CHEMICAL

PHYSIOLOGY.

MANUAL

OF

CHEMICAL PHYSIOLOGY.

FROM THE GERMAN

OF

PROF. C. G. LEHMANN, M. D.

TRANSLATED WITH NOTES AND ADDITIONS

BY

J. CHESTON MORRIS, M. D.

WITH AN

INTRODUCTORY ESSAY ON VITAL FORCE,

BY

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TRANSLATOR'S PREFACE.

No apology is necessary in presenting to the American medical public the work of one so widely known and universally acknowledged as an authority as Professor Lehmann. In so doing, however, I am surrounded with more than ordinary difficulties. A correct English translation of a German work is no easy task; but when the original is not a full discussion of the subject considered, but as compressed a statement of facts as is compatible with clearness, the difficulty of avoiding idiomatic expressions is greatly increased.

From Dr. Lehmann's views of the forces operative in living organisms, I must express my dissent. Dr. Jackson has been kind enough, at my request, to prepare an article on these views, stating the doctrines which he has so ably advocated for many years.

To adapt the work for the use of students of physiology, I have incorporated in the text additional matter (derived mainly from notes on Dr. Jackson's Lectures, Carpenter's Human Physiology, Todd and Bowman's Physiological Anatomy, Kölliker's Microscopic Anatomy, &c.), of a more purely physiological nature, which will be found included in brackets, thus [—]. Short notes have also been added, in the shape of an Appendix, on kindred subjects not treated of by the author; and illustrations selected from various sources have been introduced, instead of referring, as the author has done, to the "Atlas of Physiological Chemistry, by Otto Funke." These alterations have so changed the character of the work as to render the title of "Chemical Physiology" more applicable than that originally given to it of "Handbook of Physiological Chemistry," which has, however, been retained for Dr. Lehmann's portion of it.

I can only hope that, in its present shape, the work may prove of use to those who wish to ascertain what may be considered as established in Physiological Chemistry, and who yet have not time to wade through detail and controversy, and my aim will be accomplished if I have succeeded in aiding those who desire a more intimate acquaintance with the phenomena presented by organized beings.

PHILADELPHIA, March, 1856.

AUTHOR'S PREFACE.

We have made the attempt, in the present little work, to place together, in as compressed a form as possible, the positive facts which can now be looked on as the certain possessions of physiological chemistry, and to bring to bear only those conclusions which carry upon them, according to our present physical views, the stamp of relative truth.

Notwithstanding the very active zeal with which physiological chemistry is cultivated on all sides in so satisfactory a manner, and in spite of the many extended works and treatises on some of the most important heads of this science, we are unfortunately forced to confess that, until now, but few undisputed facts, but few undoubted propositions, are established. Hence we cannot ourselves decide whether the attempt to present the department of physiological chemistry in a short epitome, where the fixed marks are so few, and the deficiencies so innumerable, has succeeded. If one wishes not to enter the domain of debates and discussions, a number of weighty questions must remain, if not unnoticed, yet unanswered. Yet we have just attained a position in physiological chemistry where we can ask important questions, whose answers, even in part, the near future does not as yet promise.

If it is in itself more difficult to represent a subject briefly, than to enlarge on it discursively, the deficiency of our physiologico-chemical knowledge just alluded to, has increased the difficulty ot presenting this science in its outlines. We hope, therefore, for indulgence where we shall have done too much or too little.

We have throughout avoided introducing the names of investigators and authorities, as such introductions would have prejudiced the compressed brevity which we have had in view, and the purely objective treatment of the individual subjects. On this account, also, we have nowhere brought forward our own researches, or referred to our larger work (*Text-Book of Physiological Chemistry*,[1] 3 vols. Leipsic, 1853, W. Engleman), but throughout have cited, where it seemed proper, the excellent *Atlas of Physiological Chemistry*, by O. Funke, Leipsic, 1833, W. Engleman.

C. G. LEHMANN.

LEIPSIC, May, 1854.

[1] This work has been recently presented to the American public, complete in two volumes, under the auspices of Dr. Rogers, of the University of Pennsylvania.

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SAMUEL JACKSON, M. D.,

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HUMAN ORGANISM.

GENERAL RELATIONS.

THE organism of man, in its physiological, pathological, and therapeutical relations, is the subject and object of medical science.

A comprehensive view of its general nature, and of its varied phenomena, will facilitate the investigations indispensable for a perfect understanding of them, by which alone medicine can be constituted a science. Without this knowledge, it cannot rank above an art or empiricism.

Regarded in its completeness, it is an organic mechanism, the last and the most marvellous of the works of God; the fulfilment of the Creative thought in this world. In its structure, it is in the highest degree complicated; in its nature, it is compound: it comprehends within itself all organic nature. As in every mechanism, its phenomena are divisible into statical and dynamical.

The first embraces its material structure and forms: the second, its varied movements and its forces, or causes of its actions. It includes three distinct natures, or spheres of existences—vegetable, animal, and spiritual, or psychological. They form three separate classes of phenomena, or branches of science; vegetability, animality, spirituality, or psychology. The first is characterized by growth, development, nutrition, and secretion: the second, by sensibility, general and special; contractility or irritability; spontaneous and voluntary movements and locomotion: the third, by consciousness, perception, ideality, causality, moral sentiments, and instincts.

The actions belonging to the first, are vital, chemical, and physical; to the second, mechanical, physical, and dynamical; to the last, psychological and metaphysical.

The special or organic instruments of the first are germs, cells—epithelial, mucous, and glandular—fibres, and the ganglionic or sympathetic nervous system: of the second, muscular fibres, muscles, and the spinal nervous system, and nervous organs of the special senses; of the third, the cerebral lobes, hemispheres, or brain.

The above phenomena blend together, are interdependent, closely associated; and are the most intricate that exist in nature. They can be understood only when subjected to an accurate analysis, by which each component of a complex phenomenon may be separately demonstrated. This indispensable process for the acquiring a reliable knowledge of organic phenomena, necessitates a competent acquaintance with each science of which the elementary phenomena are subjects.

A deficiency of this requisite has been, and continues to be, a source of error in observation, and of fallacy in interpretation. Properly to comprehend a complex phenomenon, it must be recognized as such; it must be viewed in each of its aspects, in each of its separate attributes; the action and influence of each component part must be appreciated in the production of the general result, the object of research. A partial view, however complete it may be; the determination of a single property, or of a single component, however accurate, cannot explain the attributes, actions, or nature of the compound. Errors of this kind have abounded in medicine. It is only within a few years that the means of correctly analyzing the phenomena of living beings was possible.

The unstableness of all former theories and doctrines in medicine arose from this defect. They were based on a partial view, or on a single fact of life, mostly dynamical, as vital force, and irritability, or sensorial power; or on chemical views. Most of the organic chemists of the present day neglect all other components of a phenomenon except the chemical; and the inferences are consequently incorrect, although the chemical fact they establish may be of great value when taken in conjunction with others. The chemical view presented of the blood in most works of organic chemistry, gives no adequate idea of that fluid as circulating in the vessels, and of its relations to vital phenomena. The pure physiologists who discard chemistry and physics as the leading characteristics of organic or vegetative functions, are nearly as remote from the truth as are the chemists. A just appreciation of the complex phenomena of the human organism can be obtained in no other mode than by viewing and treating them by the lights of the collateral, physical, chemical, and other sciences, to which their elementary phenomena belong.

The material substance, the basis of the structure of the organism, is plastic, or organizable matter. The elementary plastic matter is albumen, which becomes transformed into various proximate plasmata, of which the different solid elementary tissues and organs are formed.

CHEMICAL RELATIONS.

Organic matter has for its constituents the common chemical elements of inorganic bodies. Four of these, carbon, nitrogen, hydrogen, and oxygen, may be regarded as the special chemical elements of organic matter. They alone, of all the chemical elements, possess the power of forming almost unlimited series of combinations with each other, and those series again are endowed with similar powers of combination.

This attribute adapts them to the purposes of organic nature: without it, organic matter and organic bodies could have no existence. The chemical elements that constitute organic matter, are not divested of their special nature, properties, or relations, when they enter into its composition: they do not cease to be chemical substances any more than when they form inorganic compounds. The older physiologists were firmly convinced that chemical actions and vitality were essentially incompatible; and many physicians of the present day adhere to the same opinion. From the imperfection of chemistry, the chemical actions of living beings could not be recognized or understood, and were denied. So far are these opinions from the truth, that vital actions and organization are impossible without chemical action. Organic matter is not, like inorganic, an originally created, self-existing, and indestructible substance, as it was supposed to be by Buffon. The vegetable kingdom is the great chemical laboratory of nature, in which are effected the decompositions of carbonic acid, water, and ammonia, in order to obtain the four essential chemical elements of organic matter, and to combine them along with sulphur, phosphorus, &c., into an infinite number of organic matters, vegetable and animal. These are the materials for the organization and development of the plants themselves, and animal organic substances, for the construction of animals. The albuminoid organic substances, named by Liebig vegetable albumen, vegetable fibrin, and vegetable casein, are the primary or crude organic substances, elaborated by chemical action in vegetable cells, destined to the production of animal albumen, fibrin, and casein, the crude organic plasmata, or substances from which are formed the immediate organizable or plasmatic matters of the different animal tissues. These last organic substances are produced in the formative act of nutrition or assimilation, at the moment the organic form of the special animal structure is generated. Thus, musculin, a chemical modification of albumen, does not exist in the blood. It is known only as forming the organic material composing the solid portion of the muscular fibrillæ: the transformation of the albumen must take place in the muscular fibrilla simultaneously with the production of its form. The organic matter of animal tissues is not permanent. From the great number of its chemical equivalents, or atoms, it is highly mutable. This character is most striking in some structures, as in mucous, glandular, muscular, and nervous tissues. The functional actions of organs cause waste and destruction of organic material proportioned to their activity. This is a result of chemical action, indissolubly connected with vital action. In vegetables, the predominant chemical action consists in the deoxidation of organic substances, the oxygen being chiefly discharged into the atmosphere, while new organic substances are produced, as wax, oils, acids, &c., from the deoxidation of starch. Oxidation is the predominant chemical process in animals. The oxygen introduced into the blood by the function or act of respiration, combines with the carbon and hydrogen of the organic matters of the blood and the tissues. The whole chemical arrangement is broken up, and a reduction of the complex plastic substance into simpler bodies takes place, from successive processes of oxidation. They are creatin, creatinin, inosin, inosic acid, uric acid, urea, and, in addition, lactic, sulphuric, and phosphoric acids, and other unknown substances that lie concealed in the extractive matters enumerated by the chemists as existing in the blood and urine.

Independent of these normal chemical actions, consisting in the molecular changes and transformations of the plastic organic matter, there are other chemical changes, some therapeutic, some abnormal or pathological, belonging to the relations of the plastic or organizable substances with other bodies. Albumen, fibrin, and other proximate organic bodies, unite chemically with many of the chemical elements, as with additional quantities of oxygen, or with acids, metallic oxides, and earthy, alkaline, and metallic salts. Through this combination some of these substances are absorbed into the blood. Doubtless many other bodies possess chemical relations with the plastic organic substances of the blood and tissues, some entering into combination with them, others exciting molecular action and evolving new compounds, or transforming them into new matters, by causing new molecular arrangements and production of new organic matters. In this mode, abnormal contagious animal poisons are generated in the organism, when introduced into it by inoculation or otherwise. A minute quantity of smallpox matter inserted in the skin, or an invisible miasm of it inhaled from the atmosphere, acting as a kind of ferment, will give rise to the production of some ounces of an identical matter, in a case of confluent smallpox. The inoculation of a small quantity of putrid organic matter by a slight wound or scratch in dissection, will so destroy the crasis of the blood as to cause death. Absorption of sanious discharges from the uterus, it is probable, gives rise to some of the fatal forms of what is called puerperal fever. And again, the normal chemical changes attending the organic actions are accelerated by some bodies, as acetate and nitrate of potash, iodide of potassium, and the mercurial preparations. It is this that constitutes an alterative action. Those substances are organic alteratives. Other substances retard those changes and diminish the waste of the tissues; such are alcoholic liquors, caffein, thein, and the narcotics. To a certain extent, it may be the action of some vegetable tonics.

The whole history of organic matter, it is apparent, is essentially chemical. Itself a chemical product, it is incomprehensible in its infinite, endless forms, and incessant changes, without a knowledge of chemistry. It is the elaborated product of the chemical laboratories of nature—vegetable organic cells. But the immediate plastic material of each tissue of an organized being, always a special organic material, is generated or assimilated from a crude plasma of the nutritive fluid, in the tissue itself, by the organizing or germ force of the tissue. The formation of organizable plastic matter, necessitates a living organism, independent of which it can have no existence. In this necessity, we have the scientific demonstration of a creation, and the direct primary agency of a Creator, the first cause of the organized world.

Organic chemistry is identified with physiology and medicine. No absolute progress can be made by either without it. The future progress of both those departments must depend, to a great extent, on the development of its principles and higher perfection of its methods of investigation. The present work, principally a translation of *Lehmann's Handbook of Physiological Chemistry*, is believed to be the best adapted to initiate the student in a knowledge of physiological or organic chemistry, indispensable to a scientific *medical* education.

STATICAL RELATIONS.

The animal is an organism, a complicated living mechanism. In carrying on its numerous and diversified operations, it presents a great variety of phenomena, and possesses numerous subordinate instruments, each appropriated to a special office. They are termed organs and apparatuses of organs. Each organ and apparatus possesses a special organization, is endowed with a special vital activity and properties, performs a special function, and manifests special phenomena. To be thoroughly known, they must be subjected to exact analysis, be investigated by experiment, as are inorganic bodies, and be assigned to the natural class to which their actions and phenomena show them to belong. A chemical, physical, mechanical or dynamic fact does not lose its proper nature and attributes, or cease to be subject to its proper laws, because it occurs in a living organism, and is associated with special vital facts or phenomena, or controlled and directed by vital force.

In the living organism of man are found to concentre all the actions and phenomena, chemical, physical, and mechanical, that exist in the exterior inorganic world, combined with those peculiar to organized or living beings. This may be expressed in the formula: inorganic phenomena, plus organic and psychical phenomena.

The chemistry, physics, and mechanics of the human organism are transcendental; they are each the development of the highest possible conception in each branch of knowledge; the instruments that execute them are inimitable by any of man's invention, for the purpose of exemplifying the phenomena and principles of the natural sciences. Such, for example, is the eye as an optical instrument, the ear as an acoustic instrument, the larynx as a phonetic and musical instrument, the vascular system as a hydrostatic apparatus, and the muscular system as a mechanical mechanism.

The organism of man in action is a locomotive engine, in the perfection of its machinery and adaptation to its purposes, infinitely beyond any similar engine that man ever can devise. It is composed of a number of distinct mechanisms, or machines and instruments, by which it is self-formative; by which it procures and prepares the materials for its repair and renovation, conveys them to every part of its structure where they are required, generates its own temperature and the forces that work its machinery, and brings its mechanical powers into action.

The intelligence for whose use this engine exists, whose will it obeys, whose work it performs, that rules and controls it for the purpose of accomplishing the objects of life, resides in and is a component part of the machine itself. The intellect is to the human locomotive, what the engineer is to the steam locomotive. It employs the extraordinary powers of this wonderful and magnificent mechanism to mould exterior material nature, after the ideal creations of its own interior and spiritual nature, evolved in ideas and thought. The state of society of any country, its institutions, its works, its science, its arts, the meliorating features impressed on the rude face of nature by its industry and labors, are the reflection and manifestation of the intelligence, knowledge, and moral character of its people.

By his locomotive machinery, aided by his inventions, that render it more efficient, that augment his powers, man overcomes all the barriers and obstacles of nature. No mountain is so lofty as to be inaccessible to his footsteps, no valley into whose depths he cannot penetrate; he mounts into the upper regions of the air to gratify his curiosity; he perforates the earth and descends into its bowels thousands of feet below its surface, to bring forth its buried treasures; the wide expanse of ocean he has made his highway; and he circumnavigates the earth in the pursuit of pleasure, science, or wealth. These extraordinary powers he owes to his inventive faculties and the knowledge acquired by his intelligence. With their aid he devises the required means that enable him to seize on the forces and appliances of nature, to turn them to his purposes, and, through their agency, to triumph over nature herself.

The amount of mechanical force and power, produced, and expended in the daily working of the animal machinery, is far beyond what can be conceived by those who have not investigated this subject. I will here merely state that, for the organic functions of respiration and circulation, the daily amount expended is not less than some thousands of pounds; and a considerable sum is required for the daily operations of the ingestion and digestion of food and expulsion of the excretions; while the aggregate result during labor and locomotion of various kinds, is often enormous, exceeding, frequently, two millions of pounds a day. The immediate mechanic force by which the mechanic power of the muscular system is brought into action, is generated in the spinal system, the anterior nervous ganglia of the spinal cord or axis, and appears to be either derived from a transmutation of heat into the nervous motor or excitor force; or that force and heat are correlative. A direct relation certainly exists between the two. MM. Jules, Serres, and other physicists, have demonstrated the identity of heat and mechanic force: they are mutually correlative and equivalent to each other. This fact is expressed by M. Jules in the following formula:—

One degree of heat is equivalent to 750 pound-feet. Or,
One degree of heat is the equivalent of a mechanic force that will raise 750 pounds one foot.

The same principle is equally true and applicable to animal mechanics.

In the animal mechanism, the heat, the equivalent of its mechanic nervous force, is evolved by the oxidation or slow combustion, chiefly of carbon and hydrogen, in the blood. The oxygen is introduced into the blood by the process of respiration, and the hydro-carbons and carbo-hydrates, by the food—as oils, sugar, starch, &c., digested and prepared by the functions of the alimentary canal, so as to be absorbed, and introduced into the circulatory apparatus. The amount of pure carbon that must be introduced into the blood, by the food, and oxidized, to furnish the heat correlative of the nervous mechanic force each day, in labor, is not less than from 10 to 12 ounces. In this exhibition of facts is demonstrated the close, immediate connection between different functions and actions, as respiration, digestion, absorption, circulation, oxidation, animal heat, nervous force, and mechanical actions. The working power of man is a product of the food on his dish; it comes from his meals: and so also is it with his blood, and flesh, his limbs, organs, and viscera. They are constructed of the nitrogenized organic matters of food digested in the stomach, absorbed and assimilated.

Food or aliment is the commencement of organization; it may be said, of life; for the first vital action of the germ is to absorb and assimilate nutritive matter, for the augmentation of germ material, and the formation of the germ mass, the first stage in the development of the organism; and the whole of organic or nutritive life is the repetition of its first commencing act.

FORCES, OR DYNAMICAL RELATIONS.

This word dynamics is derived from the Greek δυναμις, power, force, rule. It was confined for a long period to the science of mechanics, to designate the laws and actions of mechanical machines and movements of bodies.

It has acquired, with the progress of science, a much more extended application. It is now the equivalent or synonym of forces, and is employed to express the science of acting and moving causes, not only of solids or mechanical bodies, but of all actions and movements whose cause is unknown. In this sense it is introduced into medicine; and in physiology, is applied to designate the forces of the living organism, or causes of its actions; and in therapeutics, is used by some to express the causes of medical action as distinct from the medical substance itself. In the mechanics of the muscular system, the term is of as legitimate application as in common mechanics. The spinal nervous apparatus is a dynamical system, generating forces that excite and control muscular actions, that perform the mechanical functions of the economy.

The direct meaning of the word force, synonymous with dynamics, derived from the Latin *fortis*, is strength, power, energy. It is used for want of a more fitting word in science to express an abstract idea, a result of a mental process of reasoning. The common experience of our senses teaches us that inorganic bodies, at rest, never move unless set in motion by an impulse derived from some other body, agent, or matter. It does not move of itself. Whatever produces the motion, is regarded as the cause of the motion, and the mind infers it exerts an action indicating a force as the cause of the motion or action.

But movements and actions are observed to occur often without any known tangible or perceptible cause of the movement or action. Of this unknown cause of action and movements, the mind forms an abstract idea by a process of reasoning, as a force or unknown cause, producing actions, movements, or, in other words, phenomena. Phenomena, actions or movements, of the same natures and characters, are constantly reproduced under the same conditions. The mind infers from this circumstance the existence of constant, persistent, and special forces. The term force has no other meaning—expresses no more than an unknown cause for known or observable phenomena.

Phenomena, recognizable by our senses, and comprehensible by the intellectual faculties, are numerous, various, and different. From their resemblances, coincidences, and differences, always permanent and consistent, they are capable of being arranged into divisions, classes, orders, genera, &c.: that is, the mind arranges and classifies phenomena according to the above circumstances of agreements and dissimilarities which are observed to exist in nature.

The forces to whose action the special phenomena observed in nature are to be attributed, are divisible into two classes: the physical or general, and the organic or vital forces. The first are classed and named by physicists, as gravity, light, electricity, magnetism, and chemical affinity. These terms in reality express no more than constant modes of actions, or phenomena: characterized by Mr. Grove as "affections of matter." They are the only forces recognized by physicists. To which, it appears to me, are to be added the second class, or vital forces. They are, 1st, organic, or formative force; 2d, the spinal nervous excitor, and motor forces; and 3d, muscular contractility, or irritability.

Before proceeding further in this discussion, it will be necessary to make a short digression for the better understanding of this subject.

It is a remarkable feature of intellectual operations, that from the earliest period of knowledge, of science, and philosophy, down to our day, two distinct modes of viewing this subject, two opposite sides of this question have occupied, and been presented by, thinking and observing minds. The ideas arising from these views have lain, and yet lie, at the root of scientific principles and philosophic thought, forming two antagonist schools. They generally date from two of the eminent intellects of Grecian origin, Pythagoras, born 584 B. C., and Thales, 640 B. C. The first taught that matter was incapable of any action or movements from its innate powers. God was the power whence all natural phenomena proceeded through subordinate agents. This is the origin of the spiritual philosophy and the modern dynamic theories.

The abuses and perversions of this doctrine by the ignorant, and those incapable of enlightened and broad intellectual views, have produced ontology in science, and superstition in religion.

Thales, on the other side, regarded matter as possessed of inherent or innate forces and properties, from which all natural phenomena, and all objects, animate and inanimate, have proceeded, and continue to be produced. This is the material school, and, pushed to its extreme results, leads to atheism.

In our time, the first of these primary conflicting opinions is represented by the doctrine that matter is devoid of active forces, and that phenomena are dependent on imponderable forces acting on ponderable matter, changing, modifying its states, conditions, and forces; and are the sole causes of action or phenomena.

The second is embodied in the doctrine that matter is endowed with active forces as properties, by and through which, all the phenomena of nature, its forms, actions, motions, molecular or in masses, are accomplished. This doctrine escapes from the inevitable conclusion to which it leads—atheism—in attributing, as is done by some, the possession of these properties by matter, as endowments conferred on it by the Supreme Creator.

Modern researches have shown that the forces of nature, previously enumerated, are correlative, cannot exist independent of, and are convertible into, each other.

The conclusion from the above facts and views, is that what are termed natural or physical forces, are no more than modes of manifestation of one force, one agent. In 1836–7, I advanced this opinion, and, in addition, that the phenomena of living beings were to so great an extent identical with the ordinary phenomena of physics, that " Physiology might very properly be designated as organic physics." In 1843, Mayer, of Heilbron, promulgated the same opinion. But it was Mr. Grove, of London, who first, in a complete treatise, undertook to prove the truth of this proposition. In a 2d edition, 1850, he throws out the conjecture that the doctrine of correlation will apply in physiology; and cites muscular action and animal heat as probable instances. This very application of the doctrine I had made the year previous, 1849, to animal mechanic force as correlative of heat, in a paper read at the meeting of the American Medical Association, held in Boston.

This doctrine was announced by me as early as 1837, in a published lecture. This proposition was then laid down, "that the same causes and actions which in inorganic bodies constitute physics, in organic bodies constitute physiology, or, as it may be more aptly termed, organic physics."

The idea then broached, subsequently ripened into a complete development; and my lectures were arranged on a plan in conformity to it.

Dr. Carpenter, in the preface to the third edition of his *General and Comparative Physiology*, claims "as more particularly his own," the doctrine of the "mutual connection of the vital forces and their relation to the physical." I indulge the hope that this statement of similar views promulgated by myself eighteen years since, annually repeated and so extended as to form a full section of my course, will not be considered out of place on this occasion, or subject me to the imputation of egotism.

The doctrine of the correlation of the physical forces has been generally adopted; and consequently, if a clear insight has been obtained of the nature of any one or more of them, that of all the others must be similar or identical. Whatever theory is adopted to explain the phenomena of one must be applicable to the others.

