by the action of the latter it is contracted. The space comprised between the cornea and the iris constitutes the anterior chamber of the eye. By the opening of the pupil it communicates with the posterior chamber, a cavity situated behind the iris, and which is filled, as well as the former chamber, by the *aqueous humour*, a perfectly transparent liquid, composed of water, holding in solution a little albumen, and a small quantity of salts, such as the serum of serous membranes, or that in areolar tissue. This secretion is supposed to be formed by a membrane behind the iris, which presents a great number of radiated folds, called *ciliary processes*. Almost directly behind the pupil is a transparent lens, called the *crystalline*. It is lodged in a diaphanous membranous sac (the capsule of the crystalline lens), and appears to be the product of a secretion from it; for when taken from the eye of the living animal without destroying its capsule, a new lens is found to take the place of the old. It is also remarked, that this body is composed of a great number of concentric layers, constantly increasing in hardness, from the circumference to the centre, which agrees with our remarks upon the mode of its formation. Its posterior face is also much more convex than its anterior. Behind the crystalline lens we find a large gelatinous diaphanous mass, resembling the white of an egg, and enveloped in a membrane of extreme tenuity, a great number of lamellæ from which extend inward, so as to form partitions or cells. This membrane is called the *hyaloid*, and the humour found in it the *vitreous humour*. Every where, except in front, where are the crystalline lens and the iris, the vitreous humour is surrounded by a soft white membrane, called the *retina*, which is an expansion of the fibres of the optic nerve at the interior and posterior part of the globe of the eye. The optic nerve penetrates the membranes of the globe at about an eighth of an inch to the inner side of the centre of the retina, which is the axis of vision, at which point there is no power of vision; it is however more perfect immediately around this spot, and gradually diminishes as the nerve expands. As the nerve enters the eye, the fibres lose the white appearance of the axis-cylinder fibre, and assume the grey character of the fine nerve fibre, which makes it probable that they are devoid of the white substance of Schwann. Their mode of termination has not been determined, but grey vesicles are interspersed between the fibres, and the whole is wove into a delicate membrane, by means of fibres of areolar tissue, and fine capillaries. No caudate vesicles have been observed in the retina, but that the vesicles are intimately connected with the sense of vision is probable from the fact that in the continued state of inaction to which they are reduced in amaurotic retinæ, they become degenerated into fatty matter. The use of the *yellow spot of Soemmering*, which is a concentration of vesicles exactly at the centre of the retina, or at the axis of vision, is unknown. Immediately behind the retina is the *membrana Jacobi*, a membrane composed of transparent cylindrical bodies, placed side by side, which abut into the substance of the *choroid* behind them. The latter is principally formed by a net-work of blood-vessels, which secrete a black matter, which gives to the bottom of the eye that deep colour which is seen through the pupil, and which is wanting in those persons and animals called *albinos*. The globe of the eye receives several nerves. The most remarkable for its size and functions is the optic nerve, which traverses the posterior part of the sclerotica, and is continuous with the retina, which appears in fact but an expansion of it. The other nerves of the globe of the eye are extremely small, and are called the ciliary nerves: they spring from a small ganglion, formed by the union of some branches of the nerves of the third and fifth pairs, and are distributed to the iris, and the proximate parts of the interior of the globe of the eye. By the intervention of light, we have said, bodies placed around us act upon our sight. Those which emit light, the sun and bodies in ignition for example, are visible of themselves; but others become so only when the light striking upon them is reflected in such a way as to meet our eyes. This agent moves with an extreme rapidity; it can act upon our senses only to the extent it strikes upon the retina, situated at the bottom of the eye. Opaque bodies reflect or absorb it, but transparent bodies, such as the atmosphere and water, afford it a free passage. The first condition, then, for the exercise of vision, is the absence of every opaque body between external objects and the bottom of the eye. The diaphanous parts of the globe of the eye do not serve to give passage to the light merely: their principal use is to change the direction of the rays which enter this organ, so as to collect them upon some point of the retina. The interior of the eye resembles exactly the optical instrument known as the camera obscura, and the image of the objects seen by us is painted upon the retina, as upon the curtain placed behind the latter. To understand this phenomenon, it is necessary to examine the course of luminous rays through transparent bodies in general, and to apply the knowledge thus acquired to the study of the mechanism of vision. Light ordinarily advances in a straight line, and the different rays, which start from any one point, are dispersed according to the direction in which they travel, and the distance of the space traversed. When these rays fall perpendicularly upon the surface of a transparent body, they traverse it without any change in direction; but if they strike it obliquely, there is always more or less deviation from their primitive course. If the body, into which they penetrate, be more dense than that from which they issue,—if they pass from air into water or glass, for example,—they then form an elbow, and approach the perpendicular at the point of immersion. If, on the contrary, they pass from a dense to a rare medium, they depart from this perpendicular, and these deviations are greater in proportion to the obliquity with which the ray strikes the surface of the transparent body. This phenomenon, which is known as the refraction of light, is easily understood. It is owing to this change in the direction of the luminous rays, in their passage from water into air, that a straight stick, plunged half its length into the former liquid, always appears as if bent at the point of immersion; and if a piece of money (*a*) be placed at the bottom of an empty vase, and the edge of the latter be raised just high enough to prevent the eye of the observer from perceiving this object to render it visible, it will be sufficient to fill the vase with water. From the ray of light coming from the money, instead of always advancing in a straight line, it will be refracted in its passage from the water into air, and will depart from the perpendicular; and by this change in direction, the rays, which before passed above the eye of the observer, will strike upon it. The luminous

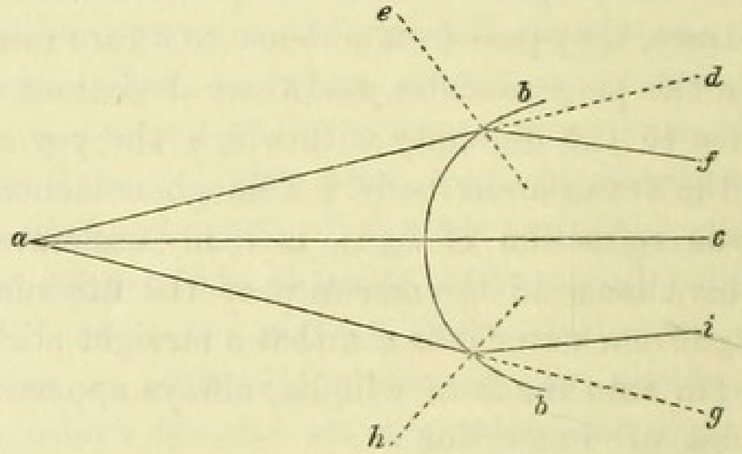
Fig. 7.



rays, we have observed, approach the perpendicular at the point of contact, whenever they penetrate obliquely a body denser than that from which they issue. Therefore, the form of bodies exerts a great influence upon the course of the light traversing them; and as their surface is convex or concave, these rays will be collected or dispersed.

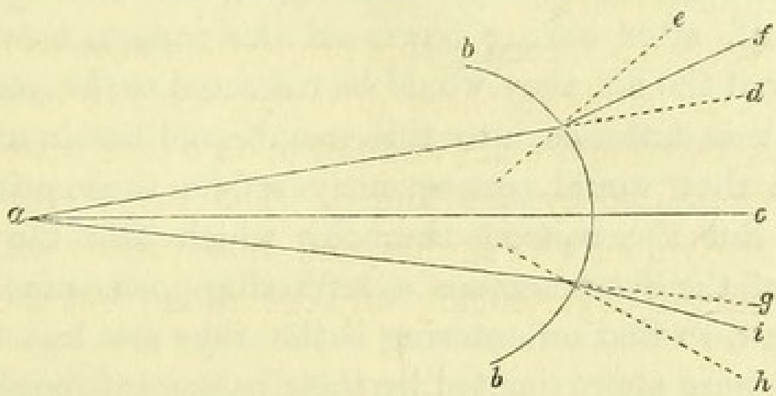
Some examples will render this proposition easy to be understood. Let us suppose three diverging rays to set out from the point *a*, traverse the air, and fall upon a lens with a convex surface represented by the line *b*. The ray *a c*, will strike perpendicularly upon this surface, and consequently will traverse the lens without experiencing any deviation; but the ray *a d*,

Fig. 8.



falling obliquely upon this surface, will be refracted, and approach the perpendicular drawn to the point of immersion: now this perpendicular will take the direction of the dotted line *e*, by approximation to which, the luminous ray, instead of following its course towards the point *d*, will follow the line *f*. The same will be the case with the ray *a g*, which in continuing its course will approach the perpendicular *h*, and be directed towards the point *i*, instead of continuing in a straight line towards the point *g*. The other rays, which strike upon the lens, will be refracted in an analogous manner, and, consequently, in the place of being dispersed, they will be collected and may even unite in one point, which may be called the *focus* of the lens. If the surface of the crystal, in place of being convex, is concave, the luminous rays will not approach the axis of the bundle, as in the preceding case, but, on the con-

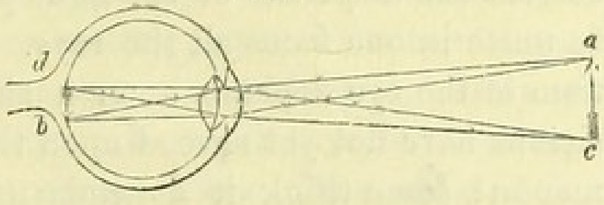
Fig. 9.



trary, will greatly diverge. The ray *a d*, for example, must approach the perpendicular at the point of contact, which will have the direction of the dotted line *e*, and by this deviation the ray will take the direction of the line *f*.

The refraction of the luminous rays, in thus traversing convex or concave lenses, is greater in proportion to the curvature of the surface of these bodies, and the mere inspection of the figures we have made use of will be sufficient to make us comprehend it must be so. For the greater the curvature of the surface upon which the diverging rays strike, the more will the perpendiculars, at the point of immersion, depart from these same rays. Physics also teach us that transparent bodies refract the light more powerfully in proportion to their density (that is to say, when under the same volume they have a more considerable weight), and when formed of more combustible materials. The light which strikes a transparent body does not entirely traverse it; a considerable portion is reflected, and, owing to this property, bodies answer more or less perfectly the purpose of mirrors. From what precedes, we see that when a collection of luminous rays falls upon the cornea, one part must be reflected while the other traverses it. It is the light thus reflected which gives to the eyes their brilliancy, and which causes our own image in the eyes of others. The rays which penetrate into this transparent plate pass into a body much denser than the air; they are, consequently, refracted and approximated to the perpendicular or axis of the collection, the more forcibly in proportion to the convexity of the cornea; for the greater the projection of this membrane, the more acute will be the angle formed by the diverging rays striking upon its surface. If, after having traversed the cornea, the luminous rays entered the air, they would be refracted to the same degree as upon their entrance into this membrane, but in a contrary direction: they would consequently retake their primitive direction. But the aqueous humour which fills the anterior chamber of the eye possesses a refracting power much greater than the air, so that on entering it the rays are less dispersed than they were approximated by their passage through the cornea: the action of these parts, therefore, renders them less divergent than before their entry into the eye, and causes a more considerable quantity of light to pass into the opening of the pupil. A great part of the light which arrives at the bottom of the anterior chamber of the eye meets the iris, and is absorbed or reflected outwardly by it: that only which falls upon the pupil penetrates to the bottom of the eye, and the quantity is in proportion to the size of the opening. Thus, when but a small quantity of light reaches the eye, the pupil is dilated, while it contracts under the influence of a brilliant light: the iris, as we see, regulates the quantity of light reaching the retina. The rays of light having traversed the pupil, fall upon the crystalline lens, which is diaphanous, and which changes anew their direction, causing them all to converge to one point, called the focus, where they unite. Now this focus is precisely upon the surface of the retina, and it is thus that the luminous rays sent to the eye from different points of a body placed at a distance are collected upon this nervous membrane so as to paint upon it in miniature the object from which they emanate. It is easy to be convinced by experiment that images are thus formed in the bottom of the eye. Take the eye of a hare or pigeon, the sclerotica of which is nearly transparent, or better yet, the eye of an albino, and place in front of the cornea a very brilliant object, a lighted candle for example, and the image of the latter will be seen depicted upon the retina. These images are always formed upside down, and the cause of this phenomenon is easily shown. When we consider the course the luminous rays, originating from the two extremities (*a*, *c*), of an object, must take to reach the retina, it will be seen they must cross before reaching it, and that consequently the ray coming from the superior extremity (*a*) of an object will be at the lower part of the space occupied upon the retina by the entire collection of rays forming the image (*b*), while that coming from the inferior extremity of the object (*c*) will occupy the top of the same space (*d*). The same will take place with all the other rays, and therefore the object will appear reversed at the bottom of the eye. The black matter, which is situated behind the retina, and which lines the whole bottom of the eye as well as the posterior face of the iris, serves to absorb the light immediately after it has traversed the retina. If this light were reflected in other points of the membrane, it would considerably trouble the sight, and prevent the clear formation of images on the bottom of the eye. Thus in albinos, whether man or animal, where this pigment is wanting, vision is extremely imperfect: during the day they can scarcely see at all. The globe of the eye serves to conduct the light and to concentrate it upon the retina. It discharges the office of a kind of spectacle-glass, but it is an optical instrument far more perfect than any of those ever yet constructed by scientific men: for at the same time that it is perfectly achromatic and presents no aberration of sphericity, its capacity may vary considerably. By *achromatism* is meant the property of turning light from its course without developing any colour, and, consequently, the achromatic lenses are those which form in their foci colourless images, or possess only the colours of the object represented. The white light results from the union of the seven coloured rays of the solar spectrum, and these different rays are not equally refrangible. Wherefore, when light is passed through a refracting body, it is more or less com-

Fig. 10.



pletely decomposed, and the objects whence it proceeds appear to have the colour of the solar spectrum. Achromatic microscopes are obtained by combining several glasses, some of which correct the dispersal of the light produced by the others, so as to unite in one focus all the rays. It is probable the achromatism of the eye depends upon a similar arrangement, but physicians have not yet agreed upon the explanation of this phenomenon: some think it depends upon the different humours of the eye; others attribute it to the difference of density in the different layers of the crystalline lens.