Now, as respects two of the forces, light and heat, physicists have, without an exception at this time, embraced the dynamical or undulation hypothesis. According to this doctrine, the phenomena of light and heat are due to motion or undulatory vibrations excited in an aerial fluid existing throughout the universe, occupying the interplanetary spaces, and penetrating and existing in the interstices, and surrounding the molecules of the densest bodies, whether inorganic or organic. This fluid is named the Ether. It is mentioned by Aristotle; Newton advocated the hypothesis, and employed it in solving some of his philosophical problems; he estimated its specific gravity as 750 times less than the difference between the atmosphere and granite rock. Euler assumed that the ether is 36,000,000 times thinner, and 1,278 times more elastic than atmospheric air.

The grounds of this hypothesis are by no means vague. It is clear, without any doubt, that in vision or seeing there must exist some agent or body between the retina of the eye, the nervous sensitive tissue or membrane, and the exterior visual object. The retinal membrane is the portion of the eye that receives the direct impressions proceeding from the external body. In this impression, in reality, consist light and color. It is not a single and simple membrane, but a complex one; it is composed of thousands of minute, independent and distinct sensitive spaces, or, as they may be regarded, associated retinas. Each one of these receives a separate, distinct impression, coming from each separate distinct point of the exterior body seen, a perfect miniature mosaic picture of which is thus represented on the retina, or is, it may be said, pricked into it by the rays of light; or, more properly, the undulations of the molecules of the ether.

This body, this agent intermediate between external bodies and the retina, exists in the interior of the eye, diffused through all its tissues and interior media. It is the sole normal or physiological excitor of the special nervous sensibility of the retina, and the nervous central optical organs, provided in the order of nature, that animals may possess the function of vision. This is effected by the immediate relation this agent possesses with the nervous sensibility of the retina of the optic nerve and the optic lobes. The two must be closely related, and analogous or identical in their nature or innate constitutions.

This accumulation of scientific probabilities almost amounts to a demonstration that a body or most tenuous fluid is present between all external bodies and the retina in the eye of animals. It is not the atmosphere, for it cannot penetrate the cornea, the lens, or the humors of the eye. Its presence would be injurious to vision by disturbing the course of the rays of light.

Vision is not limited to the surface of our globe; it extends to the infinitely remote regions of space, and consequently the ether, whose systems of undulations or waves traverse those immeasurable distances, and, impinging on the retina, cause light, or vision, must fill all space.

The present philosophical hypothesis of physical or natural forces, presented in the preceding summary, in the present state of our knowledge must be accepted as the truest exposition of the causes of natural phenomena. Having it before us, we are better prepared to examine the relation in which they stand to the forces that, in the living organism of man, are the causes of its special actions and phenomena.

These forces are manifested in the organic actions of which they are the causes, and must be studied and interpreted through them. In this manner alone can their identity or diversity, their correlation or irrelevancy with the physical forces be correctly appreciated and determined.

ORGANIC FORCES.

The only forces and phenomena that can properly be named organic or vital, are such as are exclusively found in organized and living beings. Two series of phenomena alone possess this character. They are, for the first series, the production of a formless plastic matter, and the development of typical organic forms—tissues, organs, organisms—from this formless material, and their maintenance by growth and nutrition. For the second series, they are the nervous excito-motor forces, and muscular contractility. Sensibility and intelligence, or the psychological actions, are nervous phenomena, to which the term force, and the actions of force, are not applicable.

The first series is common to all organic, or living beings—vegetable and animal: the last exists exclusively in animals.

As the causes of the above phenomena present special characters that distinguish them as much from the physical forces as they are themselves distinguished from each other, I can perceive no valid reason why they should not be placed in a separate class, named organic forces, as they are most clearly the antecedents, or causes of especial organic phenomena, or actions. Guided by the light of our present philosophy, the organic or vital forces are regarded by many physiologists, among them Dr. Lehmann, the author of this work, as correlative of the common forces of the inorganic world.

I now proceed to an investigation of the phenomena characteristic and distinctive from all others, that are specially organic, that are exclusive to living beings and to animal life. The first is—

ORGANIC, FORMATIVE, OR VITAL FORCE.

This force presides over all organic beings—vegetable and animal. No organic form or action, or any phenomena of life, can have existence in its absence. It is as perfect in the lowest and simplest as in the most complex and elevated of organic beings; in the monad as in man; in the cell vegetable as the oak; in the lowest form of tissues as in the most complex and developed.

Organic force is the first cause of organic forms. Modality, or the production of organic forms from a formless, plastic fluid, or organic matter, is its distinctive characteristic. It is embodied in the germ. No living, no organic form, endowed with vital activity, ever had existence, or can exist, independent of germs. Every organic form is the realization, in an appropriate and special organic material, of an ideal model, or type, of that form.

This force is not self-acting. It is dormant like electricity, caloric, light, until excited into action. A definite temperature is an indispensable condition. In warm-blooded animals, 100° F. to 102° F. in the blood, is the normal temperature. Below this, say 96° to 97° F., germ development is imperfect, and arrested in its first stage.

ORGANIC, OR VITAL ACTION.

The result of the activity of organic force, excited by caloric, or heat, is the production of an organic action, life or formative action, summed up in the term nutrition. The nature and constituent factors of this action are now to be analyzed.

It is a compound action, composed, 1st, of the production of an immediate, or special plastic organic matter, from a crude or protoplasm; 2d, of the creation, or production of special organic forms from the organic plastic matter; 3d, of the death, or chemical disintegration of the organized substance of the interior structures, and its transformation into simpler and lower combinations, forming the matters and substances of the excretions; 4th, the moulting, desquamation, or casting off the dead and recremental material of the organic structure of the internal and external surfaces, in communication with the exterior world. At the same time, new organic forms, and organized structure are being produced.

The organic plastic matter is special for each tissue—musculin is the material for muscular tissues, neurin for nerve tissue, the various gelatiniform materials for areolar, serous, fibrous tissues, &c. Organic forms are equally various. Each tissue and each organ has its speciality of form, and arrangement of its component parts. These component parts, each having a special plasm and a distinct organization, are interwoven with the utmost intricacy, necessitating different and complicated chemical and constructive processes simultaneously occurring in the same place and same moment of time, which are utterly inexplicable and impossible as the operations of the physical forces.

The organic form produced is maintained amidst the incessant decomposition of the organic substance in which the type of form is expressed. This is the most significant and characteristic fact of the organic or life action. It individualizes and separates it from every other kind of action. All inorganic forms are maintained by the absolute repose, or equilibrium of molecular actions. The form is destroyed utterly, when molecular actions are excited.

Incessant molecular activity, and persistence of form, are the essentialities of organic, or life action. The cessation of the special molecular activity of living structure, is productive of the cessation of organic, or life action: it is death. The organic force disappears; chemical affinity, that was forced by it to effect special combinations of chemical elements, to form special plasmata, is now set free, to exert its natural tendencies, and the result is putrefaction, if the temperature be such as to excite it into a certain degree of activity.

An organic action analyzed, reduced to its component phenomena, presents evidences of the combination of the following series of actions and phenomena:—

1. Organic, or formative force, producing, creating it may be said, organic forms, or manifesting modality, stamping the form after an ideal type of tissue, or organ. 2. Chemical affinity, chained, controlled, and forced into the formation of special chemical combinations and formation of plasmata. 3. Chemical disintegration, retrograde chemical products to be eliminated, or the dead organic material desquamated, and thrown off from exterior surfaces.

This series and union of forces and actions, entering into an organic, or life action, can occur and exist only under absolute special conditions. These are, 1st, the presence of organic force embodied in a germ; 2d, a crude organic plasm; albumen in animals of the higher classes, capable of transformation into special plasmata; 3d, a definite temperature of 100° to 102° F.; 4th, oxygen, to effect, by its direct action, the chemical decompositions of the organized materials wasted in the organic actions, and indirectly accomplishing the same result by the thousand acts of oxidation occurring in the organism, generating its temperature, and maintaining the endless chemical actions required for the production of the secretions, excretions, and numerous other products of the economy.

The preservation of the above conditions of organic, or life actions, is the object of dietetics and regimen, or art of preserving health; and the investigation of those conditions, in all their varied relations, constitutes the science of hygiene. Their restoration, when in an imperfect state, or in any mode disordered so as to constitute disease, is the object of therapeutics and the practice of medicine.

NERVOUS, OR MECHANIC FORCE.

This force is wholly dissimilar, in every respect, to organic force. The character and object of this force, is to work the machinery of the organism so as to bring into operation the mechanical power of the organism required for various objects indispensable to its existence, to maintain the conditions of the organic actions, and for the purposes of animal existence in the creation. Its most perfect manifestations are in animals of the higher classes.

This nerve force is generated in the spinal cord, or axis, and the cerebral axis, medulla oblongata, crura cerebri, thalami, and corpora striata. These organs constitute the dynamic, or force generating apparatus. Mechanic nerve force is to the animal organism what steam is to the locomotive. The dynamic apparatus, or cerebro-spinal axis, is in the organism what the boiler is in the steam engine.

This statement exhibits, in strong relief, the difference between organic and nervous force. The first exhibits no mechanic power in the organism, produces no direct mechanic effect. It is limited to the molecular actions required for the production of plastic matter and organic forms.

The spinal nerve force is exclusively manifested in the mechanical movements of masses, as of the circulation of the blood, the expansion of the chest in respiration, in movements of the limbs and body in locomotion, and in the production of other mechanical effects.

Notwithstanding these wide and strongly marked differences between them, the two have been, and continue to be, confounded together as one—as identical. This error, regarding nerve force as an organizing force, as the cause of all organic phenomena, was committed by Oken, by Carus, by Klencke, by Unger, by Lamarck, Legallois, and Dutrochet, and is yet entertained by many French and German physiologists. It is advocated by a distinguished teacher in this city, who bases many of his pathological views on this hypothesis. This error arises from not analyzing the complex phenomenon of an organic action, and of not studying it in its first inception in the formation of germ matter, and development of the multiplication of the germ into the embryonic germ mass, the first stage of the animal organization; and further, the ignoring of the process of development in the seeds of plants, and of their organization. To find the truth, it is not to be sought in complicated phenomena, but in the simplest, in which its expression is clear and distinct.

Nerve force has been shown to be limited to an apparatus. Actions or phenomena requiring an organ or apparatus are, and must be, functional. Nerve force is, consequently, a function or office of the organs and apparatus on which it depends—the spinal dynamic apparatus. The apparatus itself is constructed by the formative organic actions directed and maintained by organic or vital force.

Spinal nerve force is restricted to two series of phenomena—excitation of muscular mechanical actions and of general sensibility. Organic or vital force is universal in the organism; it requires no apparatus. It is present in every act of life, in every tissue, in the simplest as in the most complex: it is active in every living organic molecule.

Spinal nerve force is composed of two distinct forces—an excitor force and a motor force. Each has a separate nervous apparatus or combination of organs for its manifestation.

Excitor Nerve Force.

The first, or excitor force, has a close affinity with sensibility; they are constantly confounded. It is an excitor of general sensibility, as well as of motor force. It is somewhat difficult to distinguish between them. Sensibility may, possibly, be no more than the mental perception and consciousness of the excited state of the excitor force, or of the afferent nerves. The excitor force, like special sensibility, is in contact with the exterior world. Impressions on the skin or mucous membranes excite it into action, as cold air, or water sprinkled on the face, recalling respiration in fainting, and worms or indigestible food in the alimentary canal, causing convulsions or spasms.

Certain irritations and impressions also of which we have no consciousness, excite its action normally, as in respiration, maintained by the unconscious presence of carbonic acid or black blood in the lungs, and abnormally by splinters lodged in fascias, causing no sensation, yet producing tetanus after the wound has healed.

It is independent of the brain or cerebrum. This is shown in complete palsy of sensation and motion, caused by injuries to the spine. The lower extremities will be drawn up violently, from tickling the soles of the feet, though the patient is unconscious either of the sensation or the movement of the limb.

The apparatus of the excitor force are the posterior ganglia of the spinal marrow or axis, of the medulla oblongata, and nerves communicating between those nerve centres and exterior and interior surfaces. These nerves have ganglia on their roots, which is a distinguishing character, though their office yet remains unknown. All impressions on, or states or conditions of surfaces are transmitted to the excitor ganglia or the posterior nerve centres of the spinal cord and medulla oblongata.

Motor Force.

The second or especial relation of motor force is with muscular contractility, and its function is to excite muscular contractions from which result mechanical effects.

The apparatus to which it belongs, and through which it acts, are the anterior ganglia or nerve centres of the spinal marrow or axis and medulla oblongata, and the nerves that place them in connection with the muscular system. These nerves have no ganglia at their roots. This force is the direct physiological excitor of muscular contractility; and, in the normal state, is the only proximate cause of muscular action.

Excitor and motor force are, in the organism, constantly associated in action. The continuous play of the respiratory muscles, of the heart, of the muscular coats of the stomach and intestines, is maintained in this manner. They are involuntary machine or automatic actions. The two forces are not identical, and often act independent of each other. Irritation, or any excited state of excitor nerves and surfaces, will cause pain without producing muscular actions or influencing motor force, as in some pure neuralgias. Sensations and muscular actions sometimes occur simultaneously, are connected, but more frequently sensations are unattended with muscular actions.

The nervous force exhibits in some of the inferior animals remarkable varieties of susceptibility to the impressions of external bodies. The Batrachians, when placed in water of the temperature of 100° to 110° F., are immediately thrown into a state of spasmodic rigidity; a tetanic state is developed, which in a short time would prove fatal. If in this state they are thrown into water of the ordinary temperature of spring water, 45° to 48° F., the spasm immediately ceases, and they resume their usual activity. In the Ophiura, or Luidia, a species of the starfish, the very reverse of what occurs in the frog is observed. If taken from sea water, and plunged into fresh water of the same temperature, they die instantly in a state of the strongest tetanic extension and rigidity.

Motor force, associated with and excited by excitor force, produces what are called reflex actions. This name, though generally employed, is objectionable, as it involves a hypothesis which has not been verified. Excito-motor actions and automatic actions are preferable, as they indicate positive phenomena.

Motor force is also excited into action by other causes, the whole forming four classes of actions.

The first is the excito-motor or automatic actions as above described, constituting involuntary actions.

The second are the excitements of the motor force by the emotions, constituting emotional actions.

The third are the excitements of the motor force by acts of the mind, attended with a consciousness of the mental action, and are called voluntary actions. By these actions is carried out some determination, or is accomplished some desire or purpose, or is fulfilled some idea.

The fourth is a new class, unknown to metaphysicians, but recognized by physiologists. Motor muscular force is often excited by a fixed, strongly impressed and vivid idea, without that active participation of the consciousness that is called volition. Hence the individual is unaware of the cause of the muscular action, and in some instances is unconscious of its occurrence.

The nervous excito-motor or mechanic force is not constant; it varies incessantly. The apparatus generating it is exhausted by prolonged muscular exertions. This state is expressed by a sense of weariness, lassitude, or fatigue, according to the degree of exhaustion induced. It is renovated by repose, from which proceed feelings of vigor and activity.

The following are the conditions indispensable to its generation and normal action :—

1. Gray neurine vesicles grouped into centres or species of ganglia in the posterior and anterior cornua of the spinal axis and in the medulla oblongata.

2. Nerves communicating between interior and exterior surfaces and the posterior ganglia of the spinal axis—afferent or excitor nerves; and nerves communicating between the anterior ganglia of the spinal axis and muscles—efferent or motor nerves.

3. Red blood corpuscles, in the proportion of 130 to 140 to 1000 of dry blood, or 510 to 520 of liquid blood.

4. A temperature of 100° F. in the blood.

The identity of electricity and nervous force is a favorite supposition with many writers at this time. The facts relied on are far from being positive. Those of Matteucci and Du Bois Raymond possess the largest amount of probability, but are not absolutely demonstrative.

Molecular action is always attended with electrical phenomena. This kind of action is a constant characteristic of vital activity: and in those tissues and organs in which molecular action is energetic, electric phenomena are the most clearly manifested. Every living organism, as a whole, and in its several structures, is an electro-genetic apparatus.

During life, the muscles, and the mucous membranes and skin, exhibit, with the galvanoscope, the most marked and highest evidences of free electricity. The nervous structure fails to affect this instrument in a decided manner, though the more delicate sensitiveness of "the prepared frog's leg" proves its existence. This fact tends rather to show a less degree of electrical development in nerve structure, corresponding with slower molecular changes of organic substance, than in muscles and mucous membranes.

Du Bois Raymond has demonstrated, by the peculiar apparatus he has constructed, and by his manipulations, that *dead* nerve structure exhibits a feeble electric current. This can scarcely be construed as an evidence that the nerve force of the living apparatus is electricity. There is also a source of fallacy in the experiment that has not been noticed. Spallanzani had observed the fact that organized structure, when dead, until putrefaction has commenced, continues to exhibit the constant phenomena of living structures, the absorption of oxygen and elimination of carbonic acid. Robin and Verdeil assert that they have verified the correctness of this observation. This chemical action must of course generate electric currents.

Although the proofs of the identity of nervous force and electricity remain as yet inconclusive, there is every reason to regard as probable a correlation between them; and that nervous force belongs to the same class; that it is, in fact, a special modification of the physical forces manifested in living organisms, and adapted to the special class of mechanical actions in them. It is ether transformed into nerve force, or this last is itself a modification of ether.

REMARKS

ON

DR. LEHMANN'S DOCTRINE OF VITAL FORCES.

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THE foregoing views respecting the forces of the organism are at variance with the doctrine of the author of this work, Dr. Lehmann. They are the opinions I formed early in my professional studies, and have been since entertained by me. The conviction of their general truth has strengthened with time and increased knowledge. The facts and arguments of Dr. Lehmann have been carefully considered and weighed, but have failed to convince me of their correctness, or to weaken confidence in my previous conclusions.

It is a fault not unfrequent with those absorbed in the pursuit of the positive sciences, and accustomed to find the objects of their researches subject to the application of fixed laws, and their difficulties solved by experimental demonstration, to expect that similar means and processes are available and applicable to all other sciences. Habituated to reach certain results in the investigations of their limited range of phenomena, they demand the same conditions in those infinitely more complicated and widely different. The confidence with which they are inspired, leads them to assume that man's intellect is the measure of the universe, and that no truth can have a depth outreaching its capacity, or is placed beyond the grasp of its logic and comprehension. The unknowable is not acknowledged, and any hypothesis is preferred to a concession of a mystery.

Yet, a moment's reflection must show, that the causes of the laws whose unerring certainty they boast, are unknown, are mysteries, and must forever remain as such. It is the error of Dr. Lehmann, and it is common to most physicists, more particularly chemists, that he views the complex phenomena of life in one aspect—in their chemical relations. The physiological, or especial organic phenomena, are entirely neglected or overruled, though the settlement of the question in discussion must depend almost exclusively on a thorough investigation, not of the mere organic substance and its nature, but of the sole material fact to be determined—the proximate cause, or origin of specialized individual organic forms—of the different organs and organisms of living beings.

The principal arguments of Dr. Lehmann are battlings with shadows. The former physiologists were generally ignorant of chemistry, and could not recognize chemical facts in the living organism. They were denied, and the matter of the animal economy was believed to be exempt from the laws of chemical affinity. All its actions were imputed to vital forces, exclusively existing in the organism. These opinions are attacked and refuted, though no longer advocated by modern physiologists.

The identity of the chemical actions of living beings and of inorganic bodies is now generally admitted. It is granted "that the same chemical laws preside over the constitution and transformations of different compounds, whether organic or inorganic." Admitting the accuracy of this proposition, it does not authorize the assertion, that "all the differences observed between these two different classes of bodies are accidental, relative, and have nothing essential." Will it be affirmed that when an unfecundated egg is placed in the conditions for incubation, and the result is its putrefaction, while, in a fecundated egg, the albuminoid contents are transformed into blood, muscles, viscera, nerves, brain, heart, vessels, and organs of sense, and it is endowed with special sensibilities, with consciousness and voluntary movements, that these two classes of phenomena are only accidental, relative, and non-essential?

It is certainly true, that chemical affinities and molecular actions are indispensable to produce the varied special proximate organic materials of the fluids, tissues, organs, and the living organism of the chick. But, without the presence of the germ, a fact neglected by Dr. Lehmann, this extraordinary play of specific chemical affinities, and specialities of chemical actions, and the development of some hundred organic forms, included in the living being, from the formless organic matter, could not have occurred. Certainly, here are displayed, in the two classes of bodies—inorganic and organic—differences that are not accidental, or relative, and that are essential.

The same general facts are observed in the germination of seeds. If the germ cell at the hilum of a seed be artificially ruptured, and it be placed in the same circumstances of germination with a perfect seed, the first will rot, while, in the other, are formed dextrin, grape sugar, cellulose, and albuminoid compounds; and these organic matters are developed into the tissues and organs of a perfect plant.

In these, which are but single series of organic phenomena, the most absolutely marked and undeniable differences are to be observed between the two classes of bodies: it is impossible to regard them as "accidental, relative, and non-essential."

These phenomena have occurred in living beings with absolute constancy, in all generations of animals and vegetables, and are so completely under the control of positive law, that any one, or all of them, can be predicated and foretold with as much certainty as any chemical or physical action.

Another argument urged as conclusive is the following: "We should not lay down a new force, a general specific cause, until we have eliminated all other possibly operative forces from the group of phenomena in question. A proof of the existence of a purely vital force is hence only to be obtained by an exclusion of every physical force." A full assent is given to the conditions of the argument; and it is affirmed most positively that the only phenomena—the exclusive attributes of a vital or organic force—the creation from a liquid formless plasm of typical organic forms, and organic instruments to execute physical, chemical, mechanical, and dynamical actions, in the living organism, which are operative only during life, cannot be explained by any one, or all of the physical forces combined. They are absolutely excluded. Let the subject be expressed in special terms, and it is affirmed that neither heat, nor light, nor electricity, nor magnetism, nor gravity, can construct an eye, can form a retina, heterogeneous in its organic materials, complicated in the distinct organized anatomical elements of its structure, and endowed with a special sensibility—light and colors—manifested normally only when excited by a special external agent, the luminiferous ether. Nor can they generate the black pigment cells of the choroid coat, for the express purpose of suppressing the luminous rays, which have accomplished their impression, without which there can be no distinct vision; nor cause the formation anterior to the retina of the vitreous humor and the crystalline lens, admirably adapted in form, shape, and density, to refract the rays of light into a focus, the distance from the retina calculated so truly, as to subtend on it a visual focus, in which is a perfect representation of external bodies. The formation of this organic optical apparatus, constructed in the fœtus included in the ovum or uterus, excluded from the direct operations of the physical forces except heat, it is affirmed, is absolutely inexplicable by the physical forces, or by any known physical process or actions.

The insuperable difficulties presented by these facts, it is sought to evade by assuming that, as the causes of physical actions are unknown, and that new physical phenomena may be discovered, a resort to a new force is useless and unscientific. But it will not be pretended that the causes of physical actions will ever be better known than they are at present; and, whatever new physical actions may be discovered, they cannot differ in their nature from those of the present known physical actions. They will be unable to furnish any new light to solve the nature and origin of phenomena that reach far beyond the range of the physical forces; to which physical forces and actions are accessories, but cannot hold the relation of productive causes.

From the admission by Dr. Lehmann, in his argument "that a new force may be assumed in science, whenever groups of phenomena are inexplicable by any known forces," the assumption of an organic or vital force, as distinct from physical forces, and as presiding over the developments of the organic forms of living beings, is an authorized and legitimate deduction.

A third argument, and the last that will be noticed as having a bearing on the question is, "that the idea of a vital force is illogical; for a force is merely the abbreviated expression of a law from which the causal connection of certain phenomena may be deduced; and that a vital force corresponds to no law."

This statement proves that Dr. Lehmann has not investigated the physiological facts of embryology or organic development, or he could not have so broadly asserted that the vital or organic force corresponds to no law, and is not a necessary cause of multitudinous consequent phenomena.

So far is this statement from being correct, it may confidently be asserted that the evidences of law, of causal connection and dependence are as strong, as palpable, in the phenomena, the direct results of organic or vital force—those of organization—as are to be found in any of the physical forces. A few facts will prove this position. Prevent the spermatozoon from reaching the egg, no monadiform germ cell, the primary form of all animals, is produced. Let this germ cell be artificially broken or injured, and no blastoderm will be formed; injure the blastoderm, and either no embryon and chick will be developed, or this last will be imperfect.

Here are law and causal dependence and connection. Professor Owen, in his *Hunterian Lectures* (ed. 1855), has demonstrated that "every animal, in the course of its development, represents some of the permanent forms of animals inferior to itself, but it does not successively repeat them all, nor acquire the organization of any of the inferior forms which it transitorily typifies. One organic form, the microscopic infusorial monad, is either permanently or transitorily represented throughout the animal kingdom. Other forms are represented less exclusively in the development of the animal kingdom, and may be regarded as secondary forms. These are the polype, the worm, the tunicary, and the lamprey. They are secondary in relation to the animal kingdom at large, but are primary in respect to the primary divisions or provinces."