The *aberration of sphericity* consists in the union of rays which fall upon different parts of a lens, into foci sensibly different, whence results a want of clearness in the images. When the lenses are very convex, the rays which pass near the edges do not unite in the same focus with those which traverse the central part of the instrument; and to obtain clear images, the passage of the former must be intercepted by placing in front of the lens a separating medium pierced by a hole. Now, the images formed behind the crystalline lens of the eye are never diffused, and this want of aberration of sphericity has been attributed to the iris, which answers the purpose of the divisions in the interior of telescopes. Every one knows that objects may be seen with the same clearness when placed a few inches from the eye, as when at a considerable distance from this organ. In our optical instruments, on the contrary, the image formed in the focus of a lens advances or recedes according to the distance of the object. It has, therefore, been supposed that to give to our sight such varying capacity, the crystalline lens must approach or recede from the retina as necessity required, or else the globe of the eye must change its form. But direct observation does not confirm these hypotheses, and this peculiarity has never found a satisfactory explanation. However, the eye does not always possess in the same degree this precious faculty; some can see distinctly only at the distance of some feet; nearer, all images are confused. With others, on the contrary, the sight becomes clear only when the objects are brought within a few inches of the eye, and every thing beyond seems enveloped in a cloud. The former of these infirmities, known as *presbytia*, depends upon a want of convergence in the collections of rays traversing the humours of the eye. The rays which arrive at this organ from a very distant object diverge very little, and may be collected at one point of the retina, although the refracting power of the eye be small; but those which come from a near object diverge greatly, and the refracting power of the eye is too weak to collect them upon a determinate point of the retina. Those thus afflicted have usually a contracted pupil, as if they were continually making an effort to prevent any other rays from entering the eye than those falling upon the centre of the crystalline lens, and which do not require great deviation from their course to be collected together behind it upon a fixed point of the retina. This want of refracting power in the eye appears, in general, to belong to a flattening of the cornea or crystalline lens, which circumstance must tend to produce presbytia, and which may be found in nearly all old persons. *Myopia* is the result of a contrary effect. The rays which traverse the eye are then so forcibly deviated from their course, that in place of diverging they even converge before reaching the retina. This imperfection of the visual organ depends, in general, upon too great a convexity of the cornea or crystalline lens. It is remarked that short-sighted persons become less so by age, which happens in consequence of a diminution in the secretion of the humours of the eye always occurring in old age, which, by rendering the cornea less convex, renders the sight longer; in most cases it causes presbytia, but here it only serves to correct the errors of the eye, and to give to the sight its usual character: therefore, the vision of short-sighted persons is improved by age, while in others it is usually weakened. To correct these natural faults of the eye, recourse must be had to means the efficacy of which confirms the explanation just given of the cause, whether of myopia or presbytia. Glasses are therefore placed before the eyes with surfaces so directed as to augment or diminish the divergence of the rays traversing them. Short-sighted persons make use of concave glasses, which give divergence to the rays of light, and the far-sighted employ convex, which, on the contrary, collect the rays diverging from the axis of the bundle.

The sensibility of the retina is entirely limited to the stimulus of light, and can only be excited by this subtle agent. This nervous membrane enjoys little or no sensibility to the touch, and it may be touched, pinched, or even torn in the living animal without the slightest manifestation of pain. However, this peculiar sensibility of the retina has its limits: too feeble a light does not act upon it, and too strong a light injures it and renders it incapable of action. But in this respect the influence of habit is extreme: when a person has remained some time in obscurity, a light, although very feeble, dazzles the eyes, and renders for some instants the retina incapable of discharging its functions, while those accustomed to the light of day experience the same effects only when looking upon the most brilliant objects; in seeking, for example, to take the sun's altitude. When we look for a long time upon the same object without a change of position, the point of the retina receiving the image is soon fatigued, and this fatigue, carried beyond a certain limit, deprives for some time the part experiencing it of its usual sensibility. Thus, if we look for some time at a white spot on a black ground, and then change our sight to a white ground, we think we see a black spot, because the point of the retina already fatigued by the white light has become insensible to it. The fatigue experienced by the retina in the exercise of its functions depends in part upon the efforts made to fix the attention upon the object placed before the eyes. If we endeavour to examine attentively bodies in a feeble light, we soon experience a painful sensation in the orbit, and also in the head. All points of the retina are adapted to receive the impression of light; but the central part of this membrane enjoys a more exquisite sensibility than the rest, and it is only when the images of external objects are formed upon this part, that we see them distinctly. Thus, when looking at any object, we take care to direct toward it the axis of our eyes. The optic nerve, which, by its expansion on the bottom of the eye, forms the retina, transmits to the brain the impressions produced upon this membrane by the contact of light: its section, therefore, produces total blindness. The fifth pair are the nerves of nutrition of the eye, as they are also of the organs of smell and taste;

they appear to exert a more direct influence on the nutrition of the structures of the eye than is generally exercised by nerves on the nutrition of organs; for we have already seen that the division of these nerves generally ends in the destruction of the globe of the eye.

We judge of the *form* of bodies by that of the image they produce upon our retina: therefore, when, from any cause, the form of the luminous pencil of rays sent by them to this membrane is changed before reaching the eye, we fall into great errors in our judgment. The experiment already cited, of a stick half plunged into water and then appearing bent, although actually straight, is an optical delusion of this kind. We judge of the *position* of surrounding objects by the direction of the luminous rays they send to us, and we always see them in the extension of the straight line followed by these rays at the moment they penetrate the eye. For this reason, when the pencil of rays sent by one of these objects upon a polished surface (a mirror, for example), is reflected by the latter so as to make a greater or less angle and arrive at the eye, we see the object as if it were placed behind the mirror, in the prolongation of the straight line pursued by the ray meeting the eye from this instrument. Judgment may rectify the consequences we draw from this sensation; but it always exists. This accounts for our using but one eye when we wish to be certain that bodies are in an exact line with each other. When this condition is actually fulfilled, and one of our eyes placed upon the prolongation of the line occupied by these objects, the luminous ray which is directed from the more distant body towards our eye cannot arrive to it, being intercepted by the intervening body; and so of the rest: consequently the nearest body conceals from us entirely or in part all the others, when, if regarded by both eyes, the same thing happens only when the objects are so far distant from us that the rays sent to our eyes are almost parallel, or when the intervening object is very large in comparison with the more distant, or very near to it; and even then the coincidence is much less plain than if the observer uses but one of his eyes. To estimate the *distance* which separates us from objects, the simultaneous action of the two eyes is, on the contrary, of great assistance: the following experiment will convince us of the fact. Suspend a ring by a thread, and try to introduce a pointed instrument fixed to the end of a long stick: by making use of both eyes we easily succeed at every trial, but if one eye be closed we find the greatest difficulty in threading the ring; the instrument will go beyond or stop short, and only by chance, or after repeated trials, shall we succeed in introducing it into the ring. Thus, when an individual has lost one eye, he generally remains some time unable to judge correctly of the distance of bodies situated near him; and this privation renders the appreciation always much more difficult. But the utility of the two eyes in this case is easily explained upon physical laws. When an object is only a short distance from us, it is requisite, in order that its image may fall upon the same point of the retina of the two eyes, that the axis of these organs should converge toward the point looked at, and this inclination, of which we are conscious, is great according to the proximity of the object. But when objects are so far distant that in beholding them the optic axes of the two eyes become sensibly parallel, we have no longer a sure rule to determine their distance, and we can only form our judgment from data more or less deceptive—such as the degree of light, the clearness with which we distinguish the minutiæ, the size of the object itself, our previous acquaintance with it, &c. When we can compare this distant object with those intervening, this appreciation becomes much more certain; every one knows how difficult it is to judge of the distance of a light seen in the middle of the night, when the obscurity prevents surrounding objects from being seen. The concurrence of the two eyes is, moreover, essential inasmuch as it makes objects appear plainer. If we regard a strip of white paper with one eye, and place before the other an obstacle which will conceal half the object, the portion seen by both eyes at the same time will appear much more brilliant than when seen by one alone. The manner in which we judge of the *size* of bodies depends much more upon intelligence and custom than upon the action even of the apparatus of vision. Our first guide is really the size of the image formed at the bottom of the eye; but as the distance between us and an object increases, this image diminishes, so that to judge of the dimensions of the former, the distance at which we suppose it must always be considered. When, therefore, the distance is not exactly appreciated, it is difficult to judge of the size of a body seen for the first time. Regarding the apparent size of objects, Mr. Wharton Jones makes the following remarks in his Prize Treatise on Vision, 1851:—"The greatness of the apparent size of visible objects, in proportion to the extent of the retina impressed by their pictures, depends on the projection outwards of the mind's perception of the figure. The size of the retinal picture being the same, the greater is the apparent size of the mind's picture the farther distant out from the eye it appears projected: this is well illustrated by ocular spectra consequent to impressions on the retina: thus, if, after having in the morning twilight fixed our eyes on any object, we direct them to the sky, we shall see its spectrum projected of a gigantic size on the distant grey expanse. As, in viewing an object, the eyes are adjusted to the distance at which it is situated, and the mind refers its perceptions outwards to that distance, it follows, that the distance at which the object is situated, and the size of the picture it projects on the retina, are the conditions which determine its apparent size."

The estimation of the *motion* of bodies is sometimes made from the change of direction of the light which arrives at the eye, whence results the displacement of the image upon the retina, sometimes from the variation in size of this same image. In order to follow the motion of a body, its displacement must not be too rapid, for then we do not perceive it unless it project a very great quantity of light, and, in this case, the same effect is produced upon our eyes as if it instantaneously occupied the whole length of the line traversed. On the contrary, we generally recognise with great difficulty, and sometimes we even cannot recognise, the motion of bodies the image of which is very slowly displaced, either from the actual slowness of their motion, as in the hand of a watch, or from their great distance, as in the stars. The *duration of sensations* after the impression on the retina has ceased, Mr. Wharton Jones estimates at one-third of a second. It is by this property of the retina that we are enabled to view objects rapidly in succession, as in reading, and yet the sensations continue sufficiently long to be transferred to the centres of vision. The *duration of the after sensation*, or *spectrum*, is occasioned by continuing to look on a bright object the image of which is transferred for a short period to other objects; and spectra may be dark or bright according as the retina has been either excited or exhausted in nervous force by the bright object producing the spectrum. There are some properties belonging to the visual apparatus that have hitherto defeated all attempts to assign them to the physical laws of matter; nevertheless, they are only adapted to be carried out by the physical constitution of the eye. Amongst these is the *outward representation of visual perceptions*: but for this endowment the retinal picture would be in the eye, and not projected externally: that such a property is connate with the nerve-centres is clear from the well-known fact of the chick catching an insect at the moment of its escape from the shell. A law of the same description causes the position of the retinal picture to be correct in the mind while on the retina it is inverted. Single vision with two eyes must also depend on some connate endowment; for the decussation of the optic nerves at the chiasma, which was relied on for an explanation, cannot account for it unless it could be shown that the whole fibres in each optic nerve are equally divided at the chiasma; if not, that each fibre is divided, neither of which is the case.

TASTE.

The sense of taste, like that of touch, is excited by contact of external objects on certain surfaces of the body. It resembles touch, inasmuch as we localise both sensations in the organs from whence they proceed; we can associate their operations with the organs, or certain portions of their peculiar organs, but this is not the case with the other special senses, for we cannot determine whether the impressions are generated in the organs, or in the ganglia from which they derive their nerves. As a general rule, it may be said that substances that are insoluble in water have no taste, while those soluble are more or less sapid. The principal use of taste is to direct animals in the selection of their food, and we therefore find it placed at the entrance of the intestinal tube. The parts that possess most acutely this sense, most physiologists agree are from about the posterior third of the dorsum of the tongue backwards to its base, the sides being included; and if we add to this the sides and underneath portions of the tongue, to near the tip, it will form the region of the tongue that is supplied with taste by the glosso-pharyngeal nerve. The papillæ of the tongue are of three principal kinds, and the account given of them by Todd and Bowman, both as to their structure and physiology, appears to have been rather confirmed than otherwise by different views entertained by subsequent writers. The *circumvallate*, or *lenticulares*, are by far the largest in size; they consist of about eight or ten, arranged across the posterior third of the tongue, in the shape of the letter V, having its angle towards the base, where the centre papilla is observed of so large a size as to be named the *foramen cæcum*. They are round fungiform projections, with flattened surfaces, measuring about a line in diameter, and situated in a calyx about half a line in depth, and which projects to the same level as the papilla. The surface of the tongue, posterior to these papillæ, presents a puckered uneven appearance, occasioned by the projection of irregular shaped papillæ, interspersed with sulci, into which the mucous follicles open. Two functions appear to be in active operation in this district—taste, and the formation of a viscid mucus, for the protection of the delicate apparatus in which taste is seated. The *fungiform* papillæ are about half the size of the former; they are distributed singly amongst the conical papillæ, and are mostly seen on the lateral surfaces and tip of the tongue. While the whole surface of the tongue is covered with an epithelium of unusual thickness, and of the same character as the epidermis, these papillæ, and also the circumvallate, are but lightly covered with it, and as is the case in all other parts so circumstanced, the exposed capillaries give a florid or a fungiform appearance to the structure. These papillæ have narrow necks, and being encircled by the conicæ, the appearance of a fosse is given, and the advantage of a fosse is obtained for retaining sapid matters, but which does not actually exist. They are largely supplied with blood-vessels, and the loop termination of nerves has been discovered in them by Todd and Bowman. The conicæ or filiform are about the same length as the last described, and the same size at the base, but being conical they decrease in size as they lengthen. They are characterized by a tuft of hair-like processes, growing from their summits, of a horny texture, which being of greater length than the papillæ, and spreading out, the papillæ cannot be seen. These processes are of the nature of the general epithelium covering the surface of the tongue, and may be removed with it: some of them, however, closely resemble hair, being imbricated, and having a central canal. It has been shown by Todd and Bowman, that the whole surface of the tongue, whether between the papillæ or their surfaces, is covered by minute conical papillæ, into which they traced a loop of capillary vessels, but no nerve: they may be seen to cover the surfaces of the conicæ, and to stand out in sharp pointed relief, when the hair-like growth has been removed by maceration. It is the opinion of some writers, that the anterior two-thirds of the dorsum of the tongue do not possess the sense of taste; it is, however, a more probable conclusion that it exists over the whole surface, but in a much greater degree on the lateral portions of the surface, the sides, and the tip. The structure of the surface of the middle portions of the tongue bears out these conclusions, which point more to the exercise of mechanical powers than of taste: it is by this portion that the food, in mastication, is moved from the mouth to between the grinders, and the horny nature of the substance by which this portion is covered is not more than sufficient to protect it from the rough treatment to which it is both chemically and mechanically exposed. The general form of the papillæ seems to lead to the following conclusions:—that the conicæ are equally adapted for presenting a durable surface, for retaining thick mucus in their bristly ends to act as a shield, and for exercising eminently the sense of touch; and while in the other two forms we see a structure fitted for carrying out a sense of the nature of touch, but still of a more subtle character, which we suppose taste to be, we also see a contrivance in force for giving protection to the uncovered surfaces of these delicate structures, and at the same time for increasing the extent of their surface—the narrow neck and the calyx, or the adjacent conical papillæ, by which the fungiform are fenced in: thus not only protecting, but retaining in contact with them, the matters to be tasted. Taste is also seated in the soft palate, the anterior arches, and the tonsils; the posterior third, and anterior sides of the tongue, are supplied by the glosso-pharyngeal nerve. The anterior two-thirds, and especially the lateral portions, are the province of the gustatory branch of the fifth. The separate existence of taste and touch has been proved from cases of disease in which one sense has been suspended, the other remaining perfect, and *vice versâ*. The sense of smell appears to aid in a great degree the sense of taste: merely closing the nostrils during mastication, will shew how much this is the case. The seat of this sense varies much in individuals; it is also liable to much variation in the same individual: a catarrh frequently suspends both smell and taste, or at any rate the power of detecting the more pungent qualities of substances. It is generally held that the fifth is the nerve of nutrition of the organs of the special senses, and it may be that in catarrh the functions of this nerve are impaired through some change in the excited nutrition, and augmented formative powers, that take place in the nostrils and mouth in that complaint, seeing also that the same division of the fifth supplies the nose and hard palate. The taste of very sapid substances, like the bright objects on the retina, appears to have an exhausting effect upon the nerves of taste: thus, after holding sugar in the mouth, we are unable to detect a small quantity of sugar in liquids, which at another time would be easily recognised. The impressions of the sapid qualities of substances, though received by the terminal fibres of nerves, are no doubt perfected in the central ganglia of those fibres: the change that takes place is obscure, and does not always require a sapid body for its production, for it has been shown by Dr. Baly that the taste of certain substances may be produced by mechanically striking the tongue.

SENSATION.

Sensation is the faculty of receiving impressions by the sensory ganglia. It belongs to all animals, but the degree in which it is developed varies with each of them. As we ascend in the scale of animal life, and approach man, the sensations are much more varied. The animal acquires the power of taking cognisance of a greater number of the properties possessed by surrounding objects, and of better appreciating slight shades of difference. The impressions produced become more lively, and as the faculty of sensation is thus perfected, the structure of the organs of the life of relation become more complicated; for here, as well as in all the other functions, by the division of her operations does nature obtain increasingly more perfect results. Wherever the sensations produced by external objects are a little varied, there exists a distinct nervous system, and upon its action depends the faculty of perception. Its structure is at first very simple, and then all the parts composing it appear to fulfil nearly the same function. In the earthworm, for example, it is a knotty cord extended the length of the body, all the parts of which possess the same properties; for if the animal be divided transversely into several sections, each of these fragments will continue to move and feel as before; but in beings of a more complicated organization and more perfect faculties, this apparatus is composed, as in man, of several dissimilar parts, each of which then acts in a manner different from the rest, and discharges special functions. The most general phenomenon of those dependent upon the action of the nervous system is the perception of a sensation from the contact of a material object with one of the organs of the animal. These are not the sole sensations that may be experienced, and to be more precise in our language we must distinguish by a particular name the faculty on which they depend, and we therefore call it the sense of tact. All parts of our body are not equally endowed with this sense; some organs enjoy a most exquisitely delicate sense of tact, while others may touch foreign bodies, and even be cut and torn by them, without the least sensation to the animal. Now, the most sensible parts are most abundantly supplied with nerves, and where there are no nerves there is no sensation. Three properties may be distinguished in the mechanism of the sense of touch—viz., the faculty of *receiving* impressions of foreign bodies, *conveying* the same to the sensory ganglia, where they give birth to sensations, and *transmitting* these to the cerebrum; the apparatus whereby the mind takes cognizance of their existence, and by which they become perceptions.

TOUCH.

The sense of touch resides in the dermis, and seems to belong especially to the papillæ covering its surface. All parts of the skin are not equally sensible, which depends not merely upon the number of nerves distributed to them, but also upon the thickness of the epidermis covering them. The principal use, then, of the epidermis is to oppose the evaporation of the liquids contained in the body, and to protect the skin, properly so called, from the immediate contact of foreign bodies, so as to moderate the impressions produced by this contact. We have already seen, that this solid covering is insensible, and as it is always interposed between the dermis and external objects, by contact with which upon this membrane sensation is caused, it will be easy to understand that the thicker the epidermic layer the more is the dermis withdrawn from the action of foreign bodies, and the more obtuse the impressions it must receive. Now, in some parts of the body,—the heel, for example,—the epidermis is very thick; while in others,—the extremity of the fingers, the lips, &c.,—it is extremely thin. Wherever, too, the skin is exposed to friction, its epidermis is thickened.

The sense of touch, as it exists in all parts of the surface of our bodies, is sufficient to make us acquainted with the consistence, temperature, and some other properties of the bodies in contact with it. This sense is, then, only exercised passively, and may therefore be designated as *tact;* but at other times the part possessed of this sensibility is actively impressed; muscular contractions directed by the will multiply and vary the points of contact with an external object, and then we give to this sense the name of *touch*. Touch is, then, only tact perfected and made active; but it can be exercised only by organs arranged so as to be moulded in some sort upon the objects to be handled. In man, the hand is the special organ of touch, and its structure is very favourable to the exercise of this sense. Its epidermis is thin, smooth, and very supple; its chorion is abundantly supplied with papillæ and nerves, and reposes upon a thick layer of very elastic fatty areolar tissue. Finally, the mobility and flexibility of the fingers are extreme, and the length of these organs is considerable; now, these circumstances are the more advantageous, in that they tend to increase the sensibility of the part, and permit it to be applied to all bodies, whatever be the irregularity of their figure. But another organic disposition, which no less contributes to the perfection of our touch, is the power possessed by man of opposing the thumb to the other fingers so as to be able to enclose small objects between the parts of the hand, which are precisely those in which the sensation is the most exquisite.

In most animals the organs of touch are arranged in a manner much less favourable. In the mammiferæ, for example, this sense becomes obtuse as the fingers become inflexible, and are enveloped in nails, by which they are armed. Sometimes, however, the place of the hands is supplied by other organs of no less perfect structure, as the trunk of the elephant; and finally, some animals employ the tongue as an instrument of touch, while others are provided with particular appendages answering the same purposes, and which are called tentaculæ, palpæ, &c. Touch enables us to appreciate more or less exactly most of the physical properties of the bodies on which it is exercised—their dimensions, form, temperature, consistence, polish, weight, movements, &c.

The *sensation of temperature*, which is a modification of touch, is possessed in a different ratio by different parts of the body: a temperature that the tongue can easily endure will excoriate the hands; a temperature that will excoriate the hands will not injure the fore-finger; and, in the same way, the skin of the feet may be scalded by water that will not injure the hands. From this it appears that the hands, and especially the palmar surfaces of the fore-fingers, which are the most sensitive to touch, are less sensitive to temperature than other parts, and so with the hands in comparison of other parts. An impression which on a small surface produces but a weak sensation, on a large surface produces a strong sensation: thus, water which to the hand feels warm, to the whole body appears cold. *Objective* sensations are those produced by impressions given by external objects. *Subjective sensations* arise from internal causes, of which the varieties of pain produced by disordered states of the body are examples, together with rigors from the same cause, and certain sensations the products of excitement of mind; the pain also that may be engendered in a part by such mental influence, and afterwards produce positive disease.

ANIMAL HEAT.

The phenomenon of animal heat is closely allied to that of respiration, and, in most of the mammiferæ, is essential to animal life. The average temperature of the human body is from 98° to 100° Fahrenheit. During sleep it approaches the minimum: this appears to be occasioned by the withdrawal of an excitant to its production—that portion of the nervous operations that is suspended during sleep (*see* Sleep). The sudden generation of heat by intellectual operations is proved by the flushed countenance that attends mental excitement. In some diseases, such as scarlatina, the temperature rises to 107° Fahr., and in cholera it is sometimes diminished twenty degrees. Muscular action is accompanied with a considerable elevation of temperature. A temperature above 200° Fahr., however long continued, does not raise the heat of the body more than seven or eight degrees. It will be presently shown that the *efficient* cause of animal heat is the conjoint operation of chemical and nervous forces, but it must not be supposed that the heat which is occasioned by mental excitement, and that steady though slight elevation that is kept up by continued mental action, has anything to do with the mechanism by which heat is generated, and which are the efficient causes just alluded to.

The faculty of producing heat varies in different animals, and also in the same individual, according to age and circumstances; thus most mammiferæ and birds produce a sufficient degree of heat to preserve the same temperature in summer and winter, and to resist the ordinary effects of cold, though it be very severe. But there are others which produce only heat enough to raise their temperature 12 or 15 degrees above that of the atmosphere; wherefore, during summer, their temperature is nearly the same with the warm-blooded animals, but in the cold season it is much diminished; and whenever this cold reaches a certain limit the vital movement is rendered slower, and the animal experiencing it falls into a state of torpor, or lethargic sleep, which lasts till the temperature again ascends. The beings which present this singular phenomenon are called *hibernating animals*, and in this respect they are in some sort intermediate between the warm-blooded animals non-hibernating, and the animals with cold blood. In the early periods of life all warm-blooded animals are more or less nearly allied to the cold; these, as well as the latter, do not produce in general sufficient heat to preserve their temperature, even when exposed to very slight degrees of cold. But the decrease of temperature, which is without inconvenience for the cold-blooded animals, acts upon the others in a very different manner; for always, if carried beyond a certain degree, or lasting a determined period, death is the result. With regard to the faculty of producing heat, the young of warm-blooded animals which are born with their eyes open, and which immediately after birth can run and seek their nourishment, differ far less from the adults than the mammiferæ, which are born with their eyes closed, or birds, which, on issuing from the egg, are not yet covered with feathers. If, for example, new-born cats and dogs are taken away from the parent, and exposed to the air, even in summer, they are chilled to the very point of death. Infants produce also much less heat in the first days following birth than at a more advanced period of their life; their temperature then decreases very readily, and the influence of cold is very injurious to them; therefore a greater number die in winter than during the rest of the year. Everything which acts as an excitant, and which augments the energy of the phenomena of life, tends also to augment the faculty of producing heat, and everything which weakens the animal economy exercises a debilitating influence upon this function. Thus the action of moderate cold tends to augment the faculty of producing heat, and, in consequence, during winter we can better resist the causes of chill than in summer. The influence of heat, when not prolonged for too long a period, is excitant, and increases the faculty of producing caloric; but, if long continued, it weakens the body and diminishes the energy of this faculty. For this reason persons who have resided for some time in tropical regions are so sensible to the cold of our winters. Finally, exercise ever augments the production of heat, and the acceleration of the respiratory movements is followed by the same effect. During sleep, this faculty appears to be, on the contrary, less powerful than when awake; thus when men, exposed to a very low temperature, have the imprudence to fall asleep, they yield to its effects more rapidly than if awake and in motion. The disastrous retreat from Russia furnishes numerous examples of the bad effects of sleep upon the soldiers, weakened by fatigue and privation of all kinds, and exposed to a most intense cold. The cause of the production of heat in the body of animals appears to be the action of the arterial blood upon the tissues, under the influence of the nervous system. There exists an evident relation between the faculty of producing heat, the intensity of the nervous action, the amount of polar or nervous force, the exaltation of nutrition in the blood, the amount of irritability of muscles, the richness of the blood, and the more or less rapid transformation of the venous to arterial blood. Experiment has proved that everything which tends considerably to weaken the action of the nervous system tends also to diminish the production of heat. Thus, if the brain or spinal marrow of a dog be destroyed, and the respiration be continued by artificial means, the life of the animal is indeed sustained, but the production of heat ceases, and the body becomes cold as rapidly as a dead body would do, if placed in similar circumstances. If the action of the brain be paralysed by certain energetic poisons, such as opium, the same effect is produced; and these experiments varied in different ways have firmly established the fact, that one of the conditions necessary to the development of animal heat is the influence exercised by the nervous system upon the rest of the body. On the other hand, the action of the blood upon the organs appears to be equally indispensable to the manifestation of this phenomenon; for the suspension of its circulation in any part of the body is followed by coldness of the part; and, moreover, a remarkable relation exists between the faculty of producing heat in different animals, and the richness of their blood. Birds, which have the highest temperature of all animals, are also those whose blood is the most charged with red corpuscles (in general fourteen or fifteen parts to the hundred); the mammiferæ, whose temperature is not quite so elevated, have more aqueous blood, in general the weight of the globules constituting only the nine or twelve hundredths of the total weight of this liquid; lastly, in the cold-blooded animals, such as frogs and fishes, we find barely six parts of globules, and ninety-four of serum. But the action of the nervous system, and of a blood more or less rich in globules, are not the only circumstances which influence the production of animal heat; in order that the nutritive liquid may exercise upon the economy the necessary action, it must possess all the properties which characterise the arterial blood; and, as it acquires these only from respiration, the development of caloric must also depend upon this latter function. All the causes which render the transformation from venous to arterial blood less complete, or less rapid, tend also to diminish the production of the heat, and there always exists an intimate relation between it and the activity of the respiration.

The formation of carbonic acid, which is one of the most remarkable phenomena of the respiration of animals, may also explain to us the cause of the production of the greater part of the heat developed by these beings. If the oxygen absorbed during respiration is employed to form this gas by its union with the carbon arising from the blood or from the living tissues, as we have every reason to suppose, this combination must be accompanied by a disengagement of heat, as from the combustion of charcoal in the air. Numerous experiments, made with extreme precision, demonstrate that the heat which would be produced by the combustion of the carbon contained in the carbonic acid gas exhaled by warm-blooded animals is equal to more than half the quantity of caloric disengaged by these beings. And if we admit that the absorbed oxygen, without being replaced by the carbonic acid, combines in the interior of the body with the hydrogen to form water, we see that the heat produced by this combustion, taken with that of the carbon already mentioned, would be equivalent to nine-tenths of that developed by the animal. The motion of the blood, and the friction of the different parts of the body, probably produce the remainder. We see, then, that the respiration is the principal cause of the production of animal heat; and that the kind of combustion occasioned by the action of the oxygen upon the living organs is effected solely through the influence of the nervous system.

Animals have the power of resisting heat, which depends upon the evaporation of water constantly going on at the surface of the skin, or in the apparatus of respiration, and which constitutes the *cutaneous and pulmonary transpiration;* for the transformation of water into vapour withdraws caloric from everything surrounding it, and the body is chilled as fast as warmed by the external heat.

CIRCULATION.