In the above statement is demonstrated the subordination to a law, to a great overruling force in the organic world, on the presence and action of which depend the type of organic forms, and the order of development of animal organisms.

In the immutable harmony of organic nature, in the unchangeable characters that mark the distinction of species, genera, families, orders, and classes, are displayed unmistakable signs of the operation of laws, of causal connections and dependency. Cuvier demonstrated the persistence, as he believed the permanency of species, and certainly the permanency of genera and families, by his anatomical researches. Gœthe, as it were by a philosophical inspiration, had previously conceived and evolved the idea of the "Unity of Organization." In 1790, he enunciated the generalization, that "all the parts of an animal, taken together or separately, ought to be found in all animals." This deep-reaching thought of the philosopher anteceded the empirical demonstration of the anatomist. Oken and Geoffroy St. Hilaire struck on the same vein of thought, and by their researches and investigations established its truth, and made it the crowning fact of organic science. This widest and boldest generalization in natural science is, in the organic world, what Newton's law of gravity is in the universe.

In the infinitude of the phenomena and forms and beings that compose the organic world, the universality and dependence of causal connections and special law, and in the evidences of its ever-during beauty, order, and harmony that pervade organic nature, is demonstrated the supremacy of a dominant force, far transcending the physical forces in the higher nature of its productions, and more exalted character of its powers, influences, and relations. In its operations it appears as a ray emanating from the divine intelligence, stamping on each created living being types of organic structures, a revelation in material forms of the creative ideas of the Eternal Artificer of the universe. That force cannot be more appropriately expressed, than as the Organic or Vital force. This conclusion will no doubt be condemned as unscientific by physicists generally. In the present state of knowledge, the inexplicable and inconceivable in the physical, and still more in the physiological sciences, constantly cross our path, and arrest our investigations. Knowledge, science, philosophy, have their *ultima thule*, beyond which lie the vague and dreamy realms of conjecture.

The sciences are the facts or phenomena discovered in the order of their connection, and interpreted by man's intelligence, such as they exist in the world exterior to itself. Indissolubly connected, they form the circumference of a vast circle, each advancing as it progresses, and is developed like radii, and meet in one common centre. That centre is the incomprehensible, the infinite; it is the first Eternal Cause—the creative God!

It is always to me an assurance that the line of inquiry pursued is the true one, when its direction tends obviously to this termination. Whenever investigation is turned from this course, it is invariably lost in misty and groundless hypotheses.

In dissenting from the author's views of organic or life force, there has been no purpose of disrespect, or intention to undervalue his knowledge and the authority of his opinions on the special branch he has cultivated. It has been rendered necessary by the manner in which the subject has been treated. Almost exclusively physiological, it has been handled as a chemical question. All that has been urged by the author as to the extent, variety, and importance of the chemical actions and influences of chemical laws in the living organism is perfectly just; but to force chemical affinity and its laws from their appointed ordinances in nature, is not correctly scientific, and leads to serious errors and misconceptions. Yet such a perversion, it strikes us, takes place when physics and chemistry are summoned to explain the origin and the permanent constitution of the typical forms of organization, differing so widely from the molecular processes and actions, exclusively the results of their special activity and energies in the plan of creation.

In adopting the handbook of Dr. Lehmann as a manual of organic chemistry for the use of the students of the University, and in recommending his original work of PHYSIOLOGICAL CHEMISTRY for their more mature studies, the high value of his researches and the great weight of his authority, in that important department of medical science, are fully recognized.

HANDBOOK

OF

PHYSIOLOGICAL CHEMISTRY.

GENERAL OBSERVATIONS.

By Physiological Chemistry we understand the science of the chemical processes in the living organism: this science will hence have to deal not only with the chemical principles of living organisms, but mainly with the mutual reaction of the chemical elements and the influence of the external world on the same in the course of the individual life processes.

We consider so-called Pathological Chemistry, not as a separate science, but as an integral part of Physiological Chemistry, because no sharp boundary can be drawn between the two, and because, further, the laws which find their application in the illustration of life-phenomena are the same in physiological and pathological circumstances, and the difference of the phenomena depends entirely on the difference of the external conditions.

Physiological Animal Chemistry and Physiological Vegetable Chemistry must, on the contrary, be strictly separated from each other, although both sciences have many points of contact with each other: as the objects, so also the most essential chemical processes whose exploration is the subject of inquiry, are different throughout. The closer relations, in which Animal Life stands to Vegetable, form a separate chapter of Chemical Zoophysiology.

Physiological Animal Chemistry divides itself into three sections: the science of the chemical substrata, the science of the animal fluids and tissues, and the science of the zoochemical processes. This is no arbitrary systematic division: it follows of necessity from the nature of the subject.

The first part, in some measure the basis of the whole of Physiological Chemistry, the science of the chemical substrata of the animal frame, is called, in the narrower sense of the term, Zoochemistry. We cannot understand the chemistry of the metamorphosis of animal tissue in all its forms, if we do not know exactly the substances which play their parts in the animal body, *i. e.* both its actual constituents, and those substances which, adduced from without, come into reciprocal action with the former.

For a successful treatment of zoochemistry two points of observation must be maintained, viz: the chemical and the physiological. Without the most exact knowledge of all the chemical relations of a substance, a judgment of its physiological importance is impossible: but the bare announcement of all the facts derived from pure chemistry, which the individual substances accidentally present in animal bodies exhibit, is still not zoochemistry; for the most important point of observation, the physiological, is wanting. Zoochemistry should not be a compendium of facts and theories amassed from pure chemistry; these must be taken, on the contrary, as fully known beforehand, when the question should be as to their physiological relation. We therefore, in what follows, pass over entirely that part of zoochemistry which would be nothing more than a limited excerpt from Organic Chemistry; for not only those substances must be known which are accidentally constituents of the animal organism for the study of zoochemistry, but it demands, at the same time, a thorough acquaintance with the whole of theoretical chemistry.

The physiological point of observation, which we must maintain in zoochemistry, consists only in the relations in which each individual substratum stands to the other constituents of the animal organism during life: according to these we are to determine the value of the individual to the whole, that is, its physiological function. Our judgment is to be guided in this respect by the investigation of the mode of occurrence, origin, and destruction of each individual zoochemical substance.

By the second section of Physiological Chemistry, *i. e.* by the science of the Animal Fluids and Tissues (Phlegmatochemistry and Histochemistry), we obtain already data which afford us a deeper insight into the movements of animal matter: for we see physiological processes taking their course immediately in the animal fluids and tissues. Both of these, tissues and fluids, are as well factors as products of the changes of animal matter. Their investigation is, however, accompanied with much greater difficulties than that of the zoochemical substrata. One of the most important difficulties is, that here we generally have to do with complicated mechanical mixtures whose separation lies often beyond the limits of possibility. In the tissues, different organic elements are stored up together: hence nowhere more than here is there necessity for a *microscopico-mechanical analysis;* but in the fluids, and especially in the most important of them, the blood, we find morphotic constituents, not mechanically separable, the microscopical investigation of which must precede all further research. The determination of the chemical substances which belong to these morphotic elements, and of those which are only dissolved in the fluid surrounding them, is among the most difficult tasks of zoochemical analysis: and yet this circumstance is of the greatest importance in the physiological determination of the results of chemical research. Without a knowledge of the morphotic constitution of the blood, without an insight into the division of its chemical constituents into cells and *liquor sanguinis*, we would have only very partial grounds for the construction of a physiology of the blood.

When we have investigated on all sides the physiological and chemical relations of the fluids and tissues in the same manner as in the simpler substrata of the animal body, a point must next occupy us which is of the highest importance for physiology. This point consists in the *quantitative relations of the formation and secretion* of the objects in question. It is a maxim which holds good in all natural sciences, that only through the establishment of certain numerical relations, can a theory attain its full scientific worth, and authorize more general views. It is self-evident that we must have investigated the amount of the individual factors of animal tissue-metamorphosis, before we could allow ourselves a decided opinion on their activity, and the part performed by them in the general life-functions. While chemical and physiological facts give us so many conclusions on the function of this or that animal fluid or tissue, it is by ascertaining these amounts that we obtain not only a measure, but also the most secure position for judging, of the physiological importance of the object in question.

The physiological function of an animal fluid or tissue is, however, exactly equal to its chemical constitution, just as the physiological importance of each individual chemical element is entirely dependent on its chemical quality. On this account, the immediate relations which exist between chemistry and physiological function must be more closely considered in the physiologico-chemical science of the fluids and tissues; while there must remain for chemical physiology proper (the third part of Physiological Chemistry) to pursue the movements of animal matters as a whole as well as in all their closer and more distant relations to each other and to the general life-functions. By the consideration of the physiological value of each fluid and tissue, which rests entirely on its chemical qualification, we are then only collecting the stones for founding the physiology of the animal tissue-metamorphosis.

The third division of Physiological Chemistry embraces the science of the Zoochemical Processes, i. e. *the chemistry of metamorphosis of tissue, of nutrition and secretion.* In the establishment of these relations consists the highest task of our science; here the causative connection of all the chemical manifestations accompanying life is investigated, and the necessity of the consequences presented in the combination of all the chemical phenomena of life. On this field of our science we dare not content ourselves, for the attainment of this object, with parallelizing chemical character and function as in the science of the fluids; it is necessary here to take into account general physiological relations.

When we cannot observe the inner mechanism of a great organic whole, we are accustomed, by establishing certain numerical relations, to make for ourselves a safer basis for further investigations; hence it is the earliest and still the safest way which has been devised to establish a physiology of the animal tissue-metamorphosis, by investigating the matters taken in and given out by the organism, the quantities of the individual secretions and their relations to each other, the quantitative partition of each of the separate elements, and their distribution in certain proportions in different fluids, to establish exact numerical values, which form in a manner the solid framework within which the results of further investigations prosecuted in other ways may be registered. These are the *statistics of the metamorphosis of animal tissue.* They afford us *absolute proofs* of many physiological propositions, by showing their necessity; but since they lead only to absolute assertions, we only learn by them that the facts are so, and not otherwise, but not why they are so—*i. e.* we obtain by the statistical method no deeper insight into the closer connection of the facts established by it.

Another way to the same end is the *comparative analytical* or *chemico-experimental* method; this consists in an imitation of animal chemistry out of the organism, in a comparison of certain organico-chemical processes with apparently analogous zoochemical processes. The idea of comparing the processes of fermentation and putrefaction with the phenomena of life, has always guided the researches of physiologists. Later times have comprehended this idea to a greater extent. In the degree that the views of those chemical phenomena have been generalized, have we succeeded in attempting a more useful application of them to the vital processes. Certain chemical processes, which form a great series of consecutive phenomena, show undeniable resemblances to the course of certain chemical processes in the living body, so that we may hold ourselves justified in assuming the same chain of causes in the corresponding life-processes. It follows, hence, that the conclusions to which this method leads are founded upon analogy.

Owing to the imperfection of the argument from analogy, it becomes us here especially to avoid the errors into which Physiology has already often fallen in some of its departments by the misuse of this logical form; so much the more care is necessary, as this method has hitherto been the most productive for Physiological Chemistry, and as, on the other hand, it has led to many crude chemical and entirely erroneous views.

The third method of investigation accessible to us is the physiologico-experimental. The theatre of actual physiological experiments is the living body itself; it is of great use to make its vital actions appreciable by our senses under circumstances which at the same time allow of an opinion as to their causative connection. However decisive conclusions this experience of the most direct observation promises to science, and in part really performs, it has as yet done least among the modes of investigation adduced. The great pliancy which life phenomena are capable of, prevents in many cases the communication of a *categorical answer* by nature, to whom in physiological experiments we prefer to propose a *disjunctive case* for decision, a "whether—or" as a question.

Physiological Chemistry is generally confined to those processes in the living body which belong to the so called *vegetative sphere*, and in fact those parts especially of Physiology demand elucidation from it which concern the processes of nutrition and secretion; but its realm is far more extensive; for in all the processes of life, in all animal actions, chemical affinity participates simultaneously with other forces. That, parallel to the activity of the muscles, chemical processes take their course, no one doubts; that the nervous system could display its activity without simultaneous chemical action, is not to be believed; in short, *no function, no process, no phenomenon* occurs in living bodies *without chemical force as the cause or means;* hence, e. g. *every disease must be accompanied by certain chemical alterations.*

As in the living organism no force exclusive of this, *i. e.* no so-called vital force is to be proved, all animal phenomena must be referred to fixed physical and chemical laws; the investigator of nature will recognize in these only the explanations of life phenomena. The time will come, and is no longer distant, when the entire physiology of animal life will be resolved into Physiological Physics and Physiological Chemistry.

ZOOCHEMISTRY.

ORGANIC SUBSTRATA OF THE ANIMAL ORGANISM.

It is a proposition fully confirmed by the later investigations of theoretical chemistry, that no actual difference exists between organic and inorganic bodies, and that all the differences which were formerly presented as actual between the two classes of bodies, are only accidental peculiarities, limited by no other laws than such as have their force in inorganic chemistry. Those differences which in fact crowd upon us in comparing organic with inorganic bodies in no small number and very decided manner, are then not based upon forces different in principle, or (as many philosophers believed) in a peculiar element, a so-called *organo-genium*, but arise from the multiplicity of forms often passing into each other, and correspond to the more prominent extremes of series of qualities frequently intersecting each other.

In considering the differences of chemical substances, the unalterable law must be remembered that the peculiar qualities of substances are not irrelative aggregates of characteristics, but that these latter stand in the most intimate relations to each other, as do the angles and edges of a crystal. So, *e. g.*, no one doubts that the numerous tourmalines, which show so great resemblance not only in their crystalline forms but in their hardness, &c., notwithstanding the difference of their components, are yet associated by a common bond which gives rise to their integrating properties. By ascertaining the mutual relations of the actual qualities of a substance, we obtain as the idea of it an exact index, which is not the sum of loosely connected *characteristics*, but rather the product of its closest related *properties*. We must certainly, in pure chemistry, as yet content ourselves with the description of radicals by simply recounting their characteristics: for unfortunately we are still far from knowing the relations of the individual qualities of a body to each other, so that we can deduce one property from all the rest. Later chemistry has put it in evidence, however, that the properties of chemical radicals do stand in such intimate relations to each other, and that we shall soon no longer have to satisfy ourselves with barely recounting their characteristics, but shall reach, instead, clear, distinct conceptions of the world of chemical bodies. Of how many radicals, which have been hardly seen or formed once, can the properties and their intimate composition be described? How many otherwise isolated chemical facts can now be held together by a simple leading idea: thus the introduction of the idea of homology has opened at once a general survey of the relations which exist in a very striking manner between a certain mode of composition and particular characteristic properties of a large series of chemical substances. We need only refer to the volatile organic acids, to the varieties of ethers, or to the ammoniacal alkaloids to prove that a logical index has already been obtained for many substances.

It is this intimate and peculiar connection of all their properties which imparts to the different elements forming the substrata of the animal frame their *physiological* as well as their chemical character. It is the unity of the material relations which occasions the entire behavior of a substance towards all heterogeneous substances and physical influences, as well as the manner of its participation in the chemical processes of life. Since pure chemistry has shown us that the laws which govern the combination of different atoms in stones and rocks are no other than those through which the existence of the complex atoms of animal and vegetable substances are governed, the forces also (to which they are subject in the animal organism) should lead under similar conditions to analogous consequences corresponding to the chemical compounds. The essential character of a substance remains then the same whether it be subjected to the influences of atmospheric forces, or the different chemical operations of our laboratories, or the peculiar conditions of life-movements. No element is enchanted in the animal frame: its relation in the sphere of life remains ever coincident with its chemical quality. The whole of Zoochemistry affords empirical proof of the justice of this proposition; for we never find that substances chemically entirely different have similar physiological functions, or, on the other hand, that substances of similar physiological *value*, are widely separated according to chemical principles. Hence it is an established proposition that the *physiological importance of a body is dependent entirely on its chemical constitution.* Hence we can follow in zoochemistry no other system or mode of division than a chemical one; for the latter must at the same time take account of physiology, and hence will always be a physiological one also.

But, unfortunately, we possess no system in pure chemistry which corresponds with all the demands of science; for although the recent brilliant progress of chemistry has succeeded in presenting certain groups or series of bodies which possess certain concordant tendencies, certain common characters, certain fixed definitions, yet there are a great number of substances, more or less closely investigated, which cannot be classed in any of the systems yet formed, and hence escape a general view. Unhappily, here belong many of the substances most important in zoochemistry—we need only name the so-called protein bodies. Our inability to embody these and similar substances in a scientific, systematic classification, depends less on the deficiency of the present system than on our still very unsatisfactory knowledge of such substances. We must, hence, content ourselves with arranging them according to their more palpable physical and chemical properties, without possessing a fixed scientific basis therefor. Where, then, the chemical basis fails us, the analogous physiological importance of such substances may sometimes guide us.

In choosing among the systems now used in theoretical chemistry one which deserves to be adopted for a zoochemistry, that will be the best by which, with least violence, a general view can be obtained of the numerous substances which play a more or less important part in the animal organism.

There are four hypotheses which have obtained great importance in modern chemistry, and have been used as principles of classification; these are the hypotheses of radicals, substitution, pairing and homology.

In the endeavor to discover proximate elements in organic bodies, the scarce expected result was reached that, in organic substances, compound bodies exist, which, like inorganic elements, form integral constituents of certain series of combinations, partly with inorganic elements, partly with similar organic compounds. These were called *organic radicals;* they are composite elements which are capable of uniting with inorganic or other organic elements, and take the place of true elements in many combinations. Like the elements of inorganic chemistry, the compound radicals may be divided into such as correspond to hydrogen or the metals, and such as more resemble the non-metallic elements; but as no well defined boundary can be drawn between these, so also the easiest transition takes place from one to the other class of radicals. The organic metals are almost entirely carbo-hydrogens, of which many are multiples of each other; like the true metals, these unite with oxygen to form basic bodies; like them, they enter into neutral combinations with chlorine, bromine, iodine, &c.; and lastly, some of them can combine, as it is known the metals do, with hydrogen to form hydrurets; *e. g.* marsh gas = $C_2 H_4$ is regarded as the hydruret of methyl = $C_2 H_3 . H$; for more than one fact proves that the fourth atom of hydrogen stands in that gas in a different relation to the whole compound from that of the other three atoms of hydrogen.

Such oxidated carbo-hydrogens as benzoyl ($C_{14} H_5 O_2$), acetyl ($C_4 H_3 O_2$), salicyl ($C_{14} H_5 O_4$), &c., are commonly regarded as the radicals corresponding to the non-metallic elements; here also we may safely place cyanogen, which confessedly presents the most decided analogies with the chlorine group.

These radicals form with oxygen those numerous organic acids with 3 and 5 atoms of oxygen; they also unite with hydrogen, like sulphur, chlorine, &c.; for instance, hydrurets of benzoyl and salicyl; aldehyde ($C_4 H_4 O_2$) is probably the hydruret of acetyl = $C_4 H_3 O_2 . H$.

Another theory, which has been established by numerous researches in modern chemistry, viz: that of *substitution*, has given us a deeper insight into the intimate constitution of many bodies. The unexpected fact has presented itself that, in very many organic bodies, certain atoms of hydrogen may be replaced by chlorine, bromine, iodine, or peroxide of nitrogen, without destroying the original compound atom, or altering materially the physical and chemical properties of the substance. Thus, *e. g.*, in the organic bases, certain atoms of hydrogen may be substituted by those elements, or by peroxide of nitrogen, without their wholly losing their power to unite with acids. By this, as a general rule, we can judge of the influence which a certain number of the atoms have on the quality of the type of some compound atoms.

Not less fruitful has been a third mode of observing the constitution of organic substances, viz: the so-called *pairing*, or *conjugation* of radicals, by virtue of which many substances, contrary to the ordinary theory of binary combination, can so unite with each other that the one substance, be it acid or base, loses nothing of its capacity for saturation, while the other body, called the pairling, or copula, attached to it in a certain manner, accompanies it in all its combinations with acids or bases. The pairlings are hence not to be separated from the acids or bases belonging to them, by single or double affinity. At first only those compound atoms were considered as paired, in which an organic acid was combined with an organic aggregate molecule, such as sugar, glycin, &c. But latterly the theory of pairing [or of conjugate radicals] has been extended in favor of a theory of the organic acids with three atoms of oxygen; so that an element, as for instance carbon, may pair itself with an organic radical, a carbohydrogen, a view for which there are several weighty reasons. That elements can actually unite with carbohydrogens to form bodies which have great affinity for oxygen, and, combined with it, form acids, was proved by the long-known kakodyl $(C_2\ H_2)_2{}^\frown As$, stibethyl $(C_4\ H_5)_2{}^\frown Sb$, &c. It was then not inappropriate to regard bodies as paired of methyl, ethyl, phenyl, &c., and a double atom of carbon, which then would form the well-known acids, acetic acid $= (C_2\ H_3)^\frown C_2 . O_3$, metacetonic acid $= (C_4\ H_5)^\frown C_2 . O_3$, benzoic acid $= (C_{12}\ H_5)^\frown C_2 . O_3$. Then it was found that the combinations of such radicals with cyanogen, by treatment with alkalies and with the decomposition of water, yielded those acids and ammonia, *e. g.* cyanide of ethyl gave, on being boiled with potash ley, ammonia and metacetonic acid $(C_4\ H_5 . C_2\ N + 3HO = H_3\ N + C_4\ H_5 .{}^\frown C_2 .\ O_3)$: according to this, the 2 atoms of carbon appear not to belong to the radicals of the acids, and hence the hypothesis of a pairing of the radicals with 2 atoms of carbon is not inapposite. This theory affords at least the great practical advantage, that in most organic bodies, whether basic, neutral, or acid, we can recognize these carbohydrogens as elements, and thus obtain a readier survey of a great realm of organic chemistry.

Probably the recognition of the so-called *homology* of substances has had the most powerful influence in placing organic chemistry on a philosophical basis, and establishing a rational system for it. By homologous bodies are understood such as resemble each other closely in composition and properties, and differ from each other by $(2CH)n$. If some of these homologous bodies were early classed together on account of the similarity of their properties, yet others are thus recognized as belonging together, which previously no one would have ventured so to arrange. Who would previously have believed, *e. g.*, that formic acid $= C_2 H O_3 . HO$, and margaric acid $= C_{34} H_{33} O_3 . HO$, were different members of the same series? And yet no one now doubts that these acids, with their numerous intermediate members, belong together; for it is not only this similarity in their composition which causes us to regard them as members of a class, but their products of decomposition, analogous throughout, their modes of combination, their similar relations to certain basic oxides of carbohydrogens (the so-called ethers), almost force us to look upon them as one family. We obtain an advantage by forming series of such homologous bodies, not only as regards system, but also in the theoretical consideration of such substances: for we thus approach closely our object, to present definite ideas of these substances, to establish certain formulas, from which the majority of their physical and chemical properties may be calculated, as any number of given cases from a mathematical formula. Thus, we can say that in substances of the composition $(C_2 H_2)_n . O_4$, or $C_{2n} H_{2n-1} . O_3 . HO$, their consistency, their boiling point, the density of their vapor, increases with the number of carbohydrogen atoms, while their solubility, their reaction on vegetable colors, their fluidity, stand in inverse ratio to their atomic weight. Under similar circumstances, these bodies form products of decomposition, which are again mutually homologous.

In organic acids we have been able to establish thus far five series of such homologous substances, viz: besides the formic acid series, the succinic acid series $= C_{2n} H_{2n-2} . O_3 . HO$, the oleic acid series $= C_{2n} H_{2n-3} . O_3 . HO$, that of benzoic acid $= C_{2n} H_{2n-9} . O_3 . HO$, and that of lactic acid $= C_{2n} H_{2n-1} . O_5 . HO$.

We have lately arrived at a view of the intimate constitution of many bodies, principally in consequence of the more exact investigation of the organic nitrogenised bases, the so-called alkaloids—a view which is in general based upon the four chemical hypotheses above explained, but which does not coincide with their further development into theories. It has been established beyond a question by the most direct observations, that in certain bodies, and especially in ammonia $(H_3 N)$ and oxide of ammonium $(H_4 N . O)$, not only one, but several, indeed all the atoms of hydrogen may be replaced by the carbohydrogens, which we have regarded as the metallic elements of organic chemistry. For the sake of illustration, anilin may be adduced as an example; this is ammonia in which 1 atom of hydrogen is replaced by phenyl $= (C_{12} H_5) . H . H . N$; a second atom of hydrogen of the ammonia may be replaced by methyl, ethyl, &c.—ethylanilin = $(C_{12} H_5) . (C_4 H_5) . H . N$; still a third may be replaced by methyl, amyl, &c., *e. g.* methyl-ethyl-anilin = $(C_{12} H_5) . (C_4 H_5) . (C_2 H_3) . N$. In the oxide of ammonium all the four atoms of hydrogen may be replaced by four atoms of the same or different radicals, as in the oxide of methyl-ethyl-amylo-phenyl-ammonium = $C_2 H_3 . C_4 H_5 . C_{10} H_{11} . C_{12} H_5 . N . O$. By the establishment of this fact, all previous theories underwent essential modifications; the radicals do something more here than form with oxygen and other elements acids and bases, and then exhibit salt-like combinations with each other. Substitution takes place here to the fullest extent, but not in the former sense, when hydrogen atoms were replaced only by negative elements or radicals, and when substitution could not be carried back to such simple substances as ammonia and water. Especially the idea of pairing (unless it be taken in a very wide sense) finds no application in these circumstances, for those alkaloids, *e. g.*, arise not by a pairing of ammonia with those radicals, but the latter serve rather for the completion of the single atoms of hydrogen in the ammonia.