From what has been said of the part taken by the nutritive fluids in the animal economy, and of the influence exercised by respiration upon the physiological properties of these fluids, it is evident that they must be the seat of a continual change. Since it is the blood which distributes to all parts of the body the materials necessary for their nutrition, and since this liquid is also the mean by which the particles eliminated from the substance of the tissues are thrown out; and since, also, it forms an important part in the mechanism for the generation of animal heat,—it cannot remain in repose, and must necessarily traverse constantly all the tissues. But in the majority of animals these are not the sole conditions which render the motion of the blood indispensable to the support of life; when the air does not penetrate into the substance of all the tissues, as is the case in insects, but acts only by the intervention of the exterior surface of the body, or of a special organ of respiration, as the lungs, it is equally easy to see that the blood which has already traversed the tissues must pass to the respiratory apparatus to be submitted to the vivifying influence of the air before returning anew to these same tissues. Now this actually takes place, and this movement constitutes what is called by physiologists the *circulation of the blood.* In animals with the simplest structure the nutritive liquid is diffused uniformly in all parts of the body; it fills the spaces which the various organs, or their constituting lamellæ, leave between them; lastly, it presents but slow and irregular motions. But when we examine beings more nearly allied to man, the blood is seen to move in a constant direction, and there exists a particular organ for the purpose of impressing upon it this motion. This organ, called the *heart,* is a kind of contractile pocket, which receives this liquid in its interior, and, contracting upon itself, drives it in a determinate course. By ascending in the scale of beings, we see also that the blood soon ceases to circulate in simple spaces, but moves in a system of canals, having walls proper to themselves, and which are independent of the neighbouring parts. These canals bear the name of *blood-vessels,* and, with the heart, constitute *the apparatus of the circulation.* The currents of which we have just spoken are seen in some animals which have not well-formed blood-vessels, and in the incubating egg they are seen before the cavities containing the blood have acquired distinct walls. These currents may be regarded as the determining cause of the formation of these vessels, and moreover, in consequence of certain diseases, such as fistula, a part of the body is frequently traversed by liquids: the accidental passage thus worn is soon clothed with a membrane, and transformed into a canal, having proper walls, and independent of the neighbouring parts.

The phenomenon of the circulation was unknown to the ancients: the majority of the authors of antiquity supposed that blood only existed in the veins, and thought that during life, as well as after death, the arteries were empty, or contained merely air; but about the middle of the second century of the Christian era, Galen proved, by delicate experiments made upon living animals, the presence of this liquid in the arteries, and thus paved the way to the discovery of the circulation. We have, however, but a small part of the writings of this great man, for five hundred manuscript rolls, sufficient for about eighty-four octavo volumes, were burnt in the Temple of Peace at Rome, where they were deposited for safety by the Emperor Commodus. The discovery of the circulation actually dates from the commencement of the seventeenth century, and the glory of it is due to Harvey, professor of anatomy in London, and physician to Charles I. In the lectures given by him in 1619, he pointed out the mechanism of this function.

In all those animals in which respiration is made by a special organ, such as the lungs, the sanguineous vessels ramify not merely in the tissues they are to nourish, but also in the organ in which the blood must be submitted to the action of the air; and this liquid traverses two kinds of capillary vessels; one serving for nutrition, the other for respiration: the circulation carried on the respiratory apparatus is called the *pulmonary circulation*, and that of the rest of the body the *systemic circulation*. In other respects the course followed by the blood, and the structure of the circulatory apparatus, vary much in the different classes of animals; thus, in crabs and lobsters the heart consists only of a single contractile pocket, which sends the blood to all parts of the body, whence this liquid passes into the venous system, to be returned to the heart by traversing the organ of respiration. In snails and oysters, the crustacea and mollusca, the blood follows the same course, but the heart presents a more complicated structure, and is composed of a cavity called a *ventricle*, which serves to put the blood in motion; and of one or two pockets, called *auricles*, which receive this liquid from the veins, and serve as a reservoir to supply the ventricle. In *fishes* the structure of the circulatory apparatus is nearly the same,—with this difference, that the heart, in the place of being situated at the passage of the arterial blood, belongs to that portion of the circulatory circle traversed by the venous blood passing from the various parts of the body to the organ of respiration, which is expressed by saying that these animals have a *pulmonary heart;* while in those spoken of above the heart is *aortic,* or belonging to the great artery of the body, which is called the aorta. In *reptiles* the entire mass of venous blood traverses the organ of respiration, and is transformed into arterial blood before returning to the different parts of the body; the vessels of the greater circulation pass entirely into those of the less, and the circulation is double; but in frogs, serpents, and other reptiles, it is more simple; the pulmonary circulation is but a fraction of the systemic, and the venous blood is not entirely changed into arterial, but mingles partly with the blood coming from the respiratory apparatus, and thus returns to the organs. Finally, in man and all the other animals called by naturalists mammiferous, as well as in birds, the circulatory apparatus is yet more complicated. The heart presents two auricles, as well as two ventricles, and is divided into two distinct parts: the portion situated on the left side, composed of an auricle and ventricle, corresponds to the aortic heart of snails and lobsters, and serves to send the arterial blood to all parts of the body; while the right half of the heart, which is composed in the same manner, sends the blood to the lungs, and consequently performs the same duty as the pulmonary heart of fishes. The blood, arriving from the different parts of the body by the venous system, first enters the right auricle, thence passes into the ventricle of the same side, from which it is sent to the lungs by the pulmonary artery. After having traversed the respiratory organ, it returns to the heart by the pulmonary veins, which open into the left auricle. Lastly, from the left auricle the blood descends to the left ventricle, and this latter cavity sends it to the arteries, by them to be conveyed to all parts of the body, whence it returns, as we have already seen, to the right auricle of the heart. Thus we see, then, that in animals the blood passing through the circle of circulation twice traverses the heart—in the state of venous blood on the right, and as arterial on the left side of this organ; notwithstanding each circulation is in itself complete, for the pulmonary cavities and the aortic cavities of the heart do not open into each other, and the entire venous blood must traverse the respiratory apparatus to be transformed into arterial blood. The heart is endowed with strong contractile powers, the effect of which upon the movement of the blood has been compared to the action of a double forcing-pump. The contraction of the auricles may be described as the first part of the action of the heart. It precedes the contraction of the ventricles in rhythmic order, and also exhibits a rhythm in contracting in a sweep from the veins towards the auriculo-ventricular openings, but so strong and rapid is the movement that this vermicular movement cannot be distinguished unless the heart is enfeebled, and at the point of ceasing to move. The pulmonary veins, and also the venæ cavæ, have muscular fibres at their origin, in virtue of which they may be seen to contract, according to Dr. J. Reid, either simultaneously with the auricles, or previously.

The valves of the veins assist the contraction of the ventricles in damming up the blood and firmly holding it while the auricles contract upon it. The ventricles thus filled receive their stimulus to action, the result of which is a thorough obliteration of their cavities. The valves of the ventricles are the *bicuspid* or *mitral* of the left, and the *tricuspid* of the right ventricle. They are triangular-shaped curtains, one border of which is attached to a ring or zone of white fibrous element surrounding the auriculo-ventricular opening, while the other margins are attached to the interior of the organ by tendinous cords of the same material which are attached to the muscular columns—the carneæ columnæ which project from the vault of the organ. For greater security, these valves are overlapped at their unions by smaller valves, which are attached in like manner to the tendinous ring alluded to, and are about half the length of the principal valves. The valves are composed of folds of the lining membrane, having tendinous cords interposed, by which no elasticity is allowed, and by the contractility of the carneæ columnæ the hydraulic tendency of the valves to fall across the openings is promptly promoted and insured. The contraction of the carneæ columnæ causes a shortening of the valves in the same ratio as the substance of the heart is shortened by the ventricular contraction,—an effect which was observed by Dr. C. J. B. Williams and Dr. Todd when acting as a committee appointed by the British Association to report on the action of the heart. The ventricles now emptied, and the large arteries filled by this movement, the three semilunar valves at the orifice of the aorta, and again at the pulmonary artery, prevent the ventricles receiving blood from these quarters at their next dilatation, which immediately succeeds. A loaded state of the capillaries of the lungs is a frequent pathological condition of those organs, and especially that arising from valvular disease of the left ventricle, to which ventricle such disease is principally confined. One of the characteristics of this pulmonary congestion is *venous* pulsation perceptible in the jugular veins; this is occasioned by an overloaded state of the right ventricle, and the consequent imperfect closure of the tricuspid valve due to the obstructed circulation through the lungs, the efficient cause of all being the imperfect action of the valves of the left ventricle, and the consequent inability of the heart to distribute properly the systemic arterial blood. By this it appears that when the right ventricle is unduly distended, its valves do not properly close, which constitutes a *safety-valve* provision for protecting the lungs by relieving them of a portion of blood, when they are already over-distended, by setting up systemic venous congestion. By such lodgment of blood in the systemic veins, and by such partial closure of the tricuspid valves, a portion only of the whole mass of blood is delivered by the right ventricle to be circulated through the lungs: hence imperfect aëration of blood, and the blue tinge of the countenance, that is common on those occasions. The action of the three semilunar valves stationed at the orifices of each of the large arteries is governed by mechanical laws. An abrupt change from the yellow to the white fibrous element is observable where the valves spring from the walls of the arteries, both by the formation of a ring of tendon for the insertion of the fixed borders of the valves, and in the structure of the valves themselves.

In virtue of this arrangement of the yellow and white tissues a contraction of the arteries corresponding to the tendinous ring is observable, and immediately beyond this spot a bulging of the vessel occasioned by the distension given to the extensible coats of the arteries beyond the ring. When the valves are separated from the walls of the vessel, and are brought in apposition across its calibre by the regurgitation of blood, the attachments of the valves are indicated by three bulgings of the artery, and the triangular space left in the centre of the artery by the tight-drawn tendinous fibres of the free edges of the valves, is closed by the loose margins of the valves, which is generally made more effectually to close by the addition of the *corpora arantii*, little bodies composed of a multiplication of the same tendinous tissue.

There are three physical particulars belonging to the heart which demand attention, a knowledge of which is obtained by auscultation: these are, its *impulse*, its *rhythm*, and its *sounds*. For conducting auscultation of the heart it is first necessary to determine the exact position of aortic valves and the apex of the heart, the latter being the best spot for obtaining the sound produced by the bicuspid valves, to which disease is generally confined. A ready guidance to the apex is to measure two inches under the left nipple, and one inch from thence towards the sternum. If the subject is a woman, with a falling mamma, the left nipple will still be the guide for the vertical position, while the fifth rib will indicate the elevation. Dr. Bellingham observes that the aortic valves are situated at a spot even with the third left rib at its cartilaginous junction with the sternum. When the ear of the examiner, or the stethoscope, is applied to the former of these situations, the patient being erect, a slight shock is perceived synchronous with the pulse: this is the *impulse*, and it is generally believed to be occasioned by the apex of the heart striking against the parietes. According to Dr. Hughes there are three kinds of impulse compatible with a normal condition of the organ; one may shake the head of the examiner, scarcely at all, indicating a desirable tranquillity of the organ; another is a sharp knocking stroke indicating irritability, and generally

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Position of the aortic and bicuspid valves.

Two inches under nipple, and indeed
One t'wards the sternum does to apex lead;
The valves of the aorta close behind
Where third rib joins the sternum you will find.

weakness; and in a third class the impulse (without knocking) lifts up the head or communicates to it a *heaving* sensation: this state is generally accompanied by a full incompressible pulse, and is indicative of a powerful or hypertrophied heart. The rhythm of the heart consists in the regularity of the succession of its movements and the interval of rest. The natural sounds of the heart, as collected from any part of the præcordial region, resemble the pronunciation of the syllables *too-to*, followed by an interval with no sound. The long and short sound and interval make up a circuit of the heart's action. The period of action is termed the *systole*;* the period of repose the *diastole*.† If the period of a circuit be divided into fifths, the long sound is said to occupy two-fifths, the second sound one-fifth, and the interval three-fifths. The origin of both sounds of the heart is explained by the physical laws of hydraulics. If the tap of a leaden pipe, which contains a heavy column of water, be suddenly turned when the water is escaping, and the stream as suddenly arrested, the pipe will be shaken and a noise heard. This is occasioned by vibrations in the column of water which traverse also the solid walls of the pipe. The first sound is the first shock thus given to the blood by the sudden closing of the flood-gates—the auriculo-ventricular valves. The second sound is in like manner produced by the closing of the semilunar valves at the origin of the large arteries. This occasions the sounds, and the conjoint effect of this, together with the strong muscular contraction of the ventricles which immediately precedes it, is to produce a tilting forward and to the right of the apex of the heart, whereby the impulse is produced. The difference in the strength and the duration of the sounds is explained by the different construction of the respective tissues concerned: the bulky substance of the heart in comparison with the walls of the arteries is sufficient to account for the larger and more powerful sound. "The first sound," says Dr. Hughes, "will generally be found to extend over the left mammary, then over the inferior sternal region to the scrobiculus cordis, and then over the supe-

* Συστολὴ, from συστελλω, I contract.
† Διαστολὴ, from διαστελλω, I dilate.

rior sternal region ; while the second sound (if separately regarded) may first be heard over the superior sternal, then in the right and afterwards in the left infra-clavicular regions." After extension to the regions just named, they will commonly be heard with varying distinctness successively in the following order—right mammary, left lateral, left axillary, left and right subscapular, acromial, left subscapular, hypochondria, and hypochondriac regions."

The *capacity* of the ventricles is computed to be such as to enable them to receive 2½ oz. of blood, the whole of which, by the perfection of ventricular contraction, is sent to the lungs and systemic arteries at every systole of the heart. The *force* of the left ventricle, as estimated by M. Poiseuille is 4 lbs. 3 oz. ; that of the right, 2 lbs. 1½ oz. In accordance with this estimate the walls of the left ventricle are twice as thick as the right, and it is required to exert twice the amount of force, judging from the character of the two circulations. The actions of the heart in health are in direct ratio to the respirations which are maintained both in the excited or in the tranquil states of the organ. The frequency of the heart's action is in inverse ratio to the age of the individual. The actions of the heart are termed the pulse : the number in a minute is as follows :—

The Pulse.

The newly-born infant	140 to 150
During the first year	115 ,, 130
During the second year	100 ,, 115
During the third year	90 ,, 100
About the seventh year . . .	85 ,, 90
Fourteenth	80 ,, 85
Period of the perfection of manhood .	70 ,, 80
Old age	50 ,, 65

The force exercised by the auricles in contracting seems apportioned to the force requisite for the propulsion of blood into the ventricles, and also to insure the quick dilatation of the ventricles ; for, although the ventricles will dilate by their own power, such power has been shown to be extremely small. The position of the body not only affects the impulse of the heart, but also the frequency of its pulsations. In 100 experiments carefully made by Dr. Guy, on men, the average number of the pulse was, in the erect position, 81; in the sitting position, 70; in the recumbent position, 66. From these facts it may be inferred that the left ventricle does not completely empty itself under the pressure it has to sustain in the erect position of the body, and that an increased number of pulsations in that position is requisite for the transmission of the whole volume of blood through the heart—facts that have important practical bearings on the pathological conditions of that organ. The amount of pressure that is added to the walls of the heart when the body is in the erect position is the weight of a column of blood from the heart to the upper surface of the head; and according to a well-known law in physics, the heart must be pressed upon in every part of its internal surface by the column of blood which it has raised. The whole amount of blood in the body is estimated at a fifth of the weight of the body, or 24 lbs. in a person weighing 10 stone, or 120 lbs., the whole of which passes through the heart in from three to four minutes. It has been ascertained, by conclusive experiments by Dr. Sharpey and others, that the force of the heart is amply sufficient of itself for the complete circulation of the blood, though it derives support and assistance from the following sources,—the elastic walls of the arteries; from capillary nutritive changes in the tissues, and nervous influence, which aids the capillary circulation; from pressure on the veins occasioned by muscular action, and pressure from other causes; and from the movements of the chest in respiration.

Both kinds of nerve-fibres enter the structure of the heart; the axis-cylinder fibre constitutes a great portion of the fibres of the cardiac branches of the vagus in virtue of their character as cerebro-spinal nerves; they also contain the fine fibre of the sympathetic system, a ganglion of this system being placed on the vagus near its origin, and the cardiac ganglia being stationed behind the aorta at its origin, where a great intermixture of fibres takes place; and minute ganglia being interspersed in the structure of the heart. But with all this nervous mechanism it does not appear that nerves directly supply the heart with motive power: the indirect influence of nerves on the action of the heart is, however, abundantly proved both in healthy and diseased states of body. It is not positively known what influence the sympathetic ganglia exert upon the heart; from them it seems to derive its rhythm, and it is admitted that the fibres of both systems exert no influence further than that of exciting and controlling its action. It is known that a blow on the head or on the cœliac plexus, or the shocks given to the nervous system by poisons or lightning, may not only check or cause the movements of the heart to cease, but render it insensible to motor stimuli when removed from the body: but such effects find an interpretation in the loss of irritability and passive tone that is more or less occasioned to the muscles by such shocks. The continuance of the action of the heart when removed from the body proves that the efficient cause of motion exists within itself.

THE ARTERIES.

The walls of *arteries* consist of four different layers—an *external*, which is a loose envelope of areolar tissue; an *elastic* coat of yellow fibrous element; a *muscular* coat; and an *internal*, having a basement membrane and epithelium. The elastic and muscular, so named and distinguished apart by John Hunter, are most concerned in the physiology of these vessels. The uses of the external coat are severally as follows:—to give strength to the vessels; to set limits to the elasticity of the elastic coat by means of the white fibrous element contained in the areolar tissue of which it is formed; to contain the nerves and capillaries of the vessels; to connect the trunks of arteries with the adjacent structures, and to admit of their ready change of position amongst the moveable tissues. The elastic coat forms the principal substance of arteries; by means of its physical property—elasticity—the vessels distend and elongate, so as instantaneously to adapt themselves to the additional blood that is delivered to them at every contraction of the ventricles, and at the same time to foster and preserve entire (on physical principles) the force by which they were distended, and return the same upon the column of receding blood during the diastole of the heart; an additional result also being obtained, that of disposing the blood to flow in a continued stream, which is effected in its transit through the capillaries. It is also by this property that the arteries are enabled to accommodate themselves to the reception of the varying amounts of the fluids poured into the blood, and the occasional augmentation and diminution that take place in the general mass. The powers hitherto described as appertaining to the apparatus of the circulation are of themselves sufficient for the effectual performance of the circulation of the blood: other forces are, however, added, in accordance to the perfection and superabundance of resource that characterise the works of God. This is manifested in the muscular coat of the arteries: the property of elasticity is aided by the vital property of contractility. Muscular fibres endowed merely with irritability would have fallen short of the object to be attained: to this, therefore, is added, not only a nervous influence to guide, control, and excite arterial action, but also a modified influence supposed to be generated in the ganglionic nervous system, whereby the rhythm and adaptation are secured that co-ordinate the muscular contraction of arteries to the passive diastole of the heart. The aid afforded by the muscular coat may be supposed to be more needed at the greatest distances from the heart, where the contractile energy of the organ is less felt, and where the friction of small tubes begins to retard the progress of the blood; and it is here that we detect this tissue in the largest proportion, diminishing as it approaches the heart, where the muscular fibres altogether disappear. There can be no doubt that such muscular contraction on the arterial tubes must have the effect of urging onwards the blood; for if the column is firmly supported at the semilunar valves, it is evident that pressure applied to the trunk must tend to force the blood into the capillaries, taking it for granted that the fibres contract during the diastole in virtue of the same nervous influence that adapts and adjusts in rhythmical order the various movements of the heart, and which is furnished by the sympathetic ganglia. This appears more probable from the fact that the arteries are supplied abundantly with the *fine* nerve-fibres, and those only. This view of the action of the muscular coat of arteries has not been adopted hitherto by physiologists, for the reason that the contraction cannot be proved to be rhythmic: to this it may be replied, that if the contraction is not made to synchronise with the diastole, it would operate in opposing the contraction of the ventricles,—a conclusion that common sense forbids. We may fairly award to the sympathetic the power of synchronising the contraction of the arteries to the diastole, since we shall presently see that the muscular fibres of arteries are in other respects susceptible to the peculiar operations of the sympathetic nerve. The muscular fibres of arteries exhibit the phenomena of irritability and tone: it is by tone that divided arteries become obliterated, and when closed by the effects of rigor mortis, they resume the ordinary size of their calibre as soon as that power has departed from the body; and it is to the property which tone has of being excited by cold, that cold applications are effectual in arresting hæmorrhage. It is plain from these facts that contractility operates on the arteries in reducing their diameter to a size less than they can be brought to by the mere power of elasticity, for elasticity conduces only to the return of the vessels from their distended to their ordinary size, whereas contractility carries their contraction much beyond this point. The muscular fibres of arteries have not yet been thrown into the same tetanic state of contraction which has been effected on the same fibres of the bronchial tubes; but this may be looked for in the larger amount of axis-cylinder nerve-fibre that reaches the lungs in the pneumogastric nerves. That the fibres in question are really muscular tissue, has been shown by the fact that proteine is announced to be present in their composition by the application of its appropriate tests, and by the absence of those peculiar qualities that distinguish the yellow fibrous element with which the muscular fibres are in contact. Anatomy leads to the conclusion that the arteries are under the peculiar power of the sympathetic system; and this we find to be the case. The movements of arteries, exerted independently of the heart, exhibit the characters of the movements of other organic muscles: while it is removed from the direct control of the mental stimulus, it is subject to a series of indirect stimuli from the centres of the intellectual, the sensory, and the emotional centres, which is manifested by the increase or diminution of such arterial muscular action in particular districts of the peripheries; of which the flush of joy, the pallor of rage, the blush of modesty, and a variety of other like nervous operations, are the result; to which may be added the local determinations of blood coexistent with the reproductive processes, or local activity, or increased formative powers in particular organs of secretion. Certain pathological conditions of parts exhibit also the operations of the sympathetic on these muscles; such as the increased arterial action attendant upon local inflammation, and the settled redness in the face of drunkards.

THE CAPILLARIES.

The capillaries are the system of reticular vessels that connect the terminal branches of the arteries to those of the veins. The walls appear to be of the same delicate structure as basement membrane, not having an epithelium, and being very permeable to exosmosis, for transmitting the more fluid constituents of the blood, and favourable also to the operation of the various processes of nutrition and secretion, and for allowing the abstraction from their sides of the more solid materials. Although they anastomose, they do not by their union increase in size, but maintain the same diameter throughout, which varies according to the tissue in which they are found, the average being about 12-500th of an inch. As a general rule, the number and size of capillaries contained in a tissue are in direct compound ratio to the amount of blood with which the tissue is supplied. The brain forms an exception to the rule, for while it is very largely supplied with blood, it has comparatively few of these vessels: from this it may be inferred that large functional operations are carried out on the surface of the convolutions. Although several of the tissues do not admit the capillaries into their ultimate structure, and are consequently nourished by imbibition, no set of vessels has been discovered by which the circulation of the finer fluid is achieved, except in bone, in which the fine canals that join the lacunæ perform the office.

The flow of blood through the capillaries is slow in comparison with the rate of its passage through larger vessels. It is well known that the total capacities of these vessels, as well as the branches of arteries and veins, are much larger than the area of the principal trunks: the movement of blood, therefore, in the capillaries, must be slow, in accordance to a law in hydraulics, that the velocity of the stream is in inverse ratio to the capacity of the conducting tubes. It is generally admitted by physiologists, though denied by some, that the capillary circulation is promoted by the processes of nutrition and secretion: Dr. Carpenter supports this doctrine, and has set forth the evidence on which it rests. When we reflect on the local changes that take place in capillaries—their distended or their stagnant state, that depend on increased formative powers, or inflammation—and bear in mind also what has already been said regarding the influence of the sympathetic nerve upon them, and add to this the fact that an acardiac fœtus has been matured and otherwise well formed, it is difficult to suppose that the capillaries do not aid and promote the circulation of the blood.

The circulation in the capillaries may be watched, by the aid of the microscope, in transparent membranes; and the web of the frog's foot has generally the preference, in consequence of the large size of the blood-corpuscles in that animal. A singular feature presents itself for notice in this circulation,—a partial separation of the constituents of the blood—a separation of the red corpuscles from the solids of the serum. The red corpuscles keep to the centre of the stream, while the white are seen, mixed with the serum, leisurely gliding along the walls. Although this circulation has been carefully watched in parts undergoing rapid development, it has not been observed that the capillaries ever give up either of the corpuscular bodies to the active nutritive processes external to their walls. As far as such inspections can determine, it appears that whatever matters are abstracted from the blood are done immediately from the liquor sanguinis,—a fact that throws light upon the general process of nutrition, and indirectly supports Dr. Carpenter's theory, that the office of the white corpuscle is to fibrinate the blood.

THE VEINS.

The structure of the veins differs from that of the arteries only in the fact that the muscular, elastic, and external loose coat of areolar tissue are in a degree blended together; and that while the muscular and yellow elastic element are both decreased in quantity, as compared with arteries, the areolar tissue is more abundant. In harmony with this anatomical disposition, we find that elasticity is not so prominent a feature in veins as in arteries, and also that contractility, although present, is of a more passive character. That they must be elastic we look for from the areolar tissue in their structure, and we witness its effects in the bursting forth of the blood from the distended veins in the operation of venesection. The action of the muscular fibres of veins is probably to aid the elastic coat in recovering the veins from states of distension, and to add strength to the texture: in cases of muscular emaciation and weakness, the varicose condition of the veins proclaims the participation of the muscular fibres in the general debility. There can be no doubt, also, that these fibres are, like those of arteries, subject to the influences wrought upon them by the sympathetic nerve. The area of the veins is supposed to be from two to three times that of the arteries. Haller's estimate is that the arteries contain four, and the veins nine parts of the blood. The size of the calibres of veins, from their radicles to the heart, is larger than arteries. After death they are found to contain the whole mass of blood forced into them by the effect of rigor mortis upon the arteries. The venous circulation is variously aided by physical causes. The pressure arising to veins from a variety of circumstances, all tend to the onward movement of the blood, and this is the case even when force is applied in a direction reverse to the current, so as to propel the blood from the heart; for while the numerous anastomoses of veins allow it to take another course to the heart, the numerous valves which they contain prevent any retardation being given to the general stream, by shielding the pressure from the ventricles. The valves consist of a fold of the internal coat: there is generally found one in the small vessels, two placed in opposition in larger, and sometimes three of semilunar shape. The force of ventricular contraction appears to be exactly apportioned by its own unaided efforts to return the blood to the heart: there is no surplus force to be expended on dilating the auricles, and no force of suction necessary to be exerted by the auricle for drawing in the blood.

Inspiration has been ascertained by Sir D. Barry and Dr. Carson to promote the venous circulation, the effect of which may be made visible by the hæmadynamometer; and since in expiration the valves in the veins prevent an injurious backward pressure on the returning blood, and the same pressure being beneficially expended on the arteries as they quit the chest, it may be advanced as a maxim in physiology that both the movements of respiration are favourable to the circulation of the blood. A moment's reflection on the laws that govern hydraulics will make it apparent that the altitude of the column through which the blood has to traverse in its ascent from the lower extremities does not in any way retard its return, or add any obstacle thereto; and as regards the weight of the blood, precisely the same force is needful to effect its circulation, whatever may be the attitude in which the body is placed, excepting that in the erect position the weight of a column of blood reaching from the heart to the crown of the head is added to the walls of the heart. It will, however, be equally apparent, on the other hand, that pressure on the walls of the arteries, the capillaries, and the veins, exists in direct ratio to the altitude of the column of blood: and when we contemplate the delicate structure of all these vessels as they exist in the peripheries, and the facility with which they permit exosmosic percolation, it will not be surprising that in chlorosis, or any other derangement of the blood by which the balance amongst the constituents is not maintained, and the fluid portions become in excess, that at such seasons infiltrations take place into the areolar tissue of the feet in the evening whenever the body has been in the erect position through the day. How much more, then, must these effects be increased when a disease of the left side of the heart, or in the lungs or liver, add their respective obstacles to the return of venous blood, and thereby augment the pressure upon the walls of the vessels!

VOICE AND SPEECH.

Physiologists describe voice and speech under separate heads, for the reason that they find them in some degree separate in nature; the voice being produced in or by the larynx, while speech is the result of a qualification or remodelling that the voice undergoes after the air has left the larynx by the throat, tongue, mouth, and lips,—though not entirely so, for in some small degree articulation is effected by the larynx. To the student who has once examined the larynx, the following diagrams will suffice to recal it to his mind; and he will recollect

Fig. 11.