All the volatile alkaloids, then, are to be regarded as ammonias, in which one or more atoms of hydrogen are replaced by carbohydrogens; in most of the alkaloids containing oxygen, as also in the so-called amides, one or more atoms of hydrogen are replaced by radicals containing oxygen; and thus we possess a principle of classification for the great majority of nitrogenised bodies, according to which a number of homologous series may be established.

While, according to this view, many nitrogenised bodies, and indeed those best known, are formed after the type of ammonia, two other great classes of organic bodies may in like manner be conceived as formed after the type of water; for if we consider the hydrogen in water to be replaced by the organic elements, methyl, amyl, phenyl, &c., we obtain the non-nitrogenised bases of organic chemistry, the so-called ethers, *e. g.*, HO corresponding to $(C_4 H_5) . O$. If, on the other hand, the hydrogen be displaced by radicals containing oxygen, organic acids arise, *e. g.*, HO, corresponding to $(C_{14} H_5 O_2) . O$. According to this mode of observation, the idea of pairing, which we made use of above to unfold the inner constitution of the acids, must be laid aside—the internal constitution of the oxygen-containing radicals would then remain to be further developed.

These are the most important points of observation from which theoretical chemistry has hitherto been investigated, and which afford the only starting points for a rational classification of organic bodies, and especially of zoochemical substances. Although zoochemistry neither can, nor dare get rid of the views which are of force in theoretical chemistry, it does not belong to its province to enter into a closer discussion of clashing opinions; it has in general to hold to the actual and to receive the theoretical so far as it conforms closely to established facts. The simplest and safest way to classify zoochemical bodies, with reference at the same time to their physiological importance, will be to consider certain series of bodies together, whether they be really homologous or only generally very similar. But in zoochemistry, a number of bodies press upon us which cannot readily be grouped from one or other point of view; these can only be placed together according to accidental resemblances; yet the time is perhaps no longer distant when even the protein bodies shall be classed in a scientifically arranged group.

ORGANIC NON-NITROGENISED ACIDS.

FAT ACIDS = $C_{2n} H_{2n-1} O_3 . HO$.

Formic acid	$= C_2 H O_3 . HO$.
Acetic acid	$= C_4 H_3 O_3 . HO$.
Metacetonic acid	$= C_6 H_5 O_3 . HO$.
Butyric acid	$= C_8 H_7 O_3 . HO$.
Valerianic acid	$= C_{10} H_9 O_3 . HO$.
Caproic acid	$= C_{12} H_{11} O_3 . HO$.
Oenanthic acid	$= C_{14} H_{13} O_3 . HO$.
Caprylic acid	$= C_{16} H_{15} O_3 . HO$.
Pelargonic acid	$= C_{18} H_{17} O_3 . HO$.
Capric acid	$= C_{20} H_{19} O_3 . HO$.
Magaritic acid	$= C_{22} H_{21} O_3 . HO$.
Laurostearic acid	$= C_{24} H_{23} O_3 . HO$.
Cocinic acid	$= C_{26} H_{25} O_3 . HO$.
Myristic acid	$= C_{28} H_{27} O_3 . HO$.
Cetic acid	$= C_{30} H_{29} O_3 . HO$.

Palmitic acid	$= C_{32} H_{31} O_3 . HO.$
Margaric acid	$= C_{34} H_{33} O_3 . HO.$
Stearic acid	$= C_{36} H_{35} O_3 . HO.$
Cerotic acid	$= C_{54} H_{53} O_3 . HO.$
Melissic acid	$= C_{60} H_{59} O_3 . HO.$

The two extremes of this group of acids show in many respects such striking physical and chemical differences that their physiological value should, accordingly, be very different; hence we divide this series in zoochemistry, as in general chemistry, into two groups; we limit the first somewhat arbitrarily at capric acid, and call those previously mentioned, *volatile fat acids;* they are fluid, or melt, at least, below 86° F., have a strong odor, can be distilled without change, are more or less soluble in water, of strongly acid reaction; while the members of the other group are solid or buttery, melt above 86°, are with difficulty distilled (in an atmosphere of carbonic acid), entirely insoluble in water, and act but slightly on vegetable colors.

Volatile Fat Acids.

The combinations and products of decomposition of the volatile fat acids have generally been very carefully investigated; we here adduce only the following, in regard to these relations, from pure chemistry; the salts of the volatile fat acids are for the greater part soluble in water; they are harder of solution, as the atomic weight of the acid in question rises; and hence the salts of capric acid are the least soluble. The boiling point of these acids rises in an ascending series, about 34.2° F. for each acid; *i. e.* for each $C_2 H_2$.

Of many of the acids there are lower stages of oxidation, which have been called aldehyds; thus, the ordinary aldehyd of acetic acid $= C_4 H_3 O . HO$, that of metacetonic acid $= C_6 H_5 O . HO$, &c. An intermediate stage of oxidation between the acid and the aldehyd, is only known of acetic acid, the so-called acetous acid $= (C_4 H_3 O_2 . HO)$. The aldehyds are liquid, volatile, and easily oxidized.

Bodies isomeric with the aldehyds are formed by dry distillation of the salts, especially the barytic salts, of these acids, *e. g.* butyral $= C_8 H_8 O_2$, valeral $= C_{10} H_{10} O_2$, oily, volatile fluids, of very penetrating odor, less easily oxidized than the aldehyds.

Another species of very volatile, colorless, highly inflammable fluids (the cetones), is formed by dry distillation of the alkaline salts of these acids; *e. g.* butyrone = $C_7 H_7 O$. ($KO, C_8 H_7 O_3 = KO, CO_2 + C_7 H_7 O$).

As in most organic bodies, one or more atoms of hydrogen may be replaced in these acids by chlorine, bromine, or iodine, *e. g.* in butyric acid, $C_8 (H_5 Cl_2) O_3$, and $C_8 (H_3 Cl_4) O_3$, &c.

All the acids of this group are capable of forming so-called *amides;* these result from treating the salts of these acids and the oxide of ethyl, with ammonia, *e. g.*, acetamid = $C_4 H_5 O . C_4 H_3 O_3 + H_3 N = C_4 H_3 O_2 . H_2 N + C_4 H_5 O . HO$. The amides of these acids are crystallizable, colorless, soluble in water and alcohol, distil over unchanged, and are without reaction on vegetable colors. Like all amides, they are decomposed, on being treated with strong acids or alkalies, by combination with water into ammonia and the corresponding acid: by means of nitrous acid, the corresponding acid is again obtained, with the development of water and nitrogen, *e. g.* $C_4 H_5 NO_2 + NO_3 = 2N + 2HO + C_4 H_3 O_3$. Only the amides of this group of acids yield, on treatment with potassium, cyanide of potassium and a carbohydrogen.

When, lastly, the amides of these acids are treated with anhydrous phosphoric acid, the so-called *nitrils* are formed from them by the loss of two atoms of water; these are, however, nothing more than the cyanogen compounds of certain ethers corresponding to the acids. They are oily, very volatile fluids, less soluble in water than in alcohol or ether, and without action on vegetable colors: by strong acids, or alkalies, they are resolved, with the reception of three atoms of water, into ammonia, and the corresponding acid, *e. g.* $C_{10} H_9 N + 3HO = H_3 N + C_{10} H_9 O_3$. Treated with potassium, they afford cyanide of potassium and carbohydrogens. They are so much the more to be regarded as cyanogen compounds, as the artificially prepared cyanide of ethyl has all the properties of a nitril; it decomposes, for instance, by treatment with strong alkalies, into metacetonic acid and ammonia, $C_6 H_5 N = C_4 H_5 . C_2 N + 3HO = H_3 N + C_6 H_5 O_3$. Hydrocyanic acid would be the nitril of formic acid; for it readily passes, as is known, into formic acid and ammonia. On this circumstance, the theory above alluded to (p. 59) was founded, according to which the acids of this group were considered as oxalic acids, paired with carbohydrogens = $C_{2n} H_{2n+1}$. [According to this theory, for instance, the formula of metacetonic acid = $C_6 H_5 O_3 . HO$ should be written $(C_4 H_5) .\frown C_2 O_3 . HO$.] Hence we rank oxalic acid with these acids.

The acids of this group are found principally in the excretions, or appear in the primæ viæ as products of fermentation: they are met with especially in the sweat, where they are free, and hence are easily recognized by their fluidity and odor: in the urine and solid excrements, on the other hand, they are commonly combined with the alkalies, or with lime.

Oxalic acid, on account of its great affinity for lime, or rather on account of the insolubility of this salt, we find, in the animal organism, always combined with lime. In the solid excrements it is seldom

Fig. 1.

Oxalate of Lime.—1, 2, and 3. Octohedra of oxalate of lime in different positions. 4. This form arises from the juxtaposition of two octohedra, and when slightly altered produces the *ovals* 5 and 6. 7. A rare form, also derived from the octohedron. 8, 9, 10 and 11. "Dumb-bells:" these are probably carbonate of lime; they never appear in recent urine, but are formed subsequently to the octohedra of oxalate of lime.

found; in fact, only after partaking of vegetables containing oxalic acid: it is often observed, on the other hand, in the urine, of which it even appears to form a normal constituent. Its quantity in the urine may be increased by the use of vegetable food, even when this contains no oxalic acid: this appears, at least, from the appreciable quantity of oxalate of lime always present in the urine of herbivorous animals, *e. g.*, the horse, ox, &c. An increase of this salt is moreover observed after very abundant partaking of food, even of animal origin, and very often after slight debauches. An increase of oxalate of lime in the urine is commonly observed after drinks rich in carbonic acid, after the use of bicarbonated alkalies, of salts of organic acids, &c.; in short, after all food and drinks which overload the blood with carbonic acid. Corresponding with this, an increase of oxalate of lime in the urine occurs in disturbances of respiration, accumulation of carbonic acid in the blood, and especially in disordered metamorphosis of tissue; hence we have it in emphysema of the lungs, diseases of the heart, after epileptic convulsions, in the convalesence from typhus, &c.

In estimating the presence of oxalate of lime in the urine, it must not be forgotten that, in the so-called acid fermentation of urine, in connection with another acid, oxalic acid is formed, and immediately combines with the lime of other salts. In fresh urine, often no trace is to be found of oxalate of lime: it occurs after the acid fermentation has gone so far that crystals of free uric acid have separated. The urine occasionally undergoes the acid fermentation within the bladder, and thus gives occasion to the formation of mulberry calculi, which consist mainly of oxalate of lime; the origin of such concretions may often be deduced less from oxalic acid separated by the kidneys than from this fermentation.

[The appearance of oxalate of lime in the urine is esteemed very differently by different authorities. Some regard it as indicative always of serious disease of the system, demanding active medication; while others view it as a result of imperfect digestion, or of deficient oxygenation in the blood. The mode of its occurrence renders the latter the more probable view: hence the cases of oxaluria generally present symptoms of dyspepsia, or of exhausted nervous forces, as in spermatorrhœa, &c. The form in which oxalate of lime presents itself under the microscope, is generally that of the octohedron, or some of its derivatives.—J. C. M.]

Formic acid is one of the most important constituents of the *sweat;* among the fluid constituents, it is far the largest. In the *blood*, it has been found only after the prolonged use of sugar. In the *fluids of muscles*, as also in those of the *spleen*, it is found in small quantity.

Acetic acid is also a constant constituent of the *sweat*. It may be found in the *blood*, especially after the use of brandy, as also in the disease called leuchæmia (which is associated with enlargement of the spleen). Small quantities of this acid have also been found in the juices expressed from the *muscles* and from the *spleen*. In imperfect digestion, the contents of the stomach sometimes undergo an acid fermentation: we then find acetic acid in the matters vomited.

It is not improbable that small quantities of METACETONIC ACID exist in the animal frame wherever acetic or butyric acids are present, while it has never been detected with certainty.

BUTYRIC ACID is found only in relatively small quantity in the *sweat*, although this often smells strongly of it. Butyrates have never been detected in the blood, although their presence there is very probable. In the fluids of *transversely striated* and *smooth* muscles, as also in that of the *spleen*, it is found in small quantity. It seldom presents itself in the *urine*. In the contents of the stomach, it is only an abnormal constituent, arising from carbohydrates which have passed into fermentation; on the contrary, it exists pretty constantly in the contents of the large intestine, as the carbohydrates reaching there are generally disposed to the butyric acid fermentation by the fluid of the large intestine.

Whether CAPROIC ACID exists in the *sweat*, which often develops an odor similar to it, is yet undecided; the same remark is applicable to *caprylic* and *capric acids*. It is not unlikely that the peculiar odors which are developed by treating the blood of different animals with sulphuric acid, depend upon these acids, and hence they may be contained ready formed in the *blood* in some combination. That, in connection with margarin and olein, butyrate, caproate, caprylate, and caprate of glycerin or oxide of lipyle, are contained in milk, has long been placed beyond doubt, and hence their presence in the blood is not improbable.

ŒNANTHIC and PELARGONIC acids have never been found ready formed in the animal body; they present themselves at most as products of the decomposition of nitrogenised substances.

From the mode of occurrence of all the acids of this group, the conclusion may at once be drawn that they do not play an important part in the animal organism; they are either, as in the stomach and alimentary canal, accidentally present, resulting from fermentations, or they are characterized as true excretory products, and hence appear mainly in the sweat and urine. As the sweat-glands serve principally for the separation of the more volatile matters, we find almost the whole series of acids of this group in the sweat, while oxalic acid is mainly present in the urine, as it is not volatile and unites so actively with lime. All these substances, therefore, are products of the retrograde metamorphosis of tissues, *i. e.*, they arise from those changes which the tissues and organs undergo in performing their physiological functions. In the perfectly healthy state, the animal organism secretes less of these substances, as they are then for the most part further oxidised and excreted in the form of carbonic acid and water. We see them occurring in increased quantities in the excretions when in consequence of any pathological processes the process of oxidation in the blood is interfered with. That circumstances which prevent the separation of these substances from the blood must give rise to a perverted metamorphosis of tissue, and pathological phenomena, is self-evident: but of what sort these pathological phenomena are, and whether they coincide with what is called rheumatism, must remain undecided.

Fixed Fat Acids.

These acids, which, as already remarked, differ from those above described in only a few of their properties, enter very probably into the same relative combinations as the acids of less atomic weights; in but few, as cetylic acid, is the homology in this respect with the previous group ascertained by direct experiment. But as several chemical properties of these acids are entirely different from those just considered, in consequence of their higher atomic weight, *i. e.*, from the radicals, containing more numerous atoms of carbohydrogen, so their physiological relations, their importance in the metamorphosis of animal tissues, etc., through their richness in carbohydrogen, differs from what we have learned respecting the volatile fat acids.

Of the fixed fat acids referred to above, COCINIC, MYRISTIC, CETIC, and PALMITIC ACIDS occur in small quantities in animal fat, while MARGARIC AND STEARIC ACIDS occur as its principal constituents. These acids are but seldom met with uncombined in the animal fluids, in fact only in such as have already undergone, either within or without the body, a certain degree of alteration, thus, *e. g.*, in pus which has either become acid in the air, or has been discharged from so-called *cold abscesses*. The spindle-shaped and grass-like tufts of margaric acid crystals are then especially to be seen. They are also occasionally found in the fluids of encysted dropsies, and also free in the solid excrements.

More commonly these acids are combined with the *alkalies* with which they exist as salts in the blood, chyle, saliva, and secretions, particularly in the bile, and in pus.

Their physiological importance, however, rests upon the presence of these acids in the shape of so-called *neutral fats*, in which they are combined with the non-nitrogenised, glycerin-yielding base, the oxide of lipyle. Always mingled with more or less oleate of the oxide of lipyle, or olein, they form the common fat of animals, which is partly stored up in special cells, particularly in the subcutaneous areolar tissue, and partly is suspended in most of the animal fluids, especially in milk.

Fig. 2.

Fat cells imbedded in a fibrous stroma.—*a*. Isolated cells showing spindle-shaped tufts of margaric acid.

Anatomists distinguish, as is well known, a peculiar tissue, the adipose, *i. e.*, cellular tissue, in which the above mentioned oval, or polyhedral cells are imbedded. *Adipose tissue* is an integral part of many organs, from which it never vanishes entirely, even in sickness, *e. g.*, from the *orbit*, from between the muscular fasciculi of the *heart*, and between the muscles of the *face*. Very variable quantities are found, on the other hand, in the areolar tissue *under the cutis*, and in that surrounding the *muscles*, especially between the glutei, under the skin of the sole of the foot, and the palm of the hand. The *tendons* are often surrounded by fatty cysts, which sometimes extend to the joints (*glands of Havers*). Large collections of fat cells are also found between the folds of *the great omentum*, around the *kidneys*, and in the female breasts. The marrow of bones consists mainly of fat rich in olein. The lungs, the glans penis, the clitoris, and the brain, have but little fat, and are destitute of fat cells.

In the animal fluids, also, fat occurs partly free in minute drops, partly in special cell-membranes and in no small quantities, as for example in *milk*, in which each particle is surrounded by a delicate membrane; in the *yelk* of the egg the fat is partly inclosed in membranes, partly suspended in minute drops; the same holds good of *the chyle*, especially after food rich in fat, and also in part of *the lymph*. In *the blood*, on the contrary, more saponified and dissolved, than free suspended fats, are contained. Only under peculiar circumstances does suspended unsaponified fat increase in the blood, as, a short time after the use of fatty nourishment, often in pregnant women, but most frequently in drunkards, when granular degeneration of the liver has commenced. The *solid excrements* contain much free fat partly after over-abundant partaking of fat, especially when diarrhœa has simultaneously set in, or when the influx of the bile into the intestines is either prevented or interfered with, whether the cause be a mechanical stoppage of the gall-duct (by colic, gall-stones, or duodenitis), or a deficient secretion of bile.

Several organs, as the *liver*, *spleen*, and even the *kidneys*, contain normally more or less fat inclosed in, or exterior to their proper cells; but in pathological conditions, especially after parenchymatous inflammation of these organs, fine fat granules accumulate partly within, and partly outside of the cells in large quantities; this condition has been called *fatty degeneration*, and regarded as a result of inflammation.

Fat is collected abnormally in *tumors*, and so-called *lipomata;* cancerous tumors, also, are often very fatty. When cavities are formed in the body by loss of substance, too active absorption, &c., in the place of the destroyed tissue fat is often deposited, as in *paralyzed muscles* or in *bone rendered less dense* by any pathological process.

In observing the quantity of fat in the animal body in general, we find that it varies very much with the *age;* while the organism is almost destitute of fat in the early periods of fœtal life, we find it collected in great quantity in new-born infants; this abundance of fat decreases sensibly at the approach of puberty, increases during maturity, and vanishes remarkably in old age. The body of the female is, on the average, richer in fat, and more inclined to fatty deposits than that of the male. That sexual excitement, excessive muscular action, modes of living, temperament, and mental conditions have much influence upon fatty deposits in the body, is taught by daily experience.

Beyond doubt, the *source* of the fats of the animal body is principally to be sought for in the fatty matters contained in the food; nevertheless, the most careful chemical statistical experiments, partly on lactiferous animals, partly on those living on mast, partly on bees fed only on sugar, prove that the animal organism, as well as the vegetable, possesses the power of forming fat.

The animal economy must, according to these observations, which show a far greater increase of fat than could be referred to that derived from the food, be able to develop fat either from the carbohydrates afforded to it, or from the nitrogenised protein bodies. We shall hereafter, when we come to consider the metamorphosis of animal tissues in general, enter more closely into the consideration of the grounds which indicate the one or the other mode of fat formation in the animal body; but we must here make the confession that we do not know in what way, by what process, or according to what chemical equation fat can be formed from a carbohydrate, or protein substance; we know, hence, as little the parts of the organism where fat formation takes place, as we know whether the organism, when abundantly supplied with fat, still makes use of its powers of fat formation.

Fats are of great *physiological importance* in the animal organism; so that we shall return to them in considering the general metamorphosis of tissues at greater length. Thus much must here suffice for the determination of the physiological functions of the fats; we see fat accumulated, in the first place, in those parts which are exposed to heavy *blows* or pressure from without; they serve here as cushions or pads, to neutralize, as far as possible, the force of such external impressions; we find it stored up for this purpose, not only in the sole of the foot, the palm of the hand, and on the tuberosity of the ischium, but also in special sacs inclosed in the joints between the bones.

Fat fills up also the vacant spaces between muscles and other organs, so as to afford these more *freedom of motion;* hence its accumulation in the omentum, in the orbit, and among the muscular fibres of the heart. That organs, such as the bones, especially when their tissue is rendered less dense, are made less brittle and in a measure more pliable by the presence of fat, scarcely needs to be mentioned.

Fat is, besides, a *bad conductor of heat;* hence we see it deposited, in greater or less quantity, in the subcutaneous areolar tissue, in order to lessen, as far as possible, the loss of the free heat of the body by radiation. The great changes of the external temperature would operate much more readily and disadvantageously on animal life, if the body were not, in some degree, protected against them, by the *panniculus adiposus cutis;* thus, also, the fatty greater omentum serves as a protecting, warmth-preserving coat, to promote the processes of digestion.

The fats are useful more than all other substances in *exciting and maintaining animal temperature;* it is a physical necessity that a great amount of heat must be set free by the gradual or rapid oxidation of fats in the animal organism; they contain but little oxygen combined in them; hence the gaseous oxygen taken up in respiration must be applied principally to the oxidation of these substances, which are seldom excreted as such, but generally, after perfect combustion, in the shape of carbonic acid and water.

The fats are, moreover, very important *agents in the metamorphosis of animal substances.* As small quantities of fat are necessary, at least to the rapid induction of the lactic acid fermentation, so, according to some experiments, the fats appear not to be without influence on *digestion.* The presence of fat in the egg, in pus, in all plastic exudations, in all organs abounding in cells, indicates clearly that it plays an important part in cell formation; as yet no animal cell, no cell-forming plasma has been observed, in which appreciable quantities of fat were not contained. Whether fat, as has been maintained, in the form of granules or vesicles presents the first step toward cell-development, must yet remain undecided.

Finally we must not omit to mention here, that a part of the fat introduced into the body assists in *forming the resinous acid of the bile,* cholic acid; exact comparative analyses of the blood of the portal vein and hepatic veins, and comparative experiments instituted in animals with fistula of the gall-bladder, and on healthy animals, or on such as were kept fasting in order to determine the quantities of carbonic acid excreted, have, in connection with certain pathological facts, given great probability to the hypothesis that the formation of bile is impossible without fat; the chemical constitution and products of decomposition of cholic acid favor this hypothesis rather than oppose it.

SUCCINIC ACID GROUP = $C_n H_{n-2} O_3 . HO$.

The acids of this group—

Succinic acid	$C_4 H_2 O_3 . HO$
Lipinic "	$C_5 H_3 O_3 . HO$
Adipic "	$C_6 H_4 O_3 . HO$
Pimelic "	$C_7 H_5 O_3 . HO$
Suberic "	$C_8 H_6 O_3 . HO$
Pyroleic "	$C_{10} H_8 O_3 . HO$

are observed only as artificial products of animal substances, especially the fats; they are principally obtained by oxidation of the latter by means of nitric acid. In constitution they may be regarded either as a radical paired with a double atom of carbon = $(C_n H_n)^\frown C_2$, or as a radical containing oxygen = $C_n H_{n-2} O_3$.

These acids are all easily crystallized, without odor, do not melt below 212° F., sublime unchanged, are soluble in water, alcohol, and ether (the solubility stands here in inverse ratio to the atomic weight of the acid), redden litmus, and yield oxalic acid and volatile products when fused with hydrate of potassa.

Of these only SUCCINIC ACID has as yet been found in the animal body, and that but once in the fluid contents of hydatids; it may perhaps occur more commonly in small quantity.

PYROLEIC ACID, or *sebacic acid*, is only deserving of notice in that it has hitherto been obtained from no substance except oleic acid or olein, and then by dry distillation.

OILY FAT ACIDS $= C_n H_{n-3} O_3 . HO$.