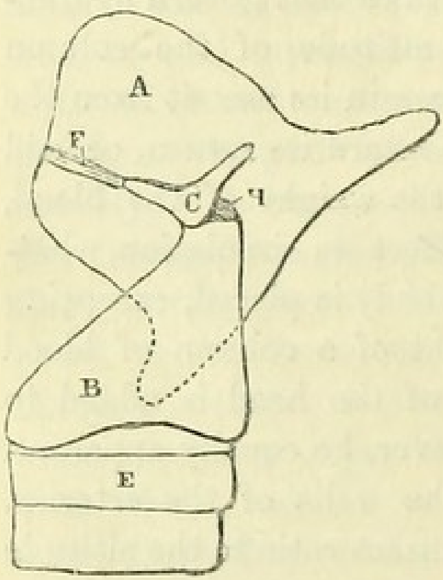
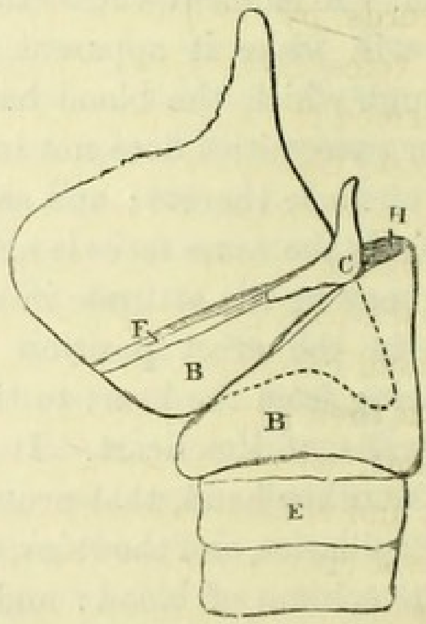


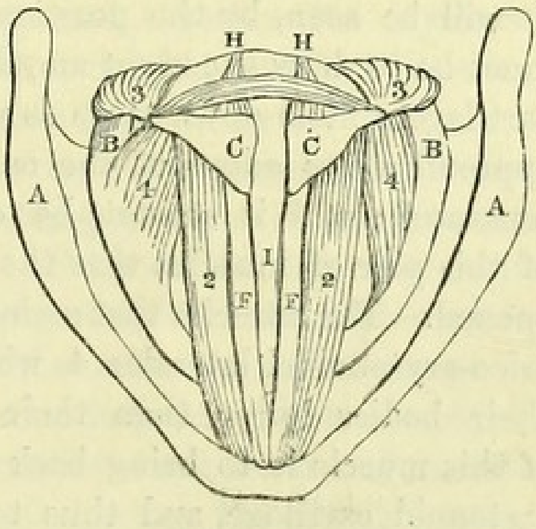
Fig. 12.



that the thyroid cartilage is connected to the cricoid by a strong fibrous membrane so loose before and behind that it admits of the thyroid cartilage moving freely up and down; and that the laxity disappears so much towards the centre of each side that it becomes a fixed point somewhere about the middle of the cricoid, at which point the union of the two cartilages admits of no more movement than is necessary at the axis of the up-and-down movement. This movement of the thyroid upon the cricoid cartilages causes the scale of tones,—a scale as well as the tones held to be perfect in music, and constituting together the inimitable "vox humana."

The *chordæ vocales* are composed of the yellow fibrous element, and are so elastic that the fullest extent to which they can be shortened by the foregoing movement does not remove their tension and prevent the sonorous vibration which is produced by the column of air that passes between them. They are named also the *inferior thyro-arytenoid* ligaments, in contradistinction to two smaller ligaments of the same attachments and composition, which are situated above them, but which do not produce tone, although they exercise an indirect influence upon it, and, as some suppose, are the cords by which the falsetto voice is formed: these are termed the *superior thyro-arytenoid ligaments :* between the upper and lower cords is a membranous cavity, the ventricle of the larynx. On the upper and back part of the cricoid cartilage, within the larynx, are the arytenoid cartilages (C C),—irregular triangular bodies articulated at their under surfaces with the cricoid by a joint of capsular ligament, which imparts to the arytenoid a horizontal movement, and is also connected to the cricoid behind by a band of ligament (H H). One of the limbs of this triangular body moves, as it were, on a pivot in this joint on the cricoid, and forms the fulcrum of a lever for opening and shutting the glottis.

Fig. 13.*



* 1, Aperture of glottis ; 2, thyro-arytenoid muscles ; 3, crico-arytenoideus posticus ; 4, crico-arytenoideus lateralis ; 5, arytenoideus. A, thyroid cartilage ; B, cricoid ; C, arytenoid ; H, thyro-arytenoid ligaments ; F, chordæ vocales ; E, rings of trachea.

Another limb of the triangular body constitutes the arm of resistance of the lever spoken of; to this the chorda vocalis F is attached, which crosses to the receding angle of the thyroid cartilage. The third limb projects at right angles to the side, and forms the arm of power of the same lever. To this projection the crico-arytenoideus posticus muscle 3 is attached, which, on contraction, draws back the arm of power and separates the arms of resistance, producing thereby the separation of the cords, and opening the glottis. Thanks are due to Mr. Bishop, who enunciated, and to Mr. Erasmus Wilson, who promulgated the fact, that this muscle is the only one by which the glottis is opened. A fact so apparent in the monotonous description of such complicated muscular action is refreshing, and forms a prominent fact on which the memory may fasten. It will be seen, by the position of this muscle, that its action must be to draw the right angular projection of the arytenoid cartilage a little downwards as well as backwards, by which the approximating edges of the cords are turned outwards as well separated; and it cannot be otherwise than by the action of this pair of muscles that the cords are made tense as well as opened. The muscles that mainly antagonise the postici are the crico-arytenoidei laterales 4, which, like their antagonists, have their bodies lower than their sphere of action. The effect of this muscle is to bring back the right angular limb of the arytenoid cartilage, and thus to shut the glottis. The crico-thyroid placed external to the larynx are the only strictly laryngeal muscles that stretch the vocal ligaments. The antagonist of this muscle claims attention by its action of drawing up the thyroid cartilage, and relaxing and shortening the cords: this is the thyro-arytenoid muscle. 2. Although this muscle lies so close to the glottis, it has no direct control upon its aperture; it runs parallel with, and is attached to the whole length of the cord externally, and, with its fellow, serves to fix them in those nice varieties of length that are necessary in executing the scale. The position that the glottis assumes when all its muscles are at rest, as is the case in ordinary respiration, is an open one; but this is not accomplished by an action which we have described on the external limb of the arytenoid cartilage, as is the case when the glottis is opened in vocalization, but by a physical tendency of the arytenoid cartilages to recede from each other and fall outwards, which, at that season, leaves the glottis open, and admits the air to pass quietly in respiration. Before, therefore, any muscle can act either to open or shut the glottis, or make tense or relax the cords, the bodies of the arytenoid cartilages must be brought up into their places, and this is done by a small powerful muscle, the arytenoideus, which grasps their bodies and stands in readiness to clasp them together and bring them to the upright position, which allows the laterales to shut the opening, and the other movements accordingly. The arytenoideus, like the postici and crico-thyroid, has a single object of action in this wonderful mechanical contrivance; and, while we attribute to it *only* the office of bringing up and together the arytenoid cartilages, we must associate with it the fact that by this bringing the cords into a state of tension it performs the preliminary step to vocalization, and puts the arytenoid cartilage in a position to turn upon its axis, enabling the postici to open and the laterales to shut the glottis. Even as the laterales derive indirect assistance in closing the glottis from the arytenoideus, so, also, it is supposed that all the other muscles (except the postici) combine in giving the same indirect aid in closing it; but in opening the glottis the postici stand alone and unaided. If we divide the whole process of shutting the glottis into two stages, which we well may do—firstly, the bringing into the erect position the arytenoid cartilages, and then closing the lips, or first lifting up the door parts and then shutting the doors, we shall find the action of the laterales is entirely confined to the closing, as much as the action of the postici is confined to the opening of the aperture. In reviewing the action of the muscles of the larynx, it may be stated that the arytenoideus muscle performs the part of raising from a semi-recumbent state of inertion the arytenoid cartilages, and tightens the cords—a state preliminary to either vocalising, articulation, or for opening or shutting the glottis. The glottis is opened by the postici and shut by the laterales. The crico-thyroid muscles, by depressing the larynx, tighten the cords; and the two last together hold the entire command of the vocal scale. The action of the laryngeal muscles (except those of the epiglottis) are thus concisely stated ;—the arytenoideus *elevates the arytenoid cartilages ;* the crico-thyroid *stretches the vocal cords ;* the thyro-arytenoidei, indirectly assisted by all the others except the postici, *relax the vocal cords ;* the crico-arytenoidei postici *open the glottis* ; the crico-arytenoidei laterales *shut the glottis.* But it must be recollected that a body of muscular fibres is attached to the great alæ of the thyroid cartilage externally, constituting a pair of muscles inserted in the sternum below—the sterno-thyroid, and to the os hyoides above—the thyro-hyoid. These not being connected with the cricoid cartilage, must act respectively both in raising and depressing the thyroid cartilage, and thus aid essentially in performing the vocal scale. Dr. Carpenter has directed attention to this fact, the sterno-thyroid not being generally reckoned among the muscles that move the larynx.

The fact that the voice is produced by the vibration of the chordæ vocales, caused by the passage of air between their surfaces, is established by experimental proof; and that this depends on the action of the laryngeal muscles is shown by the aphonia or loss of voice that follows the section of the laryngeal nerves. Before a vocal tone can be uttered, it is not only necessary that the chordæ vocales should assume a degree of tension, but also that the edges should be brought together, and for intonating the higher part of the scale it is thought that a nearer approach of the cords is needed than for the lower, or that the narrowing of the aperture aids in heightening the pitch. That modification of the voice which is termed *falsetto* Mr. Wheatstone supposes requires for its production the same degree of tension of the cords as the ordinary voice: the difference of tone is occasioned by an harmonic subdivision of the volume of the air that fills the trachea, and which, in the ordinary state of the voice, vibrates throughout its whole extent. How this subdivision is accomplished does not appear.

The intensity or volume of the voice depends in part upon the force with which the air is expelled from the lungs, in part upon the facility with which different parts of the larynx vibrate, and upon the extent of the cavity in which the sounds are produced. The same individual cannot make heard, with an equal degree of force and clearness, all the sounds his larynx is capable of producing, because the different parts of his vocal apparatus are not arranged in a manner equally favourable to their production. When a man is weakened by fatigue or illness, his voice loses its intensity, because the muscles which drive the air from the lungs can no longer expel it with their ordinary force. It is to the more considerable volume of the larynx in man, that a part of the remarkable difference between his voice and that of woman must be attributed; and owing to the existence of great cavities in communication with this organ, the howling apes, and some other animals, are able to make their deafening cries heard to an immense distance. The pitch of the voice appears to belong in part to the physical properties of the ligaments of the glottis and walls of the larynx, and in part to that of the following portion of the vocal canal. We know from experiment that the pitch of musical instruments varies greatly, according as they are constructed of wood, metal, &c.; and a coincidence has been remarked between certain modifications of the human voice, and the more or less hardened state of the cartilages of the larynx. In women and children, whose voices have a peculiar pitch, the cartilages of the larynx are flexible, and have but little hardness, while in men and women with a masculine voice the thyroid cartilage is remarkable for its power and more or less complete ossification. The form of the external opening of the vocal apparatus exerts a great influence upon the tone of the sounds produced. When the sounds traverse the nasal fossæ only, they are disagreeable and nasal; when the mouth is wide open, the voice acquires, on the contrary, power and brilliancy; and it would appear that the degree of tension of the velum palati and of the other parts of the fauces exercises an influence not less great upon the manner in which sounds are modulated. From what has been said of the mechanism of the production of sounds, it must be inferred that the diapason of the voice depends in a great degree upon the length and thickness of the vocal cords. The voice of man, as every one is aware, is much graver than that of woman; because, in man, where the larynx makes at the superior part of the neck a considerable prominence, this is much longer than in woman, where the antero-posterior diameter of this organ is so small, that the eminence alluded to can hardly be distinguished. Man also possesses the faculty of modifying the various sounds of his voice; he may articulate these sounds, and to this act is given the name of *articulate speech.* The organs of pronunciation are the pharynx, nasal fossæ, and the different parts of the mouth; and according to the manner in which they act, the sound produced by the larynx varies in its character, and constitutes a particular articulated sound. The articulated sounds are divided into two great classes,—vowels and consonants. The former are permanent and simple sounds, which cannot be confounded by union with others, and during the production of which the apparatus of pronunciation remains unchanged; the consonants are, on the contrary, articulated sounds which it is impossible to prolong as the vowels, and which require for their production particular movements of the apparatus of pronunciation,—movements in the course of which this apparatus necessarily takes the disposition by means of which it forms a vowel. Thus, the consonants can only be articulated by the addition of the sound of a vowel. They are divided into labial, dental, nasal, &c., consonants, depending upon the part called into action in the mechanism of their pronunciation, whether the lips, tongue, &c. Man is not the only animal having the faculty of articulating sounds, and thus to pronounce words; but he is the only one which attaches a meaning to the words pronounced, and to the arrangement he gives them;—he alone is endowed with the power of speech.

FUNCTIONS OF REPRODUCTION.

The various vital phenomena which have hitherto occupied our attention, all have respect to the preservation of the life of the animal, or to its relation with surrounding objects. Those now remaining to be noticed are of another order; their object is the multiplication of the individuals, and the preservation of the species. It is the essence of organised beings to arise from parents like themselves: the manner in which this reproduction is effected varies greatly in the different animals, and we are thus furnished with a striking example of the application made by nature of the principle of the division of labour, when she has desired successively to perfect the beings of her creation. In the simplest animals, the important function of generation does not appear to be confided to any organ in particular; all parts of the surface of the body of one of these animals are capable of giving origin to small slips, which increase in size, and soon become new individuals, similar in every respect to that from which they spring. The polypi are thus reproduced by slips; but this mode of propagation of the species is only met with in a very small number of the most inferior animals, and in all others the germ, which by its development is to constitute the young, is formed in a particular organ, called the *ovary*. When these organs first display themselves in the zoological series, they have a very simple structure; they are in general mere glandular vessels, and the germs they produce are adapted for development without the consent of any other apparatus: but the division of labour is soon extended, and reproduction is entrusted to two distinct organs, the consent of which is necessary to the birth of a new individual. These two kinds of apparatus, one serving for the production, the other the fecundation of the germ, and called female and male apparatus, are at first united in the same individual, which of itself alone is charged with the whole work of reproduction. Oysters, muscles, and many other inferior animals present this mode of generation. In others, where the sexes are still united—snails, for example—hermaphroditism is less complete; for the fecundation of the germs can only be effected by the individual producing them. But, as we ascend in the series of beings, we find nature pushing yet further the division of her operations, for then the sexes are always separated. This is the case with all the superior animals, quadrupeds, birds, fishes, &c., and even with insects, spiders, the crustacea, and some mollusca. In most fishes, and even some reptiles, the fecundation of the germ does not take place till after the expulsion of the ova, and is in some degree confided to chance; but in the superior animals it is better ordered, and takes place before their expulsion. In general, the germ, after being detached from the ovary and fecundated, has no longer need of the assistance of its parents for development. Abandoned to itself, it gives birth to a new individual, which carries with it the materials necessary for its nutrition during the entire life of the embryo; but in birds, the egg, which is composed of the germ, nutritive substances just mentioned, and the membranes containing them, is only developed by the influence of an elevated temperature, which the mother ordinarily maintains by incubation. Finally, in other animals the series of the phenomena of reproduction is yet more complicated, for the germ does not carry with it its nourishment; and to live after being detached from the ovary and fecundated, it must contract new vascular adherences with the walls of a particular sac, called the womb, which is destined to lodge the young individual until all its organs are formed. The animals whose germs do not thus draw their nutrition from the blood of the mother are called *oviparous;* those which present the latter mode of reproduction are called *viviparous*, because in place of being developed in an egg they are born alive and ready formed. All the inferior animals which are not reproduced by slips, such as worms, the mollusca, the crustacea, insects, &c., are oviparous; so are fishes, reptiles, and birds: but man and all animals closely allied to him are viviparous. When the young individual begins to be developed in the germ, it is not, as might be supposed, the miniature of what it will become at a later period: it does not at all resemble its parents, and has neither its future form nor structure. Its organs appear in succession, and they undergo during their evolution very remarkable changes. We may say in a general manner, that the entire organization of the embryo, as well as each of its parts considered separately, passes through a series of transitory stages, which resemble to a certain degree the permanent condition of some animal less elevated in the scale. The human embryo, for example, in the earliest moments of its existence, presents a mere round mass, destitute of limbs, having some analogy in structure to certain very simple animals; for we find in it neither brain, heart, bone, nor distinct muscles. The heart at first resembles that of some worms,—a mere vessel, which curves and presents two dilatations, forming the left auricle and ventricle. It then exhibits a mode of conformation analogous to that of some fishes; the auricle is afterwards divided into two cavities by an incomplete partition, which resembles the structure of the heart in most reptiles; and at a little later period a second partition, which arises from the bottom of the ventricle, also divides this into two, so that the heart then presents two cavities, as we find it in the superior animals. But yet the circulation of the fœtus is closely allied to that of reptiles; for the two auricles communicate by the *foramen ovale*, and the pulmonary artery is joined to the aorta by a large anastomotic branch, so that only a small portion of the blood driven from the right ventricle reaches the lung, while the remainder mixes with the blood destined for the immediate nutrition of the organs.

THE FUNCTIONS OF THE MALE.

The seminal fluid of all animals capable of procreation, when placed in the field of a microscope of about 350 diameters, will be seen to contain a multitude of minute bodies—*seminal animalcules* or *spermatozoa*—which are the more interesting in consequence of the curious vital peculiarities which they display. These bodies are not contained in the secretion coming immediately from the testes. In their examination, care should be taken that the fluid is obtained from the epididymis, vas deferens, or vesiculæ seminales; for it is by mixture in the secretions from these vessels that the spermatic fluid is brought to perfection, and thus that these bodies are produced. The length of the spermatozoa of man is from 1-30th to 1-40th of a line; they have a flattened oval-shaped body, of about 1-700th of a line in length, to which is appended a filament of much greater length, and of so fine a construction is the latter that a double contour can only be seen at its base. These bodies constitute the greater portion of the seminal fluid. Two other organic elements are observed in the semen—the *seminal granules* and the *liquor seminis.* The granules form the basis from which the spermatozoa are produced, and the liquor seminis is a homogeneous fluid for holding all in solution. In consequence of the vast number of the spermatozoa in semen, it is necessary to dilute it before inspection, which is best done by oval albumine, or the serum from the blood; and when moving room is thus afforded them, they strike with their bodies and tails in all directions, and move briskly across the field of the microscope. In the rat, and all the genus Mus, these bodies are larger than in all other animals, having a pointed scimitar-shaped body, and very long extremity. In birds and amphibia the bodies are thin, long, and waving, with a still longer filament appended. Much investigation has been expended on these bodies, and attempts made to detect in them internal organization, the nature of the polygastric structure of some infusoria; but no internal organs have as yet been discovered. They exist in blood, mucus, pus, or milk, for as long a period as in the liquor seminis itself; but in water, saliva, diluted acids, or alcohol, they are quickly destroyed. They differ remarkably from moveable cilia in the effect that certain poisons have upon them: if a fine thread is moistened in a solution of strychnia, opium, or prussic acid, and placed across the drop of semen before the microscope, the animalcules are seen to be poisoned as soon as they approach the thread, which is not the case with cilia. They are said to exist for days in their natural situations, or in the mucous discharge of the vagina. In weak solutions of sugar or common salt, or in urine, they continue to move for hours. Before the semen leaves the testis, these bodies are not distinguished in it, but amongst the granules may be seen *seminal corpuscles,* which contain granules, and from these the spermatozoa are afterwards developed. They appear in a bundle of *seminal filaments,* which are seen curved around the walls of the corpuscle like a thick skein of silk, and the corpuscle, after assuming an oval shape, bursts and distributes its contents. The nature of the movement which they exhibit is said not to be of a higher order than that of the cilia, and their history does not place them higher in the scale of life than the corpuscles of the vital fluids: the particular objects attained by their movement and their form are to hold on to the mucous membrane of the uterus, and move onwards to the ovary, in which parts they have been found after copulation. The manner of their operation upon the ovum has not been discovered.

The *vesiculæ seminales* appear to be destined for the double purpose of furnishing a receptaculum for the semen, and secreting a fluid which we have already seen is necessary for maturing the seminal filaments. It is probable that the secretion of semen is always progressing in the testis, that it is stored up in this convoluted tube, and if not discharged by emission, gradually escapes in the urine. It is well observed by Dr. Carpenter, and deserves everywhere to be promulgated, that the highest degree of bodily vigour admits of but a very moderate indulgence in sexual intercourse, and that this principle is the result of a general law, which prevails equally in the vegetable and animal kingdoms; a law, that the development of the individual, and the reproduction of the species, stand in inverse ratio to each other.

FUNCTIONS OF THE FEMALE.

The *ovaries* are two oval bodies enclosed in the broad ligaments of the uterus: their structure, which is called *stroma*, is fibrous, soft, and very vascular. In the stroma are seen the *graafian vesicles*, or the sac which contains the ovum. They measure about a line in diameter, and from ten to twenty are seen in each ovary. Being formed in the interior of the ovary, they gradually make their way to the surface, and their shining surfaces may be seen projecting on its surface through the covering of peritoneum. The walls of the vesicles consist of an external and internal lining; the external is composed of areolar tissue for the seat of blood-vessels, and an internal, into which the capillaries do not penetrate. The latter has an epithelial lining, which is not usually the case in cavities without ducts: an opening is, however, provided by the bursting of the vesicle on the surface of the ovary. The internal membrane secretes a thick albuminous mass, consisting of fine granules, which are attached to the walls of the vesicle by a tenacious fluid, forming its *granular disc*, and do not generally extend into the centre of the vesicle. Amongst these granules, and without any concurrence of the male, the ovum is produced, and is continually progressing in mammals during the reproductive period of life. The ovum, which is a vesicle within the graafian vesicle, surrounded by the granular disc, has a transparent structureless tunic, the zona pellucida, which is little else than a thick covering of very adhesive albumine: this is filled with the vitellus, which is said to have a delicate envelope, the vitelline membrane: in this is a spherical transparent vesicle—the germinal vesicle, and within its colourless contents may be seen the *germinal spot*, which appears to consist of one or two nuclei. The vitellus consists of fine granules and fat globules, and, as the ovum becomes matured, the vitelline globules make their appearance, which are corpuscles containing granules. In the order of the development of the ovum the germinal vesicle takes precedence of the yelk and its membranes. The measurement of a full-sized human ovum is in diameter, according to Wagner, from 15th to the 20th part of a line. In regard to the changes that occur in the parts up to the time of their discharge from the ovary, it is ascertained that there is a general increase in substance of the graafian vesicle, and the whole of its contents, but that comparatively little increase occurs in the germinal vesicle itself. At the period of bursting of the graafian vesicle, the fimbriated processes of the fallopian tube enclose the ovary, and draw within its canal the liberated ovum, which enters therein, with its membranes, in a perfect state, retaining on its surface a portion of the granular disc. This granular matter disappears about the centre of the fallopian tube, where the ovum becomes surrounded by a new investment of albuminous matter: at this period of the process, the germinal vesicle and its contents, in the impregnated ovum, can no longer be distinguished. In the transit of the ovum from about the middle of the fallopian tube to the uterus, the formation of the *chorion* takes place, which is constructed from the materials of the zona pellucida, and the albuminous matter on its surface. The period of the bursting of the graafian vesicles in mammalia is the rutting season, and in the human female at the period of menstruation. There can be no doubt that at this season, in mammals, not only do the graafian vesicles burst, but the fimbriæ of the fallopian tubes grasp the ovaries, and receive within their cavities the ova, and this without sexual intercommunication. This fact has been amply verified by Bischoff, on dogs and rabbits. The unimpregnated ova have been detected in the fallopian tubes, where being without the vitality derivable from fecundation, they probably undergo a rapid decay, amidst the ferments contained in discharges from the mucous surfaces, for we have no history of them after this period.

The immediate contact of the spermatic fluid is a necessary condition to the fertilization of the ovum: the exact stage of the process in which fecundation takes place is not determined, but there are grounds for believing that it is while the ovum is still in the ovary; by what means it is accomplished, whether by penetration of a spermatozoon into the ovum, is unknown. The grounds for believing that fertilization takes place in the ovary, are the facts,—1st. that Bischoff and Barry have unquestionably seen spermatozoa in the fallopian tubes, between the fimbriæ, and on the surface of the ovary. 2nd, the length of time before the ovum reaches the uterus after sexual union, amounting in some instances to eight days. 3rd, direct experiments on rabbits, which prove that tying the fallopian tube at any time within the period of forty-eight hours after coitus prevents fecundation of the ovum, but the same operation performed sixty hours after coitus does not prevent fertilization; and lastly, extra-uterine conception, in which case the ovum is discharged and matured in the cavity of the abdomen. The presence of spermatozoa within the vitellus is not demonstrable by the microscope. It is probable that the nervous stimulus of sexual intercourse is felt by the ovary and the adjacent apparatus of the process, and that such may accelerate the liberation of the ovum and its reception into the tube; but this stimulation, and the other nervous phenomena that usually accompany the sexual union, are by no means essential to the fertilization of the ova, for the artificial injection of semen into the vagina is sufficient for the purpose. And it sometimes happens in both the sexes that some peculiarity of constitution prevents the experience of the sexual propensities and all their attendant excitement, and yet in such cases the women have had families and the men have been fathers.

It is asserted by Dr. Haighton that the division of the fallopian tubes on each side in rabbits not only prevents impregnation, but removes the sexual appetite. We are ignorant of the exact condition of the ovum that renders them fit for fecundation, or what is the essential cause of barrenness: it is observed by Herbert Mayo that "barrenness in married women occasionally depends on obstruction of the os uteri by viscid mucus, and that the removal of the obstruction by a bougie has been shortly followed by conception." In cases in which the cause of barrenness becomes an anxious question, the presence of such an obstruction might be easily ascertained by inspection. There is no doubt that in some cases the spermatic fluid is incapable of fertilizing mature and perfectly-formed ova; on the other hand, it sometimes not only produces conception, but extends an obscure influence through the structure of the ovary, so as to give an impress to the incipient ova that are lying dormant, and that may not be matured and fertilized for several years afterwards. Evidence in proof of this is to be found in several instances recorded, and a most remarkable one is the following:—A seven-eighths bred Arabian mare never previously having had foal, had a mule by a quagga, and subsequently had three foals by the same Arabian horse. The two first foals by the horse were fine specimens of the Arabian breed, but had the following resemblance to the quagga—a dark stripe along the back bone, dark stripes across the fore-hand, and, instead of the fine silky mane of the parents, the hair was stiff, and inclined to stand upright. Reasoning from the fact that the ova of mammals are discharged at the season of "heat" in the lower animals, and during menstruation in women, and that the ova may take eight days or so to pass into the uterus, on or before which period the unimpregnated ova disappear, physiologists have supposed that sexual intercourse in the human subject, to be fruitful, must take place either three or four days before menstruation or eight or ten days afterwards, and that between these periods no successful intercourse can take place. When the discharged ovum has undergone fecundation, an increased flow of blood takes place to the ovary, by which the vascular membrane of the graafian vesicle becomes enlarged; the epithelium on the inner coat becomes altered in its function, and produces a thickening and a growth of a reddish fleshy-looking mass, which fills up the cavity and finally projects from the ovary. It afterwards assumes a yellow colour as the process of absorption proceeds: this is the *corpus luteum.* The change from the fleshy appearance to the yellow gradually takes place during pregnancy, and, on examination of the ovary, eventually a stelliform white mass occupies the centre of the graafian vesicle, which radiates between the fleshy excrescences that project from its contracted and puckered walls: a cavity, however, occupies the centre. They remain in size about that of a mature graafian vesicle, and, by their number, indicate the number of pregnancies that have preceded. The false corpora lutea, or those that have contained unfertile ova, always indicate the seat of the previous vesicle. They have, however, not undergone the change that takes place in the inner membrane of the true corpus luteum, and no vestige of a membrane is to be seen; they are, in fact, merely light spots in the stroma of the ovary.

The ovum, after bursting from the graafian vesicle, being received within the fimbriæ of the fallopian tube, is conveyed to the uterus. It may be easily examined in the rabbit at about the sixth day after fecundation, when its size is half a line in diameter: a change of structure is then visible; the vitellus first divides into two portions, and subsequently breaks up gradually into large globules, each containing a transparent vesicle in the centre, and surrounded by the granules and cells peculiar to the yelk; but neither has a nucleus within the vesicle, nor any external tunic around the globule, been observed. As this separation of the yelk into globules takes place immediately subsequent to the disappearance of the germinal vesicle, it is supposed that these globules arise from some wonderfully minute subdivision of the germinal vesicle. On the first establishment of the ovum in the uterus, these globules have respectively diminished in size and increased in numbers so as to acquire for the ovum a granulated appearance through its substance. Growth now commences: the globules become nucleated in their central vesicles, and acquire an investing tunic. The next change is the assemblage of these now perfectly-formed cells around the walls of the vitellus, which is still encircled by the chorion. This mass of cells is in this position converted to a thick, consistent membrane, named the *vesicula blastordermica*, or *germinal membrane*, the interior of which is occupied by a transparent fluid. The above are the first appearances exhibited by the ovum on its first entrance into the uterus. By the time it has reached the uterus a preparatory change has taken place there for its reception: vascularity has been active, and the wall of the organ become full of tubular follicles, resembling those of the stomach in penetrating the whole thickness of the walls, but unlike those of the stomach in not being arranged in fasciculi, and in taking a waving direction. Granular production is now active in the interfollicular spaces and epithelium growth in the follicles by which the *membrana decidua* is produced: this consists of two investments; an external—the *decidua vera*, and the *decidua reflexa*. The decidua vera is composed, according to Dr. Sharpey, of the inner portion of the mucous membrane itself, and is vascular; and the decidua reflexa is of cell formation, and non-vascular. The chorion of the ovum furnishes on its exterior an abundant growth of flocculent villi, and it is by the intermediation of both these villi and the non-vascular deciduous membrane that the ovum derives its sustenance from the vascular membrane. During the enlargement of the ovum, the two deciduous membranes come into contact, and soon after the second month they coalesce and form one membrane.