The following acids belong to this class:—

Acrylic acid	$C_6 H_3 O_3 . HO$
Damaluric acid	$C_{14} H_{11} O_3 . HO$
Damolic acid	$C_{26} H_{23} O_3 . HO$
Oleic acid	$C_{36} H_{33} O_3 . HO$
Doeglic acid	$C_{38} H_{35} O_3 . HO$
Erucic acid	$C_{44} H_{41} O_3 . HO$

The first three of these acids are oily, volatile liquids, somewhat soluble in water, more so in alcohol and ether, and redden litmus; they stand in the same relation, perhaps, to the other three as the volatile fat acids do to the fixed.

The three last named acids, properly oily acids, are of an oily consistence at moderate and crystallize at lower temperatures, generally above 32°, are entirely insoluble in water, easily soluble in hot alcohol, and ether, redden litmus slightly, are decomposed by heat, and in most other respects have properties in common with the fixed fat acids.

DAMALURIC AND DAMOLIC acids have hitherto been found only among the volatile constituents of the urine of cows, and hence have not attained much physiological interest.

DOEGLIC ACID has yet been found only once, viz: in the train-oil of the *Balæna rostrata*.

OLEIC ACID, on the contrary, we find wherever margaric and stearic acids exist; thus, combined with alkalies in the *blood* and *bile*, free in acid *pus*, and combined with oxide of lipyle as olein in the *fat of cellular tissue*, and wherever else free fat presents itself in the body.

The fat of animals contains, on the average, far less olein than that of vegetables. Whether a part of the oleic acid taken up in vegetable fat is transformed into margaric acid, or whether the oleic acid is consumed more rapidly in the metamorphosis of tissue in the animal than margaric acid, cannot as yet be decided. Margarin and olein are likewise not equally distributed in the animal body: in one place the fat-mass is richer in olein, in another in margarin; the *panniculus adiposus renum* contains more margarin and stearin, the marrow of the bones an excess of olein, &c.—In general the function of olein corresponds closely with that of the other free fats.

BENZOIC ACID GROUP $= C_n H_{n-9} O_3 . HO$.

To this group belong—

Benzoic acid	$C_{14} H_5 O_3 . HO$.
Myroxylic acid	$C_{15} H_6 O_3 . HO$.
Toluylic "	$C_{16} H_7 O_3 . HO$.
Cumic acid	$C_{20} H_{11} O_3 . HO$.
Copaivic "	$C_{40} H_{31} O_3 . HO$.

Although *cinnamic acid*, $C_{18} H_7 O_3 . HO$, differs in composition by 2 equiv. of hydrogen from the acids of this group, its chemical properties and physiological relations are so similar that it deserves to be classed with them.

All these acids are fixed, crystallizable in needles or plates, destitute of odor, fusible, sublime without change, are scarcely soluble in cold water, easily in hot, as also in alcohol, less so in ether, and redden litmus. Their salts are also analogous.

We should not omit here to mention that another group of acids exists, closely approximated to these, resembling them in their properties, in which the same carbohydrogen atoms are united with five atoms of oxygen, viz:—

Salicylic acid,	$C_{14} H_5 O_5 . HO$,	corresponding with	benzoic acid.
Anisic "	$C_{16} H_7 O_5 . HO$,	" "	toluylic "
Cumaric "	$C_{18} H_7 O_5 . HO$,	" "	cinnamic "
Copalic "	$C_{40} H_{31} O_5 . HO$,	" "	copaivic "

In close relation to these acids stand certain oily volatile substances existing in the vegetable kingdom, some acid, some basic, some indifferent, which contain one atom more of hydrogen and one less of oxygen than the corresponding acids:—

Hydruret of benzole,	$C_{14} H_6 O_2$,	corresponding	to benzoic acid.
" " salicyl,	$C_{14} H_6 O_4$,	"	" salicylic "
" " cinnamyl,	$C_{18} H_8 O_2$,	"	" cinnamic "
Cumarin . . .	$C_{18} H_8 O_4$,	"	" cumaric "
Cumin	$C_{20} H_{12} O_2$,	"	" cumic "

As the atom of hydrogen in these combinations can be easily displaced by chlorine, bromine, iodine, sulphur, or cyanogen, the atom of oxygen in the corresponding acids has been assumed to have been substituted for hydrogen; hence they have been regarded as simply oxides of a radical containing oxygen, viz: $C_n H_{n-9} O_3 = (C_n H_{n-9} O_2) O$.

The existence of the amides of these acids favors this mode of viewing their composition, inasmuch as these may be regarded as ammonias in which one equiv. of hydrogen is replaced by the oxygen-containing radical of the acid, *e. g.*, benzamid = $(C_{14} H_5 O_2)$ H . H . N.

On the other hand, two other groups of bodies, which are connected with these acids, favor the hypothesis, according to which there exists in these bodies a radical, paired of two atoms of carbon and a carbohydrogen = $C_n H_{n-7}$. In the first place are the nitrils, bodies free from oxygen, which, like the nitrils spoken of before, are volatile inflammable liquids of the composition $C_n H_{n-9} N$. As these yield cyanogen with potassium, one would be inclined to regard the two atoms of carbon going over to the cyanogen as forming not the carbohydrogen $(C_n H_{n-9})$, but rather = $(C_n H_{n-7})^\frown C_2$. The existence of certain carbohydrogens, which are obtained by heating the acids with an excess of alkalies, favors the latter view; *e. g.*, benzole from benzoic acid = $C_{14} H_5 O_3 . HO—2CO_2 = C_{12} H_6$; thus cumole $(C_{18} H_{12})$ arises from cumic acid, and toluole $(C_{14} H_8)$ from toluylic acid. As in these carbohydrogens, one atom of hydrogen may be substituted by chlorine, bromine, iodine, or peroxide of nitrogen, we are justified in regarding them as combinations of hydrogen with the radicals, $C_{12} H_5$, $C_{18} H_{11}$, and $C_{14} H_7$; these are exactly the radicals which the above hypothesis considers as paired with a double atom of carbon.

Of the acids of this group, only BENZOIC and SALICYLIC ACIDS deserve a short notice, from their relation to physiology; the first occurs only paired in the animal fluids, in the shape of an amide, as hippuric acid. It is only found in the urine after vegetable food, in consequence of the decomposition of the last-named acid; recent urine never contains benzoic acid.

After the use of benzoic acid, large quantities of hippuric acid are always found in the urine; it also passes into the sweat, and is found there as such, never in any nitrogenised combination.

SALICYLIC ACID is found in the urine, together with hydruret of salicyl, after the use of salicin. As it exists in castoreum (in consequence of the abundant use of willow bark by the beaver), it probably is contained as a normal element in the urine of this animal, together with hydruret of salicyl.

LACTIC ACID GROUP = $C_n H_{n-1} O_5 . HO$.

Here belong—

Glycic acid	$C_4 H_3 O_5 . HO$.
Lactic acid	$C_6 H_5 O_5 . HO$.
Leucic acid	$C_{12} H_{11} O_5 . HO$.

These acids form, when most free from water, oleaginous fluids of strongly acid taste, without odor, soluble in water, alcohol, and ether almost in all proportions, redden litmus strongly, decompose by heat, form with bases soluble salts, some of which are readily crystallizable.

According to the above empirical formulæ, we arrive easily at the idea of regarding these acids as only higher stages of oxidation of the same carbohydrogens which we recognized in the volatile fat acids. According to this, glycic acid would correspond to acetic acid, lactic to metacetonic, and leucic to valerianic; but a different hypothesis has attained a high probability in consequence of certain facts. According to this, they are to be regarded as formic acid paired with aldehydes—

Glycic acid . . .	$= C_2 H_2 O_2 . C_2 H O_3 . HO$.
Lactic acid . . .	$= C_4 H_4 O_2 . C_2 H O_3 . HO$.
Leucic acid . .	$= C_8 H_8 O_2 . C_2 H O_3 . HO$.

We have an analogy for this composition in amygdalic acid, which has long been viewed as paired of hydruret of benzoyle and formic acid ($C_{14} H_6 O_2 . C_2 H O_3 . HO = C_{16} H_7 O_5 . HO$). Several salts of lactic acid actually develop the aldehyd of acetic acid by dry distillation; but the artificial formation of lactic acid from alanin ($C_6 H_7 N O_4$) favors this hypothesis still more. Alanin itself is formed from aldehyd-ammonia and hydrocyanic acid by digestion with hydrochloric acid ($C_4\ H_4\ O_2 + C_2\ H\ N + 2HO = C_6\ H_7\ N\ O_4$). If alanin is treated with nitrous acid, nitrogen, water, and lactic acid are formed; it may hence be supposed that the aldehyd has remained unchanged in alanin, and formic acid has been formed from the hydrocyanic, as happens easily elsewhere.

GLYCIC AND LEUCIC ACIDS have never as yet been found preformed in the animal organism; the first forms with benzoic acid a conjugate or paired acid, of which hippuric acid, so constantly present in the urine of the herbivora, is the amid.

LACTIC ACID is very frequently, but by no means always, contained in the *gastric juice*, together with hydrochloric acid; in the *saliva*, it is only recognized with certainty in diabetes. The acid reaction, which the *contents of the duodenum and jejunum* exhibit, especially after vegetable diet, depends in a great measure on lactic acid; lactate of lime is often found in the duodenum of herbivorous animals. The contents of the large intestine also, which exhibit so strong an acid reaction after amylaceous and saccharine food, owe this to the lactic acid developed by fermentation, and accompanied, as remarked above, by butyric acid.

This acid may be detected in *the chyle* of the thoracic duct of the horse, especially after feeding on oats and starch; it is probable, according to some observations, that it also exists in *the lymph.*

Lactic acid is not to be detected in *the blood* in normal circumstances, as it is there quickly oxidized and entirely consumed, whether introduced from the intestines or other organs; lactates of the alkalies injected into it disappear rapidly, and show themselves in the urine as carbonates. In pathological blood, however, especially in puerperal fever and leuchæmia, it is detected beyond doubt. Occasionally, it exists in puriform exudations, which have remained long in abscess-cavities.

This acid is not contained in healthy *milk;* it is soon formed in it from lactin by fermentation.

Lactic acid is further found in the juice both of *striated* and *smooth muscles* in tolerably large quantities. In the acid juice of the *spleen*, also, lactic acid and lactates of the alkalies are found. In the *urine* it is occasionally, but not constantly found; it only passes into this when it is not all consumed in the blood; hence we find it in the urine of animals after feeding them on amylaceous food, and confining them constantly in stalls, also in disturbances of respiration by emphysema of the lungs or tuberculous deposits. Very often it is formed in urine during the acid fermentation. (See "Urine.")

It is obvious, from the circumstances in which lactic acid is found, that it has a double *origin* in the animal economy; it arises in the *primæ viæ* by the fermentation of the amylacea; but as it exists in the muscles in proportion to the previous energy of their action, it may be regarded as a product of the metamorphosis of the muscular fibre.

The physiological importance of lactic acid must not be too lightly esteemed; for in the first place, it is the cause, actually, with hydrochloric acid, of the digestive power of the gastric juice; no other mineral or organic acids can take the place of these two in the gastric juice; secondly, lactic acid assists, as free acid, in the absorption or transudation of the digested food from the *primæ viæ* into the alkaline blood or lymph; thirdly, by the ready combustibility of its salts in the blood, it becomes an important assistant in maintaining the animal temperature; and finally it excites an electric tension in the muscles as opposed to the alkaline blood, which possibly is not without influence on the muscular function.

NON-NITROGENISED CONJUGATE ACIDS.

The bodies which we place together under this title, do not form a well-defined group, and by no means possess common characteristics; it is only the impossibility of classifying them, at present, more rationally, and the circumstance that, if the theory of pairing be admitted, substances with more than three atoms of oxygen may safely be regarded as paired, which induces us here to institute such a group. In zoochemistry there are only three of these acids, viz:—

Benzoglycic acid	$C_{18} H_7 O_7 . HO.$
Lithofellic "	$C_{40} H_{36} O_7 . HO.$
Cholic "	$C_{48} H_{39} O_9 . HO.$

Benzoglycic acid, which, then, is regarded as paired of benzoic and glycic acids $= C_{14} H_5 O_3 . C_4 H_3 O_5$, as it is resolved into them so easily by digestion with dilute acids, has never been found preformed in the animal organism; it possesses interest in zoochemistry only inasmuch as it is formed from hippuric acid by treatment with nitric oxide, on which account that acid is usually regarded as the amid compound of benzoglycic acid.

LITHOFÉLLIC ACID, a crystalline, resinous acid, is only found in certain rare intestinal concretions of several species of goats, in so-called bezoars; it is not known, however, whether it is derived from the food of the animals, or is a product of the secretion of the liver, or of some other excretion, into the intestinal canal.

CHOLIC ACID, which passes so readily, by the action of acids, into *choloidic acid*, isomeric with it, and, after longer action, into *dyslysin*, is found in the bile paired with taurin or glycin, and in these combinations passes also, in abnormal conditions, into the blood and other fluids; in the alimentary canal, however, it is soon separated from its nitrogenised pairlings and changed partly into choloidic acid and dyslysin. It is found in very small quantity in normal excrement; only in diarrhœa does it occur in larger quantities.

That cholic acid is formed in the liver, has been placed nearly beyond doubt; but it is uncertain from what materials or substances in the liver this resinous acid is elaborated. Since fats are especially applied to the formation of the bile, as is proved, partly from exact comparative analyses of the blood flowing to and from the liver, and partly from careful statistical experiments on living animals, the hypothesis is not at all absurd, that this acid is a combination, principally, of oleic acid and a carbohydrate ($C_{36}\,H_{33}\,O_3 + C_{12}\,H_6\,O_6 = C_{48}\,H_{39}\,O_9$); at the same time, a carbohydrate, sugar, is proved to be formed in the liver. The products of its chemical decomposition are at least not against this hypothesis; for cholic acid yields, on treatment with concentrated nitric acid, the same products of decomposition as oleic acid, and, together with these, another carbohydrate, cholesteric acid $= C_8\,H_4\,O_4$.

NITROGENISED BASIC AND NEUTRAL BODIES.

We embrace here only the simpler nitrogenised substances which were formerly regarded as organic bases, or as alkaloids; but so easy is the transition from strongly basic to perfectly neutral bodies that no fixed boundary can be drawn between them. Such more complex radicals as the protein bodies, the gelatinous substances, we are the less disposed to consider in this class, as we are not yet in condition to make the remotest guess at their theoretical constitutions, while on the other hand, according to the principles before alluded to and now acknowledged in chemistry, we are able to form an idea of the theoretical constitution of the substances belonging to this class. We have already remarked in the introduction, that ammonia may be taken as the type of a great number of nitrogenised organic bodies, one or all of whose atoms of hydrogen may be replaced by compound elements, the so-called radicals. Strongly basic and indeed volatile substances arise when carbohydrogens take the place of one or more atoms of the hydrogen of ammonia; thus are formed the so-called volatile non-oxygenated alkaloids, of which, according to the composition of the carbohydrogens, several homologous series may be defined; thus we have a methylamin series = $(C_n H_{n+1}) . H . H . N$, a phenylamin series = $(C_n H_{n-7}) . H . H . N$, &c.

This method of regarding them, so simple in itself, does not extend far enough to indicate the theoretical constitution of all the bodies (some of them strongly basic) belonging here. Thus lactamid, alanin and sarcosin are perfectly isomeric = $C_6 H_7 N O_4$; if in all these 1 atom of the hydrogen of ammonia were replaced by the aggregate $C_6 H_5 O_4$, these bodies could not possibly exhibit the differences which we recognize in them. There are also alkaloids which contain more than one atom of nitrogen, so that the nitrogen must be contained in them in another form than that of ammonia. As alkaloids have been artificially prepared which contain cyanogen ($C_2 N$) as a pairling, the idea is not improbable, that in the alkaloids which contain more than one atom of nitrogen, either cyanogen or one of its compounds is coupled with the ammonia base. If cyanogen itself be taken as the type of an especial class of bodies, several of the neutral bodies belonging here, must rather be regarded as analogues of the cyanogen type than of the ammonia type. But, as the group of bodies belonging to the former is not sufficiently defined, and as this separation is very difficult, or quite impossible, especially in reference to individual substances, we embrace all these bodies in one group.

Of the volatile alkaloids, none have yet been found preformed in the animal organism: as artificial or spontaneous products of decomposition, TRIMETHYLAMIN ($C_2 H_3 . C_2 H_3 . C_2 H_3 . N = C_6 H_9 N$)

was found in herring pickle, in putrid urine, and in alcoholic preparations of animal objects. BUTYLAMIN OR PETININ, $C_8 H_{11} N$, PYRIDIN, $C_{10} H_5 N$, PHENYLAMIN or ANILIN, and its isomeric PICOLIN, $C_{12} H_7 N$, and LUTIDIN, $C_{14} H_9 N$, are formed only by the dry distillation of animal substances.

Among the oxygen-containing bodies, we first mention a group of crystallizable homologous bases $= C_n H_{n+1} N O_4$ viz:—

Glycin	$C_4 H_5 N O_4$.
Sarcosin	$C_6 H_7 N O_4$.
Leucin	$C_{12} H_{13} N O_4$.

These are changed by nitrous acid into acids of the lactic acid group, so that glycin yields the above-mentioned glycic acid ($C_4 H_5 N O_4 + NO_3 = 2N + 2HO + C_4 H_3 O_5$); on the other hand, by means of strong alkalies, they develop hydrogen, ammonia, carbonic acid, and one of the volatile fat acids: glycin thus yields formic, sarcosin acetic, and leucin valerianic acids, *e.g.*, $C_{12} H_{13} N O_4 + 3KO + 3HO = 2KO . CO_2 + H_3 N + 4H + KO . C_{10} H_9 O_3$.

No one of these three has been found isolated in animal fluids.

GLYCIN,[1] which often appears as a product of decomposition of animal substances, by means of strong acids or alkalies, has attained a higher interest from its occurring in certain animal acids as a nitrogenised pairling or conjugate: thus, *e.g.*, in the bile, it is contained paired with cholic acid as *glycocholic acid;* hippuric acid also yields glycin when treated with strong acids, on which account it was long regarded as glycobenzoic acid.

SARCOSIN is known only as a product of decomposition of creatin by means of caustic baryta.

LEUCIN arises very frequently in the putrefaction of animal substances, or by fusing them with hydrate of potash, or when they are disintegrated by sulphuric acid.

Next to the above-named bodies is ranked TYROSIN, $C_{18} H_{11} N O_6$, a nearly neutral substance, which is formed by the decomposition of nitrogenised animal matter, by means of concentrated acids or alkalies.

The following nitrogenised, crystallizable substances are all found ready formed in the animal body, but are characterized as products

[1] This substance is also known as glycochol, or gelatin sugar.

of decomposition resulting from the metamorphoses of nitrogenised tissues and fluids. We here consider :—

Creatin	$C_8\ H_9\ N_3\ \ O_4$.
Creatinin	$C_8\ H_7\ N_3\ \ O_2$.
Urea	$C_2\ H_4\ N_2\ \ O_2$.
Allantoin	$C_8\ H_5\ N_4\ \ O_5$.
Guanin	$C_{10}\ H_5\ N_5\ \ O_2$.
Lienin	?
Cystin	$C_6\ H_6\ N\ S_2\ O_4$.
Taurin	$C_4\ H_7\ N\ S_2\ O_6$.

These immediate elements of animal fluids are not properly to be reckoned among the alkaloids; for it is very improbable that they are constituted according to the ammonia type, not only because they mostly (except creatinin) have so slightly basic, or quite neutral properties, but also because their large content of nitrogen corresponds but little with that hypothesis. The cyanogen type is rather to be suspected in them.

CREATIN forms a constant element of the juices of voluntary and involuntary muscles. In different animals, and in different muscles

Fig. 3.

Creatin.

of the same animal, it is found in very different, but always very small quantities, *i. e.*, 0.07 to 0.32 per cent. of flesh. Lean meat contains always rather more creatin than fat meat. In the flesh of fowls has been found the largest proportion of creatin; then, in a descending series, in the horse, fox, doe, stag, hare, ox, sheep, calf, and fish. The flesh of man contains about 0.067 per cent. of creatin.

Creatin has also been found in the *blood*, and more decidedly in the *urine*, though always in very small quantities.

[It has been suggested that the substances in the urine, frequently taken for lactates, were in reality creatin and creatinin. The ready solubility (one part in 70 of water) of creatin prevents its being often presented in urinary deposits, as its proportion in health cannot be more than one part in 1000; but, recently, attention has been called by Dr. Miltenberger, Professor of Pathology in the University of Maryland, to crystals of creatin formed by spontaneous evaporation of urine containing oxalate of lime. Some doubt was thrown upon this at first, and it was suggested that they might be irregular forms of chloride of sodium: but I have succeeded in finding them in two cases of oxaluria. The application of a drop of the solution of nitrate of silver removes all suspicion of their being chloride of sodium; the latter is instantly transformed, under the microscope, into a dark, granular mass, while creatin is unaffected, or slightly browned.—J. C. M.]

It is formed by the action of the muscles in life, and therefore is a product of their retrogressive metamorphosis. Its ready decomposition into different excretory elements, such as creatinin, sarcosin, and urea, as also the fact of its being secerned in the urine, are in favor of its excrementitious nature.

Creatinin, which may be artificially prepared from creatin, and distinguishes itself from the rest of these bodies by its strong alkaline reaction, is found likewise in the *fluids of muscles;* it has been detected, also, in the *blood*, the *liquor amnii*, and particularly in the *urine*. In the latter, it occurs in relatively greater, in the muscles in relatively smaller, quantities than creatin. That it also results in the animal economy from creatin, is then highly probable, not only from the mode of obtaining it artificially, but also from its mode of occurrence; hence it is to be regarded, even more than creatin, as an excretory substance.

Urea is the most important constituent of the *urine;* in that of man, it forms 77 to 82 per cent. of the solid constituents, in that of the carnivora often more. In human urine, whose very varying quantity of water causes the proportions of its solid constituents to appear very different, from 1.5 to 3.8 per cent. of urea are contained, averaging 2.5 per cent., under ordinary circumstances.

[In order to ascertain, approximately, the quantity of urea in a specimen of urine, a small portion of the urine is evaporated to half its bulk, and an equal quantity of nitric acid is added; on standing, a crystalline deposit, the nitrate of urea, separates, which should be

Fig. 4.

Nitrate of urea.

collected on a filter, redissolved in alcohol, and recrystallized. This method is sufficiently accurate for practical purposes.—J. C. M.]

A healthy man excretes, in 24 hours, from 340 to 679 grains (on the average about 494 grains); but the quantity depends very much on the external and internal conditions of the organism: thus, by men whose weight is over 238 pounds, 570 to 617 grains are discharged daily; by those, on the other hand, whose weight is only 132 pounds, 432 to 494 grains. Under exclusively animal diet, as much as 895 grains, under food containing little nitrogen, less than 232 grains, are excreted in 24 hours. Under non-nitrogenised diet, urea does not entirely disappear from the urine, any more than by prolonged abstinence from all food; the quantity excreted is only notably lessened. Hence, in diseases in which a spare diet is observed, the quantity excreted is much diminished, although the concentrated urine discharged at one time appears rich in this substance.

Violent bodily exercise causes an increased excretion of urea. *Men* discharge in an equal time more of this substance than *women* and *children;* but, in proportion to their weight, children often discharge twice as much as adults.

It is worthy of remark that the quantity of urea secreted daily increases with that of the water (without any determinate numerical ratio being observable). If much water, then, is discharged in the urine, more urea is also secreted.

In healthy *blood*, only very small quantities of urea are found, as it is separated from it so quickly by the kidneys. An abnormal increase appears only to occur in cases of deficient function of the kidney, which are usually combined with a degeneration of that organ.

When urea is secreted in but small quantity, or not at all, by the kidneys, it is found in most of the animal fluids, especially in the *sweat;* sometimes in such quantities that the latter, by spontaneous evaporation, forms a bluish-white crust, consisting mainly of urea, on the skin (especially the face). Under these circumstances it is met with not only in all *serous transudations*, but also in the *saliva*, in the *bile*, and especially in the *fluids vomited*.

Urea is also found normally in the *aqueous humor* and in the *liquor amnii*.

The opinion that urea is formed in the kidneys has long been abandoned, as it was proved that it accumulated in the blood and other fluids, upon their extirpation or entire degeneration. That it arises out of the nitrogenised constituents of the organism, scarcely needs proof; we know from theoretical chemistry how readily it occurs as a product of decomposition or change of other nitrogenised substances; its artificial preparation is well known. As the metamorphosis of tissue in the muscles is the most active in the organism, it is generally regarded as for the most part the product of the effete muscular tissue; but doubtless it is also formed by the metamorphosis of other organs: hence it is found in the urine after non-nitrogenised diet or prolonged abstinence. Whether it is formed in those places at which the metamorphosis is progressing, or in the blood, cannot be decided with certainty; while there is much reason for supposing that it is formed by preference in the blood, from other nitrogenised substances, which are to be regarded as the *debris* of the organs, as products of the metamorphosis of tissues. Thus, out of the organism, creatin and uric acid, as we know, separate readily into urea and other substances; these, as well as glycin, alloxantin, theïn, &c., when taken by the mouth, are decomposed into urea and other substances, of which the former is found in increased quantity in the urine. In the muscles themselves, creatin has been detected, but not urea. Finally, it is not very probable that the increase of urea in the urine would take place so soon after partaking abundantly of gelatin-yielding substances, unless the nitrogenised materials are immediately consumed in the blood, and their nitrogen united with certain other elements to form urea.