The development of the embryo can be more closely watched in the egg; therefore we shall select it as an example for the study of this curious phenomenon. Birds have not, as most of the superior animals, two ovaries. We find in them only one, which is fixed in the abdominal cavity in front of the vertebral column by a fold of the peritoneum, and which consists of a collection of small membranous sacs, rounded, more or less developed, and united in clusters. The walls of these sacs abound in blood-vessels, and secrete the ova, which are formed in their interior, and which consist of a yellow material enveloped in a very thin membrane. These bodies slowly enlarge, and when they have acquired the volume to be possessed by the yellow of the perfect egg, the ovarian sac, in which each of them is contained, bursts and allows it to escape into the cavity of the pavilion, a kind of membranous tunnel applied upon the ovary, and conducting outwardly by the oviduct, a tube of the same nature, the inferior orifice of which is seen in the cloaca, near the anus. At the moment when the ovule descends into the oviduct, it is merely composed of *vitellus*, or yellow, enveloped in a membranous sac, at one point of which is a whitish spot, called the *cicatricule*, and which deserves notice, because in its interior the embryo is to be developed; but, in proportion as the ovule descends, it is covered by other substances secreted by the walls of the canal it traverses. About the middle of the oviduct it is enveloped by a thick and glairy matter, which is the white of the egg, and a little lower down there is formed around this new layer a thick membrane, the external coat of which is finally encrusted by an earthy deposit, and thus constitutes the shell of the egg. In this condition the egg is laid. When it has not been previously fecundated, it does not undergo any important change; but, in the opposite case, it becomes the seat of an active progress as soon as its temperature is suitably elevated. If the cicatricule be now examined by the microscope, there will be seen towards the centre a small white oblong body which may be considered the rudiment of the germ, and which presents a central white line rounded at its summit: this spot marks the place in which the cerebro-spinal cord will be developed, and, according to some physiologists, it is itself the first appearance of the nervous system. Around the germ is seen a kind of membranous and transparent disc, which in its turn is bordered by a darker zone and by two concentric light circles. About the eighteenth hour of incubation the germ contracts, takes nearly the form of a lance, is rounded at its superior part, and forms a fold, which doubles like a cloth in front of the cephalic extremity of the cerebro-spinal line. Upon the sides of this longitudinal line may also be remarked two small ridges which enclose it as in a canal. Soon after, these ridges unite by their inferior extremities, and approach so as to conceal the line which separates them; finally, about the twenty-fourth hour, three pairs of rounded points make their appearance, which are the first rudiments of the vertebræ, the number of them now rapidly increasing. The transverse fold alluded to upon the anterior extremity of the germ is the first rudiment of the head, which soon tends to detach itself and become distinct. Towards the thirty-sixth hour of incubation the eyes of the chicken may be perceived: soon after, the posterior part of the body is plainly defined, and the embryo curves upon itself. During the third day the head becomes more and more distinct; its pointed extremity, which corresponds to the beak, is bent upon the chest, and on the sides of the vertebral column, under the form of small white tubercles, may be recognised the earliest traces of the upper extremities; soon after, the inferior limbs are formed in the same manner; two small appendages fixed below the neck also appear, and constitute by their development the lower jaw; finally, the eyes are coloured black. The fifth day of incubation, the limbs, which as yet resemble mere stumps without form, begin to execute some slight motions, and twenty-four hours after they are so far developed that the thighs can be distinguished from the legs, and the fore-arm from the arm: the general form of the individual also approaches a little to what it will be in future; about this period the heart enters the cavity of the chest, and the walls of the abdomen are completed. The seventh day the feet are formed, and about the ninth day, upon the skin of the embryo may be found little pores, which are the openings of the capsules destined to secrete the feathers, which begin to make their appearance at the end of the tenth day, and cover the whole body in the space of twenty-four hours. The size of the head, at first excessive, diminishes proportionally to that of the rest of the body; and the eyes, which were remarkable for their size, increase more slowly than the other parts: the limbs, on the contrary, are developed with greater rapidity, so that the entire chick approaches more and more nearly the perfect animal. Considered with regard to its external form merely, the embryo presents, as we have seen, true metamorphoses; but the most curious part of the history of its development is that which displays the manner in which the different sets of apparatus most important to life are successively formed in the interior of its body. About the twenty-seventh hour of incubation, on the anterior face of the chicken, and precisely at the point where the membrane folded in front of the head terminates, may be perceived a small transverse cloud, which enlarges at its two extremities, and is insensibly lost upon the transparent area in the middle of which the germ is placed. This cloud is the rudiment of the left auricle of the heart. Three hours after, the centre of this organ will be found surmounted by a straight vessel directed towards the head, and which is the left ventricle; soon after, a third enlargement is seen above the latter,—it is the bulb of the aorta, which afterwards disappears, but is permanent in certain reptiles, such as frogs; the heart then enlarges and curves upon itself; a contraction is established between the auricle and the ventricle, and, about the thirty-sixth hour, the former of these cavities begins to ascend to the summit of the apparatus: at this period the heart begins to beat, but it does not yet contain blood, and is only filled by a colourless liquid. From the earliest hours of incubation, the transparent area around the germ also presents important modifications: the membrane forming it is divided into two leaves between which is developed a layer of spongy tissue, which, about the thirtieth hour, begins to thicken in certain places, and to take a yellow tint: this tissue gradually extends over the whole surface of the yellow, and little islets filled with a reddish liquid form in its interior; finally, these soon communicate together and form a vascular net-work, which surrounds the embryo and sends the blood to the heart by two vessels, the extremity of which is lost in the left auricle. The blood is at first formed in this vascular membrane, and far from the embryo; and when it begins to appear its globules are circular.

The circulation is then easily traced: the blood passes through the ventricle, arrives in the bulb of the aorta, thence enters the descending aorta, which soon divides into two branches, which issue from the body of the fœtus and are lost in the vascular area by which it is surrounded: the blood which thus leaves the chick on the right and left is divided into a collection of capillary vessels, then runs into a general vessel which conducts it upward or downward, whence it returns to the heart. Between the third and fourth day of incubation, the right ventricle may be clearly distinguished, and appears as a small sac placed in front of the left ventricle, communicating freely with the cavity of the auricle, and continuous with a vessel the extremity of which is directed towards the point occupied by the lungs. On the second day the right auricle also begins to be formed by means of the development of an annular fold, which divides the left auricle into two distinct parts. Finally, about the sixth day we begin to perceive in the blood elliptical globules, and the ninth day these have taken the place of the circular globules which at first existed alone: their appearance coincides with that of the liver, and with the obliteration of the vessels of the membrane of the yellow, in which we found sanguification to commence; therefore there is reason to consider this viscus as the seat of secretion of these corpuscles. The lungs begin to be developed about the fourth day: at first they consist of two oblong, almost transparent tubercles, placed behind the heart; they soon acquire a reddish tint, but do not serve for respiration till the chick has broken its shell. This function is, however, very actively executed from the earliest moments of incubation; and if air be prevented from penetrating the egg, the chick dies almost immediately. At the moment when laid the egg is completely filled by the white and the yellow, but these liquids gradually lose by evaporation a certain quantity of their water, and there is thus formed under the shell a vacuum filled with air: at the same time the yellow undergoes important modifications which render it lighter than the white, so that it occupies the superior part of the egg whatever be its position; and the serosity which accumulates during the second day of incubation under the cicatricule, producing the same effect upon this, causes it to float so as to be in contact with the air spoken of. The respiration of the embryo is at first effected by the contact with the air which has thus penetrated beneath the shell, or by the membrane of the yellow; but, soon after, this function becomes the duty of a new membrane called *allantois.* This begins to make its appearance about the forty-fifth hour of incubation, under the form of a membranous and transparent vesicle, of the size of a pin-head, placed in the abdominal region of the chick. This sac is rapidly developed, expands upon the superior surface of the yellow, and finally occupies the whole internal surface of the shell against which it is placed. Lastly, its external leaf is quickly covered by a magnificent vascular net-work, which receives the venous blood coming from the embryo, and places it in contact with the air to be transformed into arterial. The intestinal canal appears to originate by two folds of the internal layer of the cicatricule, which at first resemble tunnels open at one end, situated above the vertebral column and opposite each other; these folds gradually contract and close; but their cavity still remains in communication with the yellow, which little by little enters it and serves to nourish the fœtus: thus it is more and more diminished, and towards the end of incubation it is introduced into the interior of the abdomen. Finally, the nervous system undergoes in its development a series of modifications yet more remarkable than those we have observed; and the transitory forms seen in it have the greatest analogy with the permanent condition of these same parts in animals less elevated in the zoological series. The majority of animals have, on coming into the world, nearly the forms and the mode of organization they are to preserve during the whole of life, but it is not so with all; there are many which, even after birth, pass through changes analogous to those already experienced during the development of their embryo, and sometimes these changes are so complete that the animal undergoes true metamorphoses before reaching the perfect state. Frogs, and especially insects, furnish remarkable examples of these transformations.

MENSTRUATION.

The menstrual discharge commences in the human female with puberty, ordinarily between the periods of fourteen and fifteen years of age, and continues to the age of from forty-five to fifty. Circumstances that tend to render the constitution delicate, whether the temperature of a tropical climate, or luxurious habits in colder regions, have the effect of occasioning its earlier appearance. It is at these seasons that the graafian vesicles become matured and burst, and, judging from analogy in the lower animals, that they find their way through the fallopian tubes. We have seen that in mammalia, at the season of "heat," vascular excitement prevails in the ovarics, of which the uterus and external parts of generation participate; and at this time the ova are then discharged. There are no grounds for believing that ova are ever liberated when this periodical excitement has departed from these organs; and bearing in mind that the ova may occupy six or eight days in descending the tubes, and that the spermatozoa may exist three or four days in the mucous discharges of the uterus and vagina, we may fairly conclude, so far as we can rely on these premises, that the ova of the human female cannot be fertilized unless the semen of the male has been introduced into the vagina either within the three or four days previous to menstruation, or within the six or eight days subsequently.

The menstrual discharge consists of blood and mucus exuded from the inner surface of the uterus, together with the mucus of the other passages concerned; and a peculiar feature in its physiology is the very imperfect coagulating property of the blood.

It has been commonly supposed that this peculiarity arises from the absence of the fibrine of the blood, and the acid reaction which the effusion exhibits.

The analysis of the menstrual flux has been made by the following chemists, and the figures attached to their names give the amount of solid constituents in 1000 parts of the discharge: —Dr. Letheby, 142·6; Rendskoph, 179·170; Vogel, 169·10; Scherer, 187·8. By comparing these results with the solid matters of normal blood, as given by Becquerel and Rhodier—208·9—a considerable deficiency appears. In one of these experiments the discharge was obtained from a prolapsed uterus, and in another from a strong and healthy female; but in no case was any coagulum formed. No fibrine could therefore be obtained, although it is generally supposed to be present in its due proportion. The acidity of the mucous discharge, and the admixture of mucus, is generally relied on as the cause of the absence of coagulation. The author, however, has ascertained that a larger proportion of acid (the acetic) than that contained in the discharge, and the same proportion of mucus, when both are artificially mixed with ordinary blood, will not prevent its coagulation: the following explanation is therefore submitted:—It has long ago been proved by Spallanzani, that on suspending the body of a frog in the gullet of a crane, its solution is very shortly effected, and that the solving action immediately commences on the surface of the frog. More recent experimenters have proved that the solution is due to certain ferments contained in the mucus,—to wit, animal diastase and the lactic acid ferment. The operation of these ferments is confined to the non-azotic principles of aliment. Now, although blood contains but little of these non-azotic matters, it contains enough, under the forms of fats and extracts, to account for this partial dissolution, and a change in the molecular state of its whole structure, when these non-azotic matters are acted on by the fermentations in question. It is therefore probable that the ferments in the mucous portion of the discharge immediately act upon the fibrine of the blood, and produce the same molecular change that characterizes blood when, from certain causes, nervous polar force has been exhausted in the body (see Irritability), and which causes a very imperfect coagulation of the fibrine, if it do not suspend it altogether, producing that slight rearrangement of its organic constituents which is the first and preliminary step towards its ultimate decay or its inorganic finality. The acidity noticed in the menstrual discharge is probably due also to one of these ferments; saliva rapidly becomes acid, although in the first place it is alkaline.

The period of life at which the menses cease in women is regulated by the time of their first appearance; and it may be stated as a general rule, that the earlier it commences, the longer it lasts. It generally ceases during pregnancy and lactation, though it occasionally continues through the whole of these periods; and such irregularity is not necessarily inconsistent with good health. The average interval between the successive returns of the menstrual discharge has been computed by Dr. Locock to amount to twenty-eight days to an hour.

The appearances which the menstrual discharge exhibits under the microscope are the ordinary blood-corpuscles, and the epithelium scales, and other characteristics of mucus.

NOTE ON GELATINE.

Subsequently to printing off the articles on gelatine in the former part of this volume, the author has been favoured by Dr. Taylor, Professor of Chemistry at Guy's Hospital, with some results of experiments on this substance undertaken by himself in conjunction with Mr. Brande, Mr. Aikin, and Mr. J. P. Cooper; and as they differ in two important particulars from the account there given, a reference is again made to the subject. These gentlemen have come to the conclusion that when the membranous part is separated from ordinary gelatine, there is no trace of sulphur to be discovered in it, and they are equally unanimous that gelatine exists as gelatine in the gelatinous tissues, or is an *educt* therefrom by the operation of oxalic and acetic acid, potash, and other reagents, and is not a *product* by boiling in water. It has been stated, at page 14, that Scherer had lately discovered sulphur in gelatine to the amount of 0·56; the analysis was made on isinglass, and the amount of sulphur obtained was 0·56 to 0·727. The former of these two amounts was selected by the author that some latitude might be allowed for the small quantity of sulphur contained in the walls of the membranous cells in which the gelatine is contained, the same being a proteine compound; and as the gross amount of sulphur indicated is twice as much as that formerly found in albumine by Mülder, the question between the London and the German chemists as to the existence of sulphur in gelatine is left at issue. The opinion that gelatine does not exist in the gelatinous tissues, but that its atomic constitution is altered by organization, is of long standing, and is adopted by Professors Liebig and Gregory in their last edition of Turner's Elements of Chemistry. This opinion is no doubt founded on the obscure chemical combinations that gelatine enters into by the process of organization, and in which its ordinary characters are changed: as, for instance, the combination that gelatine forms with the earthy portions of bone, and which, unlike ordinary gelatine, will for centuries resist the tendency to decay common to all animal matter. We must, however, remember that this opinion rests on negative evidence, whereas the conclusions of Dr. Taylor and his colleagues, that it does exist in the tissues, is positive.

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