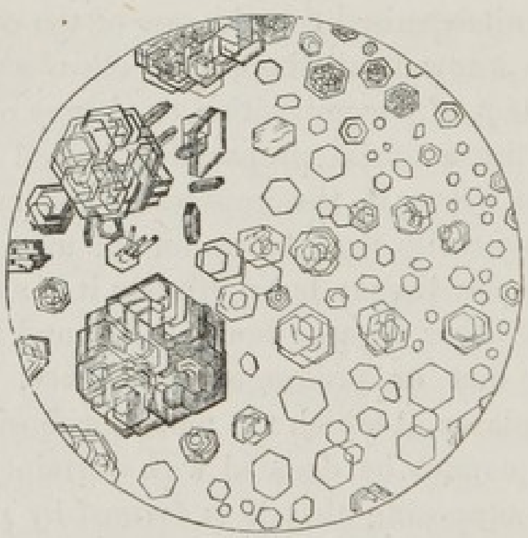
Its formation, then, takes place principally in the blood, and its origin, according to the last-mentioned phenomenon, is to be sought not only in the destruction of nitrogenous parts of organs, but also partly in the species of food taken.

ALLANTOIN is found in the fluid of the allantois of the cow, and in the urine of calves while they are suckled; as soon as they partake of vegetable food it disappears, and hippuric acid, which previously was wanting, takes its place.

GUANIN is found in the excrement of certain sea-birds (in guano) and spiders, as also in the green organ of river crawfish, and the organ of Bojanus of the *Anodonta cygnea.*

CYSTIN has been found, though rarely, in urinary calculi, and as a sediment in the urine. As neither its internal constitution has

Fig. 5.

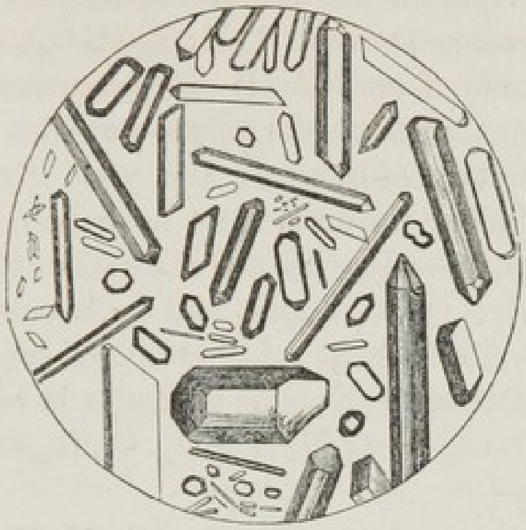


Cystin.

been investigated, nor the pathological conditions ascertained under which it is formed in the body, we are still wholly in the dark as to its origin. This substance contains a large proportion of sulphur.

TAURIN is found in the bile of most animals, coupled with cholic acid. As taurocholic acid is soon decomposed in the small intestines, we find small quantities of taurin in the contents of the *small and large intestines, and in the solid excrements.* That it is formed in the liver is highly probable, according to what we shall learn of its origin under "Bile."

Fig. 6.



Taurin.

LIENIN has hitherto been found only in the fluid of the spleen, and has not been very closely investigated. As most of the peculiar components of the splenic juice are characterized as products of retrogressive metamorphoses, lienin probably belongs also to them.

NITROGENISED PAIRED ACIDS.

We embrace in this group the following nitrogenised bodies, whether a determinate nitrogenised pairling has been detected in them or not:—

Hippuric acid . . .	$C_{18} H_8 N O_5 . HO$.
Glycocholic acid . .	$C_{52} H_{42} N O_{11} . HO$.
Hyocholic acid . . .	$C_{54} H_{43} N O_{10} . HO$.
Taurocholic acid . .	$C_{52} H_{45} N S_2 O_{14} . HO$.

These four acids are characterized especially as conjugated, or paired, since, on being treated with concentrated acids, or even alkalies, they are resolved into a nitrogenised body, which is usually regarded as the pairling, and a non-nitrogenised acid.

Hippuric acid has hitherto been commonly regarded as benzoic acid paired with glycin, as it is resolved into glycin and that acid by digestion with concentrated mineral acids ($C_{18} H_8 N O_5 + 2HO = C_4 H_5 N O_4 + C_{14} H_5 O_3$); but, as it yields with nitrous acid the before-mentioned benzoglycic acid ($C_{18} H_9 N O_6 + NO_3 = 2N + 2HO + C_{18} H_7 O_7$), the opinion has become more probable that it is a true amid of benzoglycic acid ($H_2 N . C_{18} H_7 O_6$), which, like asparagic acid (the amid of malic acid), still possesses acid properties. It is uncertain whether a similar relation obtains in regard to glycocholic and hyocholic acids, which also yield glycin by treatment with acids or alkalies; hitherto they have been viewed as acids paired with glycin, according to the theoretical formula for glycocholic acid $= C_4 H_3 N O_2 . C_{48} H_{39} O_9$, and for hyocholic acid $= C_4 H_3 N O_2 . C_{50} H_{40} O_8$. Taurocholic acid is resolved into taurin and choloidic acid by treatment with acids; hence it is regarded as cholic acid paired with taurin $= C_4 H_6 N S_2 O_5 . C_{48} H_{39} O_9$.

The two acids—

Inosic acid	$C_{40} H_6 N_2 O_{10} . HO$,
and Pneumic acid . . .	?

have been as yet too little investigated to enable us to indicate their pairling, and the acid paired with it.

One of the most important acids belonging to this class stands in composition, and even in some of its properties, in very close relations to two neutral animal substances, hypoxanthin and xanthin, as is seen by the following formulæ:—

Hypoxanthin	$C_{10} H_4 N_4 O_2$.
Xanthin	$C_{10} H_4 N_4 O_4$.
Uric acid	$C_{10} H_4 N_4 O_6$.

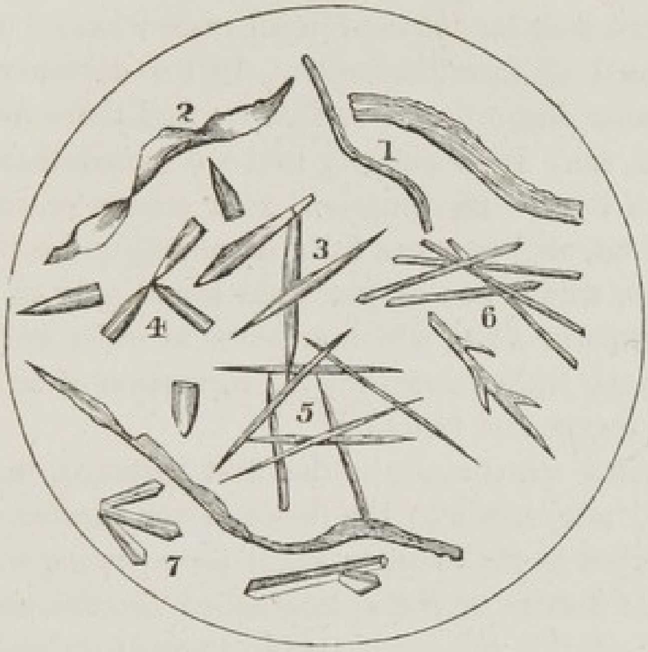
These combinations resemble different stages of oxidation of the same radical $= C_{10} H_4 N_4$. It is also worthy of note that xanthin forms a homologous series with two vegetable nitrogenised bodies, which, according to this, differ from each other by a certain number of carbohydrogen atoms, viz:—

Xanthin	$C_{10} H_4 N_4 O_4$.
Theobromin	$C_{14} H_8 N_4 O_4$.
Thein	$C_{16} H_{10} N_4 O_4$.

That, moreover, the homology of these three bodies is no accidental freak of nature, results from other investigations as to the mode of disintegration of thein and theobromin; for, according to these observations, these vegetable substances afford, under analogous conditions, products of decomposition which are perfectly homologous with those of the animal substance.

HIPPURIC ACID is found in great quantity in the *urine* of herbivorous mammalia; it also exists in that of some of the amphibia, *e.g.* of *Testudo graeca;* it is also a constant element of human urine

Fig. 7.



HIPPURIC ACID.—1, 2. Irregular crystalline masses of hippuric acid. 3, 4, 5, 6. Acicular crystals in different positions, sometimes also crossing each other at right angles.

after the use of mixed or vegetable food. Our observations are not yet sufficiently numerous to enable us to decide how far the amount of hippuric acid is increased or diminished in disease. It has been detected in the *blood* in very small quantities, though with certainty. From what substances especially, and in what places, hippuric acid is formed, cannot be determined with certainty; for neither its theoretical constitution, nor the well-known change of benzoic acid in the organism into hippuric acid, nor the appearance of unaltered benzoic acid in the sweat, is sufficient for forming an opinion as to its mode of production.

GLYCOCHOLIC ACID is found principally in *ox-gall*, and exists also in the bile of several other animals, although mostly in relatively small quantities. It is speedily decomposed in the *alimentary canal.* It is probable that this acid is formed in the liver. Its function in the alimentary canal may correspond with that of the bile in general, viz: the absorption of fat.

Hyocholic acid is found in the *bile* of swine, taking the place of glycocholic acid in the organism of other animals.

Taurocholic acid is found in the bile of man and the ox, and probably in the sulphuretted bile of the fox, bear, sheep, dog, wolf, goat, of several birds, and fresh-water fishes; in the bile of the boa anaconda it appears to exist alone, *i.e.* without any non-sulphuretted resinous bile acid. In the *blood*, in *transudations*, and in the *urine*, taurocholic acid may be detected in all cases where the excretion of bile is repressed or interfered with. In the *alimentary canal* this acid is also soon decomposed, so that we find there free taurin and choloidic acid, &c. It is scarcely to be doubted that this acid is formed in the liver. Its function, as a means of promoting the absorption of fat, will be more fully discussed under "The Bile."

Inosic acid, which has as yet been found only in the fluids of flesh, and Pneumic acid, which appears to exist only in those of the lungs, are too little known for the formation of an opinion concerning their origin and function.

Hypoxanthin was found, in the first instance, in the juice of the *spleen*, and afterwards in the fluids of the *cardiac muscle* of the ox. It also exists in the *blood*, in small proportions, which increase notably in that disease of the spleen called *Leuchæmia*. The close relation in which this substance stands to xanthin and to uric acid indicates significantly enough that it is to be regarded as a product of change, and an excretory substance.

Xanthin has been found, though rarely, in urinary calculi. Under what conditions this substance is formed in the body, and gives rise to the formation of such concretions, is entirely unknown.

Uric acid is a constant constituent of *human urine*, which contains, on an average, about 0.1 per cent. of it. It is found in smaller quantities in the urine of carnivorous mammalia, but not at all in that of omnivora or herbivora (it is only found in that of calves while sucking). The urine of birds and serpents consists almost entirely of urates. Uric acid has, finally, been found also in the urine of tortoises, and in the red excrements of butterflies, as also in those of beetles and caterpillars, in the biliary ducts of which, especially, it is accumulated.

The proportion of uric acid in human urine varies, of course, with its concentration; hence the highly concentrated morning urine contains often 0.8 per cent., without any absolute increase of the acid. The absolute quantity of uric acid in human urine varies but little, according to the kind of *diet;* an absolute increase of the quantity daily excreted is found in disordered digestion, especially

Fig. 8.

Crystals of uric acid.

after the use of indigestible food and alcoholic drinks, and in all diseases accompanied by violent fever. In these cases, uric acid is deposited from the urine as it cools, generally combined with soda

Fig. 9.

Urate of soda.

as an amorphous granular sediment, which may be recognized by its ready solubility on the application of heat. We observe, especially, an increase of uric acid with the formation of this sediment (which, however, does not always indicate an absolute increase of uric acid, but only a greater concentration of the urine), in all cases which are connected with a disturbance of the respiratory functions or of the circulation, as *e.g.* in emphysema of the lungs, diseases of the heart, liver, &c. In acute arthritis, the uric acid in the urine is augmented before the occurrence of the paroxysm; during it, however, and in chronic gout, it is diminished. *Free uric acid* is very seldom found in recently passed urine; but the urine of fever has this peculiarity, that it becomes acid in the air sooner than normal urine, and deposits crystals of uric acid. *Urate of ammonia* is likewise a product of fermentation of urine, but of the alkaline, which generally occurs out of the body; but in obstinate vesical catarrh (especially in paralysis of the bladder) the urine becomes alkaline in the bladder, and contains then, when recently discharged, this salt in the shape of dark-brown granules surrounded with delicate needles. Uric acid is found in the *blood* only in very small quantities, slightly increased in arthritis and in Bright's disease. It is detected as a constant element of the fluid expressed from the *spleen*. Urate of soda, crystallized, is contained in most of the so-called *chalk-stones*. It is thought also to have been found in the *sweat* of those suffering under gout.

Uric acid is, like urea, an excretory product. It stands in very close relation to the latter, inasmuch as a great part of the urea in the organism, and even in the blood, seems to be formed from it; at least this is indicated by the circumstance that, after the ingestion of uric acid, this appears again in the urine, not as acid, but as urea (exactly as uric acid yields urea on being treated with peroxide of lead). On the other hand, in urine which contains much uric acid, relatively little urea is usually found. We also find uric acid occurring in increased quantities in the urine in cases of interruption of the respiratory functions and of the circulation of the blood.

NON-NITROGENISED BASES. HALOID BASES.

We have seen, in the introduction to Zoochemistry, that there are many carbohydrogens, in part polymeric, which comport themselves like elements, and resemble in many respects the metals. These carbohydrogens form, with one atom of oxygen, basic bodies which unite with water, as also with acids, forming with the latter both neutral and acid salts.

It is well known that the study of these bodies has greatly advanced theoretical chemistry; but, unfortunately, these studies have as yet exercised no very important direct influence on zoochemistry, as in the latter these substances are as yet only of secondary importance. Hence we recall to remembrance, in regard to them, only the following:—

All these oxides form combinations with water, the so-called *alcohols*, which present in some respects very important differences from the anhydrous oxides, the so-called *ethers*. The alcohols are generally regarded as hydrates of the ethers, but later discoveries, viz: those of the compound species of ethers, have rendered this view somewhat doubtful. If potassio-alcohol [$C_4H_5O.KO$] is treated with iodide of methyl, or the bisulphate of the oxide of methyl and potash, we should expect the simultaneous formation of oxide of methyl (C_2H_3O) and oxide of ethyl (C_4H_5O); but, instead of this, a new ether is formed, of the composition C_3H_4O. It has, hence, been concluded that ordinary alcohol contains but one atom of oxygen, and thus is not $C_4H_6O_2$, but C_2H_3O. It has then been further conceived, in conformity with the atomic theory, that water contains two atoms of hydrogen to one of oxygen, and that in alcohol only one, in ether both, atoms of hydrogen are replaced by ethyl; that in the above-mentioned compound ether, one atom of the hydrogen of water is replaced by ethyl, the other by methyl. This mode of viewing them, which has much in its favor, makes the alcohols appear in a light very different from that of hydrates.

The better known non-nitrogenised organic bases, and their so-called hydrates, are generally fluid and very volatile bodies; but here, as with the fat acids, they become less volatile as the atomic weight increases, *i.e.* the more carbohydrogen atoms they contain, and present themselves as soft, and finally as solid bodies. The alcohols are, as a rule, less volatile than the corresponding ethers.

The combinations of these bodies with acids, whether organic or inorganic, have many peculiarities by which they differ from other salts. We may mention that they are not as easily resolved into their proximate components by single or double elective affinity, and that when decomposed they absorb water, so that both acid and base become hydrates; for it is worthy of remark that these neutral salts never contain water, and hence never form hydrates, as inorganic salts often do. It is also remarkable that the neutral salts of most of these bases volatilize unchanged, while their acid salts all decompose on heating. The acid salts all redden litmus, but none of the neutral.

Several homologous series of these bodies also may be arranged, whose individual members differ by $C_2 H_2$; the best known of them is the ethyl series $= C_n H_{n+1} O$. Of these the following have some interest in zoochemistry:—

Doeglic oxide	$C_{24} H_{25} O$.
Oxide of cetyl	$C_{32} H_{33} O$.
Oxide of cerotyl	$C_{54} H_{55} O$.
Oxide of melissyl	$C_{60} H_{61} O$.

The existence of DOEGLIC OXIDE has been as yet determined only from the analysis of the unsaponified train-oil (fat of the *Balæna rostrata*), and the absence of glycerin.

The hydrate of OXIDE OF CETYL, *ethal*, is found combined with cetylic acid only in spermaceti, the fat of the sperm-whale.

The OXIDE OF CEROTYL, *cerotin*, is contained principally in China wax combined with cerotic acid.

The OXIDE OF MELISSYL, *myricin*, exists in wax.

A second homologous series of non-nitrogenised bases corresponds with the formula $C_n H_{n-1} O$. Among these the hypothetical OXIDE OF LIPYLE, $C_3 H_2 O$, alone possesses any physiological interest: from this base, it is supposed, GLYCERIN $= C_6 H_7 O_5 . HO$, results in the decomposition of neutral fats. Of the combinations of this body with the fat acids, and their entire relations in the animal organism, we have spoken above (pp. 68–72). It is only necessary to mention here GLYCERO-PHOSPHORIC ACID $= C_6 H_7 O_5 + 2HO + PO_5$, which has been ascertained to be probably a constituent of the *yolk* of the eggs of birds and fishes, and also of the *brain*. The origin of glycerin in the animal body, from the neutral fats, is undoubted; the circumstance, however, that neutral fats, in glycerin-yielding substances, almost exclusively are introduced into the animal body, while many free fat acids exist in the organism, in connection with the small quantity of glycerin combined with phosphoric acid, indicates its application to a far different purpose. It is possible that it passes into metacetonic acid (as in fermentation with yeast), which is immediately consumed in the blood.

A third group of these bodies has scarcely any basic properties. As yet only two members of it are known, viz:—

Hydrated oxide of phenyl . .	$C_{12} H_5 O . HO.$
Hydrated oxide of tauryl . .	$C_{14} H_7 O . HO.$

HYDRATED OXIDE OF PHENYL, also called *phenylic* or *carbolic acid*, has been found with certainty only in castoreum. Whether it occurs, together with salicylous and salicylic acid, after the use of salicin, is yet doubtful, inasmuch as, even in very small quantities, it acts poisonously on animal life.

HYDRATED OXIDE OF TAURYL, *taurylic acid*, has been found only in the urine of cows, in very small quantity.

LIPOIDS.

These bodies, often called also *unsaponifiable fats*, are neutral, resembling the fats in many of their physical properties, but corresponding with them neither in composition nor in modes of decomposition. Among these bodies are reckoned—

Cholesterin	$C_{28} H_{24} O.$
Castorin	?
Ambrin	?
Serolin	?

CHOLESTERIN exists very abundantly in the animal organism, partly dissolved by soaps or taurocholate of soda, partly suspended or deposited in rhombic plates, the obtuse angle of which measures 100° 30′. Its presence in the *bile* is well known, where it is almost always in solution. Suspended cholesterin has very seldom been found in diseased bile; but biliary calculi are very common, the most of which consist of it almost wholly. This body is also a normal constituent of the *blood*, but in very varying proportions (from 0.0025 to 0.0200 per cent.); it increases in that of old persons, and on the occurrence of diseases accompanied with fever. Cholesterin is likewise a constant constituent of the *brain*. In *pus* it is seldom wanting. It is often found in dropsical *transudations*, viz: in great quantities occasionally in the fluid of hydrocele; also in *exudations*, especially in softening tubercles, old sacs of echinococci, degenerated ovaries, and testicles; also on the inner coat of *atheromatous* arteries, in *tumors*, particularly encysted tumors (me-

Fig. 10.

Crystals of cholesterin, with mucous corpuscles and blood-discs.

licera), cholesteatomata, and carcinomata. From the bile, cholesterin passes into the *solid excrements*, and thus is found in *meconium*.

We are wholly in the dark as to the *source* of cholesterin. It is never found in the vegetable kingdom. Its theoretical chemical constitution is so little ascertained, that no hypothesis of its mode of origin can be grounded thereupon; but its mode of occurrence in the animal body indicates that it is to be regarded rather as a product of metamorphosis and an excretory substance. It scarcely appears to subserve any important purpose in the animal body previous to its excretion.

The two easily crystallizable lipoids, CASTORIN, which is found only in castor, and AMBRIN, found in amber, have been too slightly investigated, chemically, to possess as yet any physiological interest, even on account of their rarity.

SEROLIN, so called, is nothing more than a mixture of the crystallizable fats contained in the serum of the blood.

NON-NITROGENISED NEUTRAL BODIES. CARBOHYDRATES.

The substances belonging to this class have been called carbohydrates, because in them, together with carbon, hydrogen and oxygen exist in the same proportions as in water; it is also worthy of remark that, according to the determinations of their atomic weights, the number of atoms of carbon is always divisible by 6. In spite of the numerous investigations which have been made with several, at least, of these substances, it is still impossible to form an exact conception of their theoretical constitution. However different the physiological properties of these bodies may be, even when perfectly isomeric, they have many resemblances in their products of decomposition. They are all so indifferent as to unite with difficulty with other bodies, and generally in several proportions. They are all decomposed by heat, forming acid products of distillation, and inflammable gases together with watery vapor. By digestion with dilute acids, they pass generally into grape sugar. By concentrated nitric acid, they are changed into oxalic, or mucic and saccharic acids; other concentrated mineral acids produce from them humus-like substances. As is known, these bodies are separated into four groups—sugars, gums, starches, and vegetable fibrin. The following individual members only of these groups stand in relation to animal chemistry:—

Grape sugar . . .	$C_{12} H_{12} O_{12} + 2HO$.
Lactin	$C_{12} H_{12} O_{12}$.
Inosit	$C_{12} H_{12} O_{12} + 4HO$.
Paramylon	$C_{12} H_{10} O_{10}$.
Cellulose	$C_{12} H_{10} O_{10}$.

GRAPE SUGAR, or *mucous sugar* (so called), glucose, is always found in the primæ viæ after the enjoyment of saccharine and amylaceous food, especially in the small intestine; the quantity is generally small, since the sugar is immediately absorbed as fast as formed from the starch. In the *chyle*, only traces of it are found after amylaceous diet. Sugar is a constant constituent of the *blood;* that of the hepatic veins is especially rich in it, while in that of the portal vein (although so much sugar is developed in the intestinal canal, and necessarily absorbed by the veins) only traces of it are accidentally found. Sugar passes into the *urine*, in normal conditions, only when very large quantities are partaken of at once, or in a short space of time; and then not commonly, as it is rapidly decomposed in the bladder. It passes readily into the urine when it has been injected into the veins in sufficient quantity. Direct experiments on rabbits have taught us that when the proportion of sugar in the blood rises above 0.4 per cent. it appears in the urine; if there is less than this in the blood, it is decomposed within the circulation. In that very obscure disease, *diabetes mellitus*, notable quantities of sugar are daily excreted with the urine. In other diseases, sugar has seldom been seen to pass into the urine; the circumstances and conditions under which this happens abnormally are as yet by no means satisfactorily established. The discovery that the injury of the base of the fourth ventricle of the brain—that is, of the medulla oblongâta at a certain point—is followed, for several hours, by the presence of sugar in the urine, has been confirmed, though no satisfactory explanation of the fact has been presented. In the fluids of the *amnion* and *allantois*, sugar has occasionally been found. In the *white* and in the *yolk* of the egg a little sugar is constantly present; during incubation, its proportion appears to increase. In the *parenchymatous fluid of the liver*, sugar is also found, when neither amylaceous nor saccharine food has been introduced into the organism. In the liver of man, mammalia, and birds, the proportion of sugar is much more important than in that of reptiles; in the recent liver of man, mammals, and birds, we find, on an average, 2 per cent. of sugar; in that of reptiles, at most, 1 per cent. It is remarkable that sugar appears not to be contained in the liver of fishes. In disease, it frequently vanishes from the liver.

In diabetes, sugar is found in all the *serous fluids*, in the *saliva*, in the *matters vomited*, in the *solid excrements*, and occasionally even in the *sweat;* not, however, in the brain, spinal marrow, pancreas, or spleen.

Two *sources* of sugar in the organism are apparent: the saliva, the pancreatic and intestinal fluids, change the starch of the food into sugar. It is, however, also developed in the liver, probably from nitrogenised matters; this is rendered probable not only by the abundance of sugar in the liver, but also by the circumstance that the blood flowing to the liver (that of the portal vein) is so poor in sugar, while that flowing from it (that of the hepatic vein) is richer therein than the blood of any other vessel.[1] Under

[1] See note on the blood of the hepatic veins.

"Metamorphosis of Tissue" we will treat more at large of the high physiological importance of sugar.

LACTIN appears to be an integral constituent of the *milk* of all the mammalia; it is found, however, in far less proportions in that of carnivorous than in that of herbivorous animals. (As to the quantities of sugar contained in the milk of different animals, see "Milk.") Lactin has not been hitherto detected with certainty in other animal fluids. As only the fermentable grape sugar is found in the blood, it is more than probable that lactin is first developed in the mammary glands, and from the former. The object of this sugar for the nourishment of the suckling will be discussed under "Metamorphosis of Tissue."

INOSIT, a sugar incapable of the vinous fermentation, is found, singularly enough, only in the juice of the *cardiac muscle.*

PARAMYLON, a substance closely resembling starch, has been found in the body of an infusorial animal, *Euglena viridis.*

CELLULOSE, which forms, as is known, the basis of all vegetable cells, is found only in some of the lower animals, *e.g.* in the mantle of Phallusia mammillaris, in the cartilaginous covering of the simple Ascidiæ, in the leathery mantle of the Cynthiæ, and in the external tube of the Salpæ. Whether cellulose, or a similar substance, exists in certain parts of the brain of higher animals, as also in certain pathological deposits, is still very doubtful.

[The existence of cellulose in the human economy is now generally acknowledged by physiologists. It has been found normally in the ependyma of the brain, and pathologically in that form of degeneration of the spleen known as the "waxy spleen." Its occurrence in other organs is still doubtful.—J. C. M.]

ANIMAL COLORING MATTERS.

The coloring matters, especially those which are animal, belong to the substances whose theoretical composition is but imperfectly known. To animal chemistry belong—

Hæmatin	$C_{44} H_{22} N_2 O_6 Fe.$
Bile-pigment	?
Urine-pigment . . .	?
Melanin	?

HÆMATIN is found only in the colored blood-cells of the higher animals, intimately mingled with their hæmato-crystallin; but whether the hæmatin, as separated artificially, is identical with that dissolved in the blood-cells, and whether it differs from the latter somewhat, as coagulated albumen does from uncoagulated, or whether it is wholly a product of transformation, has not yet been positively decided, as all attempts to separate soluble hæmatin from hæmato-crystallin have hitherto failed. It is scarcely to be expected but that the proportion of the hæmatin to the blood, as a whole, should alter with the number of the blood-corpuscles; but it is also at least probable that the proportion of this pigment to the blood-corpuscles, or to the hæmato-crystallin, is variable; for, on the one hand, we find the intensity of color of the individual blood-corpuscles very different, as well as the colored hæmato-crystallin artificially prepared from them; and, on the other hand, if we may judge of the proportion of hæmatin from the quantity of iron in the blood-corpuscles, direct analyses have proved a difference in the proportion of this substance in them. We are entirely in the dark as to the origin of hæmatin in the blood. That it must perform a particular function in the blood-corpuscles, is hardly to be doubted; but what this is has not yet been ascertained, for it is only an hypothesis, founded upon the changes of color which it undergoes under the influence of certain gases, that the interchange of gases in the blood is affected by its agency. Hæmatin appears to be disintegrated, like the blood-corpuscles, principally in the spleen; at least, a modification of it has been found in the fluid expressed from the latter. When blood is extravasated in the body (escapes from a vessel), and stagnates for some time in the cellular tissue or parenchyma of an organ, it is transformed into a crystalline body, generally of a pomegranate-red color, *hæmatoidin*.

BILE-PIGMENT is found, as its name indicates, in the bile, usually in solution; though it also forms either entire concretions, or their nuclei. Chemically, this pigment has been so little investigated, that we have no exact idea of the essential difference of its modifications; we only know that the original pigment, especially in man and the carnivora, is brown, *cholepyrrhin*, and that it becomes green even in the gall-bladder, by gradual oxidation, or when exposed to oxygen itself. In the bile of most birds, fishes, and amphibia, green bile-pigment, *biliverdin*, alone appears to exist. In the *intestine* the bile-pigment is very soon altered, so that, even with nitrous and nitric acids, it no longer affords the well-known play of colors;[1] it passes into a yellow pigment, which we find in the *excrements*. Bile-pigment is found in all varieties of jaundice, in the *blood* and in *serous fluids*. It is also constantly found in this disease in the *urine*, which is then colored brownish-red, and becomes green by its own acid fermentation or by the addition of acids. That bile-pigment is formed in the liver, we have the same reasons for believing as were considered valid for the development of the bile-acids there (see above, p. 79). In the meanwhile, the hypothesis that bile-pigment is produced from hæmatin has found support in the fact that the former, when detained long in the gall-bladder, is transmuted into a substance precisely similar to, and crystallizing like, hæmatoidin. The club or sausage-shaped masses of bile-pigment, *bilifulvin*, found not seldom in stagnated bile, are changed by ether, as also by drying and moistening again with water, into perfect crystals of hæmatoidin. Whether the bile-pigment has any special function to perform in the intestine, or whether it is wholly an excretory product, no opinion can be formed.

MELANIN, contained in dodecahedral cells, forms a thick layer on the inner surface of the choroid; it covers, also, in branched cells, the vessels and nerves of the frog and other amphibia. Probably the black pigment masses, also, in the black bronchial glands, in the tissue of the lungs, in the rete Malpighi of the cutis of the negro, and in melanotic tumors, consist of melanin; and perhaps also the black molecules in granular cells undergoing absorption, and in old extravasations of blood. That melanin is a product of the transformation of hæmatin, is proved both by its containing iron and its mode of origin. The physical importance of this pigment in the choroid is obvious; whether melanin fulfils important purposes in other places, we know not.

The URINE-PIGMENT, of which at least two species exist in normal, and whose different physical relations are so often visible in pathological, urine, has been as yet so little investigated, chemically, that physiology and pathology have gained nothing by the observations.

[Iron has recently been detected in the coloring matter of the urine.—J. C. M.]

[1] On the gradual addition of nitric acid (particularly if it contain some nitrous acid) to bile, or any fluid containing unaltered bile-pigment, the latter becomes first green, then blue for an instant, passing rapidly into violet, red, and finally yellow.—J. C. M.

HISTOGENETIC SUBSTANCES.

The nitrogenised substances universally distributed in the animal organism, which belong here, have been, chemically speaking, subjected to numerous and careful investigations; but we have not yet succeeded in forming an accurate opinion as to their theoretical composition, and the relations of the members of this class, in some respects so similar, to each other. In this most important part of Zoochemistry, theoretical chemistry affords us but few points of support. The cause of this much-to-be-regretted phenomenon is to be sought in the fact that we have not succeeded in fixing the atomic weight of any one of the substances belonging to this class; in fact, probably no one of them has been obtained absolutely or chemically pure. The numerous elementary analyses of them have, with their doubtless too high atomic weights, led to no results which can be relied upon. Hence we cannot make use of these analyses to unfold the relations of these substances to the matters which result from them in the metamorphosis of animal tissues. Thus we are deficient in the very foundations for a theory of animal tissue-metamorphosis; for without a knowledge of the essential constitution of these important substrata of the animal organism, we can, at best, prepare only a tissue of hypotheses, or must content ourselves with arraying together physiological facts.

Precisely because the chemical characters of these substances cannot be drawn in a few strokes of the pen, we must enter more closely, in zoochemistry, into their physical and chemical relations than we have done with regard to other chemical substances more exactly investigated.

Dried in the air, they are all solid and pulverulent, or form gelatinous, brittle, translucent lamellæ; in the moist state, they are sometimes transparent and yellowish, sometimes not transparent and white, sometimes firm and elastic, or soft, tender, and viscid, sometimes gelatinous. Only one of them all has hitherto been obtained crystallized. They are all tasteless and inodorous, generally insoluble in water; the few that are soluble lose this property, some by heating, some by concentrated alcohol, and some by acetic acid. Although very hygroscopic, they form no definite hydrates with water. They are wholly insoluble in alcohol, ether, and other indifferent menstrua. No one of them can be volatilized without decomposition. On being heated they are decomposed, yielding water, and developing together with ammonia a great number of different nitrogenised neutral and basic products, besides non-nitrogenised. By boiling with water they are all metamorphosed, and in this respect have been divided into *albuminoid* and *gelatin-yielding*. They are disintegrated by concentrated sulphuric and hydrochloric acids, forming, especially after long digestion, together with ammoniacal salts, brown, humus-like substances which contain principally leucin and tyrosin, and a crystallizable, volatile substance of offensive odor, which has not been more closely investigated. By concentrated nitric acid, especially when warmed with it, they are colored yellow. The mode of decomposition of these substances by oxidizing agents, as chromic acid, or binoxide of manganese and sulphuric acid, is worthy of remark; the non-nitrogenised products which arise all belong to the volatile fat acids, from formic to caproic acids, or their aldehyds; they afford also benzoic acid and oil of bitter almonds; with ammonia they form likewise the nitrils of those acids, especially prussic acid and valeronitril (*i. e.* cyanide of hydrogen and cyanide of valyl). By caustic fixed alkalies, either by means of long digestion of their solutions or on being melted with them, they are changed into a number of nitrogenised basic and neutral substances, leucin, glycin, methylamin, &c., ammonia, formic, and carbonic acids being at the same time developed.

Especially worthy of notice is the liability of these substances to undergo, without visible or recognizable co-operation of other materials, mainly through the influence of ordinary atmospheric influences, so-called spontaneous processes of decomposition—in a word, putrefaction; while all other substances, when chemically pure, undergo no decomposition by means of the atmosphere alone. The duration of their resistance to atmospheric influences depends very much on their state of cohesion; hence tendon putrefies less easily than areolar tissue, and coagulated albumen more slowly than uncoagulated. The results of putrefaction are, carbonate of ammonia, sulphuret of ammonium, butyrate and valerianate of ammonia, leucin, tyrosin, &c.

There is still another property of these bodies which must not be overlooked, viz: that they are always accompanied by other substances, such as fat, alkaline and calcareous salts, from which they cannot be separated without decomposition. It is, unfortunately, hard to determine how far these accompanying substances are chemically combined with these bodies, and how far they are simply mingled. Hence it has been so far impossible, as the majority of them want the property of crystallization, to obtain them themselves or any of their combinations chemically pure. Clearly defined chemical compounds with these substances have not been attainable; partly because they unite in very numerous proportions with other substances, as oxide of lead, &c., and partly because even in these combinations, the above-mentioned appendages follow them, and cannot even then be entirely separated.

These bodies may be divided into two great groups, which also express in several respects the physiological functions of the individual members of them; the first group embraces the albuminoid substances, or so-called PROTEIN BODIES; all the chemical qualities of these substances, their forms of metamorphosis and modes of decomposition, indicate clearly that a peculiar type must be common to them, but what this type is, what the chemical fundamental idea of their constitution, the numerous researches hitherto made have not been able to ascertain. That their physical characters are very similar, results from the fact that these protein bodies are either dissolved in the fluids of the animal body which subserve nutrition, and hence are subject to the most active tissue-metamorphosis, or are stored up in the organs of greatest vital activity, *e. g.* the muscles and nerves; while the members of the second group are found generally in those tissues which are subservient to the organism merely by their mechanical properties.

As the latter in all probability result from the protein bodies, we call them, as they have no common chemical character, simply PROXIMATE PRODUCTS OR DERIVATIVES OF THE PROTEIN BODIES. We see here, again, in these most important elements of the animal body, the proposition confirmed, that the physiological function of a substance is always dependent upon its chemical nature; for while the derivatives of the protein bodies, which generally firmly resist artificial, chemical, and atmospheric influences, are useful almost solely by their physical properties, we see in the protein bodies substances which are the actual factors of animal tissue-metamorphosis, and by means of which the most important functions of the animal organism are accomplished. They are eminently fitted for this by their chemical nature; their chemical equilibrium is very unstable; they undergo on account of their, at all events very complex, constitution, transformations, which we are not yet in a condition to follow chemically, nor even to conjecture; according to recent observations, however, oxygen and carbonic acid act very quickly on them, modifying them importantly, while it has been believed hitherto that these gases were able to affect them only after some time in consequence of putrefactive processes.

PROTEIN BODIES.

These bodies exist in the animal organism under so many forms, and with such various chemical qualities, that we are entirely in doubt, owing to the impossibility of obtaining them individually pure, whether we have to do with isomeric or polymeric modifications, or with different combinations of the same elementary substance, or only with bodies of analogous constitution. We must hence, from the want of a scientific chemical basis, hold to the common classification and statement of these substances, and adduce the following as individual members of this group:—

Albumen.
Fibrin.
Syntonin (musculin).
Casein.
Globulin.
Hæmato-crystallin.

[The generic designation of this class of bodies has been retained, although the hypothesis upon which it is based is no longer maintained by physiologists. The fact remains unchanged, that all of them are capable of yielding, upon certain chemical treatment, a substance differing slightly in some of its reactions according to the source whence it was derived, but similar in its general behavior, to which the name of *protein* was given. This substance was supposed to give rise, by its combination with sulphur, phosphorus, oxygen, and various salts, to the bodies comprised in this class; but it has been found impossible wholly to separate all of these substances from it without destroying its identity; sulphur and phosphorus especially, have been found necessary to its integrity. Hence the hypothesis has fallen to the ground; but the designation is still convenient, to indicate those bodies which resemble albumen in their reactions.—J. C. M.]

One of the most striking peculiarities of these substances consists in the fact that they all exist under *two modifications* differing importantly from each other. They exist in the animal organism in only one of these, commonly called the soluble modification, even when they are not dissolved and cannot be artificially dissolved in water. They undergo, however, especially by boiling, so important an alteration in their state of cohesion and the degree of solubility, that they present themselves as very different from the original substances. This passage from the more soluble into the more insoluble modification has been called *Coagulation* (*Gerinnung*), without our being hitherto enabled to ascertain exactly the chemical alteration which takes place. It might be thought that coagulation depended simply on a rearrangement of the molecules resembling the passage of oxide of tin, titanic acid, &c., by heat into the insoluble state; but direct observations have shown that, in the coagulation of the protein bodies, something is separated from them, although this amounts only to 2 per cent. of the original substance; it is almost proved that in the coagulation of albumen, alkali is separated from the soluble modification; in that of hæmato-crystallin, an acid together with salts. According to this, the soluble substances are to be regarded as compounds, which by heating lose an important element, the principal part thus becoming insoluble; it loses also at the same time the power of uniting itself directly with the separated substance, as is so often the case in paired substances, or the salts of the oxide of ethyl.

The *soluble protein bodies* form in the dried state, slightly yellowish, translucent, pulverizable masses, without smell or taste, soluble in water, insoluble in alcohol and ether; they are precipitated from their watery solutions by alcohol, becoming thereby insoluble; they are precipitated by mineral acids and tannic acid, but not by the other vegetable acids, or by alkalies; the salts of the metals affect them very differently, sometimes precipitating them, sometimes not. It is especially characteristic, that they are precipitated neither by acetic acid nor the neutral salts of the alkalies, but are, however, when both together are added to their watery solutions; the precipitate thus arising has properties different from the original substance, but is soluble in pure water, and hence not to be confounded with the coagulated form.

In the *insoluble* or coagulated state, the protein bodies, when recently precipitated, are white, flocculent, and lumpy, or viscid and gelatinous; when dry, white and pulverizable; more or less easily soluble in concentrated acetic acid, from their solution in which they are precipitated by ferrocyanide of potassium. With mineral salts, they enter into combinations which generally are insoluble in acidulated water, but dissolve in pure water. By concentrated nitric acid, especially when heated, they are colored intensely yellow; by concentrated hydrochloric acid, with gentle heat and prolonged contact with the air, gradually blue. They are colored intensely brownish-yellow by a solution of iodine, and red by that of proto-nitrite and proto-nitrate of mercury.

All the protein bodies contain *sulphur;* but in what shape is not yet known. That they stand to each other in relations somewhat similar to those of salicin, populin, and phorrhizin, is rendered probable by the fact, that on the application of oxidizing agents, fibrin yields more butyric and valerianic, casein more acetic, acids than albumen. Hence might be inferred, as the other products of decomposition of these bodies are very similar, the homology of these bodies; but, as homologous substances are generally isomorphic, all the protein bodies cannot be regarded as homologous, inasmuch as such similar bodies as the species of hæmato-crystallin crystallize in entirely different systems, according to the animals from whose blood they are derived.

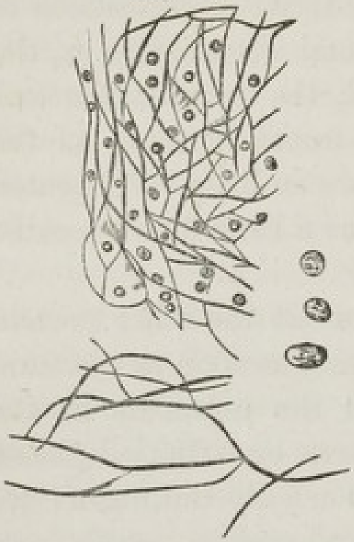
[Another hypothesis has been suggested with a great deal of plausibility: according to it, we should consider fibrin, casein, &c., as *allotropic* forms of albumen; *i. e.*, as standing in the same manner to it as graphite, stonecoal, and the diamond, do to lampblack, or pure carbon; then, as we have carbon α, carbon β, carbon γ, &c., we would also have albumen α = ordinary albumen, albumen β = casein, albumen γ = fibrin, &c.—J. C. M.]

ALBUMEN has few characteristic marks; that protein body is commonly recognized as such, the solution of which coagulates wholly at 146° F.; but it must be remembered that the coagulability is in every respect an entirely relative property: for both the temperature at which it coagulates, and the mode of coagulation, are principally dependent on substances mingled, or combined, with the albumen; by careful addition of salts of the alkalies, or of alcohol, it may be made to coagulate at almost any degree under 146° F. Excess of alkali, and excess of free acids which do not precipitate albumen, prevent its separation by heat, but it is precipitated in the insoluble form on the subsequent neutralization of the fluid even when cooled. On the evaporation of very acid or alkaline solutions of albumen, a thick, colorless film of coagulated substance collects on the surface. From slightly alkaline solutions, it coagulates in a gelatinous form, or so that the liquid remains milky; the latter has then a more alkaline reaction than previously to being heated. From perfectly neutral, or slightly acid solutions, albumen coagulates in lumps and flocculi, while the liquid becomes perfectly clear, and filters readily. By coagulation, moreover, it loses part of its content of sulphur.

Albumen forms a constant constituent of all those animal fluids which carry material for nutrition or repair to the organism, or individual parts of it: thus, it is found especially in the *chyle*, *blood*, and *lymph*, in the *egg*, *Graafian vesicles*, *&c.;* it occurs, besides, wherever normal or abnormal transudations have taken place from the bloodvessels: thus, in the fluids of serous sacs, and in the parenchymatous fluids of all vitally active organs. It forms the principal constituent of the serum of the blood: in the fluid serum, amounting to 7.8 to 9.8 per cent., or about 85 per cent. of its solid elements. The *secretions* and *excretions* of the animal body contain albumen only under abnormal circumstances; especially in an inflammatory state of the secerning surfaces. That the albumen of the animal fluids is derived from the nitrogenised [elements of] food, *i. e.*, from its protein substances, is not to be doubted; at least, the most careful quantitative analyses have shown that the quantities of protein bodies taken in the ordinary food of animals, are fully sufficient for the wants of the organism. In what manner, however, such protein bodies as casein, legumin, fibrin, &c., after they have been changed in the stomach into so-called peptones, and reabsorbed into the mass of the fluids, are changed into normal blood-albumen, is yet wholly unknown. The physiological importance of albumen as the material for the formation and nutrition of all the nitrogenised tissues of the animal organism, may be plainly seen from the circumstances under which it is found. The investigation, also, of the substances of the tissues, shows that it needs only slight modifications in order to be changed into the contractile substance of organic or animal muscles, or the contents of the nerve tubules. We know not, in the meanwhile, in what manner cells and tissues are formed from albumen. We think, indeed, that we have found among the so-called derivatives of the protein bodies, some of the transition stages from albumen to the elements of tissue; but we are still far from being able to follow, step by step, the chemical history according to chemical equations. For, even those modifications of albumen which have been found in the animal organism, *e. g.*, the coagulable material of the pancreatic fluid, the paralbumen and metalbumen of many dropsical fluids, the transformations of the protein bodies by digestion in the stomach, are so little investigated chemically, that they can in no respect serve as a basis for a scientific solution of this question.

FIBRIN, *animal fibrin*, is distinguished from all the other protein bodies especially by its property of separating as soon as the fluid in which it is dissolved is withdrawn from the organism, in the solid form, in the shape of [granules] fine fibres, or wrinkled plates. The properties of dissolved fibrin are almost wholly unknown; we know, only, that it is precipitated by ether and caustic potash from its natural solution, but not by acetic acid. Spontaneously coagulated fibrin shows several properties different from that which has been boiled. The former is a substance easily decomposed in the air, as it passes into putrefaction, with absorption of oxygen, more quickly than any other protein substance; the peroxide of hydrogen is immediately decomposed by it; it is also distinguished by its swelling up gelatinously in water containing 0.1 per cent. of hydrochloric acid, without dissolving like other protein substances, and that by digestion with a dilute solution of nitrate of potassa (1 part of the salt in 17 of water), it dissolves, forming a fluid coagulable by heat. [According to some recent observations, fibrin seems to be composed of two closely allied substances, coagulating in two different forms, fibres and granules: the former swell up, and become transparent on being treated with crystallizable acetic acid, without being dissolved; the latter, however, are dissolved in the acid, and may be again obtained on neutralizing the solution with potassa.—J. C. M.] We will speak more fully of the modifications of spontaneously coagulated fibrin under "The Blood." There are no properties to be noticed in boiled fibrin, materially different from other protein bodies. Fibrin is found in natural solution, in the *chyle* (averaging 0.1 per cent.), in the *blood* (0.3 per cent.), and the *lymph* (0.05 per cent.). The quantity of fibrin is not the same in the blood of different vessels; that of the arteries contains, on the average, more than that of the veins; there is very little in the blood of the splenic vein, none in that of the hepatic veins. The blood of newborn infants contains less fibrin than that of adults; in the latter months of pregnancy, it increases materially. In all inflammatory diseases, fibrin is considerably augmented in the blood. Only in case of genuine exudation is fibrin found in the fluids of *serous sacs*, or upon *mucous membranes*, or in the *parenchymata* of organs, and then much more rarely in solution than spontaneously coagulated. It must be concluded, from the whole occurrence of fibrin, that it is a product of the transformation of albumen. In the meanwhile, we are not yet in a condition to point out the mode and manner of this transformation. If we could rely upon the elementary analyses of these substances, the small excess of oxygen which is found in fibrin might characterize it as a product of oxidation. When oxygen is abundantly introduced into the blood, protein does not remain long in this stage of transformation; hence we find less of it in children and healthy persons than in pregnant women, and those suffering under inflammations, in whom the access of oxygen to the blood is interfered with, so that the protein is delayed longer in this stage of transformation. The physiological importance of fibrin as a transitionary state towards the more highly oxidized tissue-materials, is readily seen from what has been said. But whether all animal cells and fibres must previously have passed through the transition state of fibrin, is at present an unanswerable question.

Fig. 11.



Coagulated fibrin with blood-discs entangled among the fibrils.

SYNTONIN,[1] or fibrin of muscles, bears great resemblance to spontaneously coagulated blood-fibrin, but differs from it by *dissolving* in water acidulated with 0.1 per cent. of hydrochloric acid, from which solution it is precipitated as a jelly on the neutralization of the fluid. This jelly yields, with lime-water, or very dilute alkalies, a solution coagulable by heat; in a solution of carbonate of potassa it swells up, but does not entirely dissolve; it is also insoluble in a solution of nitre. Syntonin is the most important constituent of the substance of the fibrillæ of the transversely striated

[1] Also frequently called MUSCULIN.

muscles, as, also, of the smooth muscles or [contractile] fibre-cells (Faserzellen). How far this substance, so similar to albumen and fibrin, is subservient, more than the rest of the protein bodies, to the vital contractility of the tissue, cannot yet be conjectured.

CASEIN differs from the other protein bodies principally by its mode of coagulating, viz: it does not coagulate by heat, but does with acetic acid, and with the mucous membrane of the fourth stomach of ruminants, or the gastric juice of carnivora. Magnesia and lime salts precipitate it only on heating. Between coagulated casein and other coagulated protein bodies, there exist no actual, but, at most, only relative, differences. Casein is found in the *milk* of all the mammalia (from 3 to 17 per cent.). In the *blood*, a substance[1] has been found, in small quantities, which is very similar to casein, and hence has been called *serum-casein*. This has been found in the blood of pregnant women, and in that of the placenta, in larger quantities.

Casein is found, also, in the *interstitial fluids* of *organic muscles*, of the *thymus gland*, *areolar tissue*, *elastic tissue*, and in the fluid of the *allantois*. It is, finally, found in the *yolk* of the egg; it is here mixed with albumen, and this mixture was formerly considered a peculiar protein body, called *vitellin*. As to the genetic connection of casein with the other protein bodies, no opinion can be given, owing to our deficient knowledge of the theoretical constitution of all these substances. It must hence remain undecided whether the casein of the milk is formed in the mammary glands, or exists previously in the blood. It is further unexplained how casein appears so constantly in the milk as a means of nutrition, while, elsewhere, albumen presents itself as the principal nutritive element. It is also unknown in what relation the casein in the fluids of organic muscles stands to their function.

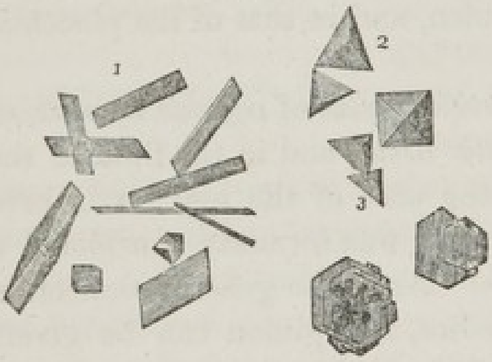
GLOBULIN is very similar to albumen; it coagulates, however, at 163° F., to a milky liquid or globular mass; when its solution, after being acidulated with acetic acid, is neutralized with ammonia, or, inversely, the ammoniacal solution is rendered neutral with acetic acid, it is precipitated; it is, finally, characteristic, that it is

[1] The substance here referred to was formerly considered as casein, from its coagulation by acetic acid: but later investigations have inclined some physiologists to the belief that it is a slight modification of albumen, to which the term *albuminose* has been applied. It is capable of endosmose (which albumen is not ordinarily), and is coagulated but imperfectly by heat. A not improbable view is, that it is merely albumen combined with an excess of alkali.—J. C. M.

precipitated from its aqueous solution by carbonic acid gas, the precipitate redissolving, however, in pure water, on the introduction of atmospheric air, or of oxygen. Globulin has been found with certainty only in the *crystalline lens* of the eye, in the proportion of 36 per cent. That this concentrated solution of it performs the office of a refracting liquid, is as evident as that the arrangement of the layers of the lens, the inner containing a denser, the outer a more dilute solution, serves the purpose of achromatization.

HÆMATO-CRYSTALLIN is the only crystallizable protein substance; but its very crystalline form shows us that, notwithstanding the most marked concurrence of most of their physical and chemical characters, we have to deal with three or four different substances. For the substance prepared from the blood of the guinea pig, rat, or mouse, crystallizes in tetrahedra, that from the blood of man and most carnivora, in prisms; that from the blood of the squirrel, in hexagonal plates; and that from the blood of the marmot, in rhombohedra. Besides their capability of crystallization, these substances, standing so close to each other, are distinguished from all other protein bodies, by not being precipitated by nitrate of silver, bichloride of mercury, chloride of zinc, or basic acetate of lead, but only by proto-nitrate of mercury, and bichromate of potassa. Coagulation takes place with them between 145° and 149° F., and the supernatant fluid then reddens litmus. All these bodies retain obstinately the blood-pigment, so that they have not been yet presented free from it. Hitherto, beside their crystalline forms, differences in solubility only have been found between the several members of this group. These substances occur only in the colored blood-corpuscles of vertebrate animals; they have been obtained, crystallized, from the blood of all animals hitherto examined with regard to them. In our perfect ignorance of their chemical constitution, no opinion can be formed of their genesis: the question of their physiological function will be considered under "The Blood."

Fig. 12.



CRYSTALS OF HÆMATO-CRYSTALLIN.—1. Prismatic from human blood. 2. Tetrahedral from that of the guinea pig. 3. Hexagonal from that of the squirrel.

PROXIMATE DERIVATIVES OF THE PROTEIN BODIES.

Under this head we enumerate several substances whose chemical constitution has been by no means sufficiently investigated, and which constitute the essential principles of several tissues of the animal organism, namely:—

Glutin-yielding substance.
Chondrin-yielding substance.
Substance of the elastic tissue.
Fibroin, and
Chitin.

These substances, beside their insolubility in neutral menstrua, have only in common the want of the essential properties of their parent substances, the protein bodies. Those resulting from gelatin-yielding tissues, glutin and chondrin, have been very often investigated, but a fixed view of their composition has not yet been obtained, notwithstanding the close analogy of their properties.

GLUTIN, also called *bone glue, colla*, as is well known, is characterized by its solubility in hot water, from which it gelatinizes on cooling; it is precipitated from its aqueous solution by chlorine, corrosive sublimate, bichloride of platinum, tannic acid, and alcohol; by dry distillation it yields, together with carbonate of ammonia, butylamin, and picolin; with chromic acid, it gives the same products of decomposition as the protein bodies, except that it affords far more valerianic acid than they. Treated with alkalies, it affords much leucin and glycin. Glutin is obtained by boiling only from the following tissues: from the cartilages of the bones (after ossification), from tendons, cutis vera, areolar tissue, hartshorn, bladder of the sturgeon, fish-scales, the permanent cartilages (when these are ossified), and the fibrous interarticular cartilages. It has been found preformed only in the fluid of the *spleen*, and in the *blood*, in the disease which has been called leuchæmia. As cartilage and areolar tissue have, according to their elementary analyses, the same composition as the glutin resulting from them, the transformation appears to depend merely on a rearrangement of atoms. It is not known according to what chemical equation, or under what conditions the glutin-yielding substance results from the protein bodies of the organism. That its uses are principally mechanical, will be more clearly shown in "Histo-chemistry."

CHONDRIN, the *gelatin of cartilage*, differs from glutin principally in being precipitated by hydrochloric and acetic acids, acetate of lead, alum, and persulphate of iron, as well as by chlorine, corrosive sublimate, bichloride of platinum, tannic acid and alcohol. Treated with concentrated sulphuric acid it yields leucin, but no glycin: with hydrate of potassa, both. Chondrin is formed by boiling with water, from all permanent cartilages, except the fibrous interarticular and ossified cartilages. As it contains some sulphur, it has been thought to stand nearer to the protein bodies than glutin; as, moreover, bone-cartilage, before it is ossified, affords chondrin by boiling, and this is changed during ossification into glutin, there is some ground for the assumption that chondrin is an intermediate degree between protein substance and glutin. The uses of chondrin in the animal body coincide with those of the tissues yielding it.

The *substance of the elastic tissue* [or ELASTICIN] is insoluble in all known menstrua, but becomes changed, after thirty hours' digestion, at 325° F. (in Papin's digester), into a brownish substance, which does not gelatinize on cooling. It is decomposed by concentrated acids. Concentrated sulphuric acid educes from it only leucin (no glycin); by concentrated potash ley it is only decomposed after digestion for days. This substance exists in all *connective tissue* in the form of so-called nuclear fibres, in single threads, accumulated in great quantities in the proper *elastic ligaments*, e. g., in the *ligamentum nuchæ* of mammalia, in the *yellow ligaments* of the spinal column, the inferior vocal ligaments, the *fenestrated membrane* of the arteries, &c. The investing membranes of cells often consist of a substance not unlike elastic tissue. We know nothing of the chemical transformations which accompany the development of this substance. Its occurrence in the tissues named indicates sufficiently that its function is mechanical.

FIBROIN, a substance soluble only in concentrated sulphuric and hydrochloric acids, and precipitated therefrom by tannic acid, while it is decomposed by alkalies, is found only in silk and gossamer-threads.

CHITIN is a substance insoluble in water, acetic acid, or alkalies, which is decomposed by concentrated acids; does *not* melt by dry distillation, and affords *acid* distillatory products. It seems thus as if a carbohydrogen entered into its composition. This substance forms the skeletons of all insects. It is found both in their external coverings, in the wing-cases, the tracheæ, scales, and hairs. If the hypothesis is confirmed that chitin is a nitrogenised body paired with a carbohydrogen, we should advance a step towards the explanation of the formation of this substance from the food of the insects.

MINERAL SUBSTANCES OF THE ANIMAL BODY.

Our knowledge of the inorganic substances and compounds which exist in the animal body is by no means so perfect as might be expected from the condition of mineralo-analytical chemistry. This depends upon the fact that the nature of these substances was mostly determined only from the ashes; but, in incineration, entire transmutation of the elements in part, or volatilization of some of the substances, takes place, so that the pre-existing substances cannot be inferred from the constitution of the ashes; and partly also because the analytical methods applied to the investigation of these ashes were by no means in such a state as to give reliable results. The relations, moreover, of the individual mineral substances to the organic substrata of the animal body, especially to the protein bodies and their derivatives, have been far too little investigated for physiological chemistry to be able to give important conclusions on their functions in the metamorphosis of animal tissues; yet the mineral substances occurring in the animal body may be reviewed at present in the following manner:—

A portion of them subserve principally mechanical purposes in the organism. They are stored away in the solid tissues, which owe to them, at least in part, their solidity and their capability of resistance.

Another portion of the mineral substances participates actively in the metamorphosis of tissue. They thus operate rather chemically, and affect many functions necessary to life.

A third portion embraces those mineral substances which have either accidentally entered the organism, or, resulting from the metamorphoses which occur in the living body, are only to be regarded as excretory products.

Mechanically-useful Mineral Substances.

We enumerate as the mechanically-useful mineral substances of the animal body—

Phosphate of lime.
Carbonate of lime.
Phosphate of magnesia.
Fluoride of calcium.
Silicic acid.

PHOSPHATE OF LIME stands first among these substances, as upon it depends, in great measure, the solidity of the *skeleton*. Bone-cartilages, as also the so-called permanent cartilages, ossify, that is, become solid and more rigid, only as they take up this lime-salt, in connection with their histological changes.

In all diseases of the bones, of however different nature they may be, phosphate of lime is withdrawn from them as an organic material, and they thus become more brittle, or more flexible. There is, moreover, no *animal tissue* which does not contain more or less phosphate of lime. It has not yet been ascertained how far the proportion of this salt influences their physical properties. We find it dissolved in almost all *animal fluids*. It is here generally combined with the protein substances and dissolved in them, for there is no protein substance which does not afford phosphate of lime on incineration. It is, doubtless, chemically combined with them, and effects possibly some of the changes which those substances undergo in the metamorphosis of animal tissue. The protein bodies are the vehicles by which the phosphate of lime is deposited in the cells and tissues. Besides, many facts indicate that phosphate of lime is indispensably necessary for cell-formation; at least that it plays a part in the latter process, may be concluded from the fact that even in lower animals, where carbonate of lime is the principal mineral substance, phosphate of lime is accumulated wherever new cells are forming. [The fact, also, that animals, from whose food the phosphates are carefully abstracted, soon perish, points to their importance in nutrition. The necessity of this substance to the vital processes of the vegetable kingdom is shown likewise in the deterioration of soils after the removal of successive crops which abstract from them considerable quantities of phosphates.—J. C. M.] In animal *concretions*, phosphate of lime is often found largely. The quantity of phosphate of lime in the *urine* is dependent on the quantity of it taken in with the articles of diet (animal food, or the legumin, albumen, or gluten of vegetable food), and the need of it by the organism. On account of this demand, *e. g.*, phosphate of lime often disappears from the urine during the latter months of pregnancy, in spite of good diet. But a small proportion of it is found in the urine of herbivorous animals, as the lime-salt supplied barely meets the demand. That phosphate of lime is supplied to the organism not only ready formed with the food, but is developed within the body from other lime-salts and phosphates, is taught especially by the observation of eggs during incubation. Phosphate of lime is found in far greater[1] quantity in the developed embryo than in the unincubated egg.

CARBONATE OF LIME is found in smaller quantity, together with the phosphate, in the *bones* of vertebrate animals; it is deposited, on the other hand, in great quantities in the solid portions of invertebrata, where it apparently subserves the same purposes as phosphate of lime in the bones of the vertebrata. In many animal fluids, bicarbonate of lime is found in solution; it exists thus, in no small proportion, in the *parotid secretion* of horses and of dogs, in the *urine*, and probably, also, in the *blood* of herbivorous animals. In *concretions—e. g.* in so-called salivary, venous, and urinary calculi —more or less carbonate of lime is found. In a crystalline form, it is constantly found on the outer and upper wall of the *oval sac* in the vestibule of the organ of hearing (in prisms, not in rhombohedra); similar accumulations of crystals are found in the Batrachians on the *dura mater*, and in white, shining sacs in the *intervertebral foramina*. There can be no doubt as to the origin of carbonate of lime from vegetable food and from the water drunk; but a part of it may be formed in the blood by the decomposition of the organic salts of lime.

PHOSPHATE OF MAGNESIA always accompanies phosphate of lime. As it occurs in the solid excrements in greater quantities than phosphate of lime, it has been inferred that the lacteals possessed a greater power of absorption for phosphate of lime than for phos-

[1] The German text probably contains here a typographical error, which I have corrected. It reads a "far less quantity." By reference to Dr. Prout's observations on incubation (*Philos. Transac.*, 1822, p. 365), we find that the quantity of phosphorus remains unchanged, but that of the lime increases by absorption from the shell through the *membrana putaminis*. This combines with the phosphoric acid developed from the glycerophosphoric acid originally present in the ovum.—J. C. M

phate of magnesia; but independently of the fact that considerable quantities of it are absorbed in the intestines, as we may conclude from its large proportion in the *urine*, we may well account for this fact from the great proneness of phosphate of magnesia to form with ammonia the insoluble crystalline salt which we never fail to find in the excrements, and often see accumulated in extraordinarily large concretions in the *contents of the intestines* of herbivora. The abundance of this salt in the cerealia sufficiently explains its origin.

FLUORIDE OF CALCIUM is constantly found in the bones in small quantities, more in fossil bones than in those of animals now living. Its proportion is greater in the enamel of the teeth, the hardness of which has been attributed partly to its containing this substance.

In the organisms of higher animals, the occurrence of SILICIC ACID is confined to the *hairs* and *feathers*. Very small quantities of it have also been found in the *blood*, *bile*, and *urine* of birds. In the *solid excrements* it is always met with, partly as actual sand, partly depending on the tissues of vegetable food. It is well known that the *skeletons of many infusoria* consist mainly of silica.

Chemically-operating Mineral Substances.

We enumerate as the mineral substances which take part especially in the metamorphosis of tissue and operate more chemically—

Hydrochloric acid.
Chloride of sodium.
Carbonate of soda.
Phosphates of the alkalies.
Iron.
[Water.]

HYDROCHLORIC ACID exists free only in the *gastric juice*, although [there] rather perhaps as a paired acid. Without free acid, the gastric fluid possesses no digestive power, and lactic acid only can supply the place of muriatic acid in it. What chemical processes in the gastric follicles set this acid free, is as yet entirely inexplicable.

CHLORIDE OF SODIUM is contained in all parts of the organism, solid and fluid. It is an important fact that this substance, on one hand, forms constantly the greatest part of the soluble constituents of the ashes of animal fluids, and, on the other, that it is contained in most of the animal fluids, and especially in the blood, in nearly constant quantities, independent of the quantity of salt in the food. The distribution of chloride of sodium in the animal organism is by no means accidental; while it is accumulated in the serum of the blood, in the chyle, lymph, white of the egg, as also in alkaline fluids, in large quantities, it diminishes in the blood-corpuscles, in the fluids of muscular flesh and of the thymus gland, and in the yolk of the egg, so that often only traces of it can be detected. In the blood-serum, moreover, its proportion stands in an inverse ratio to that of albumen, to a certain degree; the less albumen is contained in the blood, the more chloride of sodium do we find in it. In transudations it is, for mechanical reasons, contained in quantities larger, relatively to albumen, than in the serum. It is found in especially large quantities in the saliva, gastric fluid, mucus, pus, and inflammatory exudations. As we shall have occasion to enter on the physiological value of chloride of sodium in the consideration of the metamorphosis of animal tissue, we say nothing here of its application to physiological purposes.

CARBONATE OF SODA is mostly developed by the incineration of organic matters; but it also is found pre-existing in the *blood*, *lymph*, *transudations*, *saliva*, and *urine* of herbivorous animals. The various purposes which this salt has to fulfil in the blood and other fluids, will be brought under observation partly under the latter and partly under "Metamorphosis of Tissue" in general.

PHOSPHATES OF THE ALKALIES exist in most of the animal fluids, but in very different quantities: it is worthy of remark that they are opposed exactly to the chloride of sodium as the potash salts to the compounds of sodium; hence they occur in greatest quantities where the soda salts, and especially chloride of sodium, are deficient—thus, in the *blood-corpuscles*, the *yolk of the egg*, the *fluids of muscles*, and of the *thymus gland;* on the contrary, they are found in but very small quantities in the alkaline fluids of the animal body—as in the blood-serum, in the white of the egg, &c. As, according to this, they are abundant in the acid fluids, there will be found there most acid phosphate of potash—as *e. g.* in the juice of flesh. Their proportions in the *urine* are as much dependent on the relations of the articles of diet, and the demand for these salts for the metamorphosis of tissue, as those of the earthy phosphates and chloride of sodium.

As the earthy phosphates are mostly introduced into the organism in vegetable food, these alkaline salts are probably formed within the organism by double elective affinity. Their physiological function will be more fully discussed under "Exudations" and "Metamorphosis of Animal Tissue."

IRON, which we find in the animal body—partly as chloride, as in the *gastric fluid;* partly as phosphate of the oxide, as in the *fluid of the spleen;* partly in an organic combination, as hæmatin in the *blood-corpuscles*—plays a part in the animal economy at present incomprehensible to us. That this is a not unimportant one, is indicated by its occurrence in the ashes of *milk*, as also of the *egg*. Iron is excreted principally by the liver, for we find it especially in the *bile*. Our ordinary diets and drinks contain so much iron, that the source of that found in the body is easily ascertained.

[Among the mineral substances of the animal body which are active in consequence of their chemical properties, WATER holds an important position. Chemical actions generally occur much more readily when the substances concerned are in solution than otherwise; hence the almost universal solvent powers of water entitle it to a short notice. Its source in the organism is mainly the drink which is taken in connection with the food; it assists in digestion, not only by dissolving the food as prepared by the digestive fluids, but also by promoting its passage into the capillaries by endosmose. It is also largely developed in the various vital processes which take place in the organism, from the carbohydrogens and carbohydrates of the food, as well as from the tissues, in the course of retrograde metamorphosis. Its proportion in the different tissues is various, but always large; hence it is one of the principal constituents of the human frame. The quantity of water contained in the tissues varies with the age, being greatest in infancy, and least in old age: in fact, *natural old age* is said by some physiologists to consist in a *drying up* of the tissues. It is excreted from the economy principally by the kidneys, lungs, and skin, a balance being maintained in the blood between that received and formed in the organism and its other constituents by means of these organs. Pathologically, it may be in excess in the blood, constituting anæmia (or, more properly, hydræmia), and giving rise to dropsy, diarrhœa, &c.; or it may be deficient, as in cholera, &c. The demand of the organism for water is expressed by the sensation of *thirst*, which is referred to the fauces: so powerful is this instinct, that the will does not possess the same control over it as over the other instinctive desires of our nature; thus, no instance is on record of self-destruction by voluntary abstinence from water.—J. C. M.]

Accidental Mineral Substances of the Animal Body.

To the accidental mineral constituents of the animal body we refer—

Sulphates of the alkalies.
Carbonate of magnesia.
Manganese.
Arsenic.
Copper.
Lead.
Salts of ammonia.
Sulphocyanide of sodium.

The SULPHATES OF THE ALKALIES are found pre-existent in nearly all animal liquids, but, except in the *urine*, in very small quantities. The analyses of the blood, and other liquids rich in protein, yield, indeed, often large quantities of sulphates; but these have arisen mostly from the incineration of the protein bodies which contain sulphur. In the *blood* there are very small quantities pre-existent, as they are soon withdrawn from it by the kidneys. Their proportions in the *urine* are very variable, according to the supply from without. The total absence of them in the milk and in the non-incubated egg indicates that they can fulfil no important purpose in the animal tissue-metamorphosis, but are products of tissue-metamorphosis of a purely excrementitious nature. It is remarkable that in the bones of reptiles and fishes there exist, pre-formed, no small quantities of sulphates.

CARBONATE OF MAGNESIA presents itself but rarely in the organism, in the *bones*, and in *concretions*. In the *urine* of herbivorous animals it is often met with in greater quantities. As the phosphate of magnesia, not the carbonate or compounds with organic acids, is contained in the cerealia and grasses, the carbonate found in the urine of herbivora is probably formed in the metamorphosis of tissue.

MANGANESE is found only in very small quantities accompanying iron, as it so often does in the mineral kingdom. Like iron, it is principally excreted through the liver in the *bile*.

ARSENIC was long esteemed a constant constituent of the animal body, but it appears to enter the organism only under very favorable circumstances, and then to be excreted in the *bile*.

COPPER and LEAD were also thought to exist in small quantities in the organism of the higher animals; but they have been detected with certainty only occasionally in the bile and biliary concretions of man and of oxen. In the blue *blood* of some of the ascidiæ, cephalopoda, and mollusca, copper has been recognized as an integral constituent.

AMMONIACAL SALTS are found far more seldom in the animal organism than was previously supposed; even in the *urine* their quantity is normally extremely small. Here, as in the *sweat*, ammonia is developed only after its discharge, in the air. The ammonia found in *air after expiration* is probably also not directly excreted from the blood. Only in the *gastric fluid* have minute quantities of sal ammoniac been detected with certainty; but, in many severe diseases, ammoniacal salts, particularly carbonate of ammonia, occur in the gastric fluid, the blood, and especially in the urine.

SULPHOCYANIDE OF SODIUM has hitherto been found only in the saliva, in extremely small quantities, although pretty constantly. Its origin, as well as its probable uses, are yet unknown.

PHLEGMATO-CHEMISTRY.

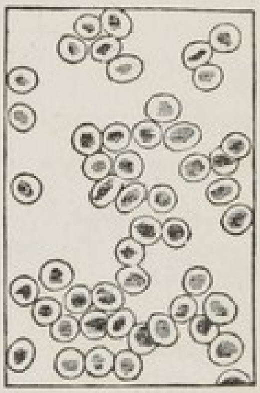
THE SCIENCE OF THE ANIMAL FLUIDS.

We have already spoken of the mode of treating this portion of physiological chemistry in the general introduction. It is only necessary here, therefore, to mention that the requirements for a successful investigation of the animal fluids and of their physiological importance, are small neither in number or importance. In consequence of the difficulties of fulfilling all these requirements, we find, in our knowledge of the science of the fluids, chasms even more important than in the knowledge of zoochemistry. How difficult it is, *e. g.*, to obtain from certain animal fluids the pure material requisite for investigation. With several, as, for instance, that of the colon, this has so far been impossible. There are greater hindrances to analysis to be struggled with here than in any other field of investigation. The protein bodies, generally contained in great quantities in animal fluids, are too little known and investigated chemically to permit of their being always accurately isolated or separated by analysis. Other substances, often highly essential for the physiological recognition of the importance of an animal fluid, are frequently contained in quantity far too small to be accessible for an exact chemical investigation. We have already alluded to the doubtful investigation of the constituents of the ashes (p. 115). In addition to this, it often happens that in the fluid a quantity of suspended morphotic elements is contained, which cannot be separated mechanically; so that a pure object cannot, on this account, be obtained. Hence quantitative analyses of animal fluids attain a relative degree of certainty only by the application of different *controlling methods*. It is, then, almost self-evident that, since the analysis of the animal fluids is so imperfect, we can with difficulty attain to results in anywise reliable as to the physiological function, the origin, application, and destruction of an animal fluid. Though we may, by ascertaining the mass of the constituents which can be quantitatively determined, and their sum total, reach certain points of observation, which support, at least in a measure, the hypotheses to be adduced, and thus afford us certain values for judging of the mechanical metamorphosis of tissue in the animal organism, yet the grounds are still wanting for a knowledge of the far more important chemical metamorphosis of tissue, without which the science of the chemical processes in living animal bodies must remain merely a tissue of logical hypotheses, possessing various degrees of rational support.

THE BLOOD.

By the blood we understand that fluid which flows through the bodies of the higher animals in more or less elastic tubes, and is set in motion by special organs. The *physical properties* of the blood are as follows: It is a thick liquid, considerably denser than water (on an average 1.055 sp. grav.); generally of a bright cherry-red color (arterial blood always being much lighter, venous much darker); very slightly translucent. As soon as it has passed from the current of circulation in the animal body it becomes more viscid, gelatinous (by coagulation), and finally separates into a solid, thick, generally dark-red mass (the *clot*), and a tolerably clear, slightly yellowish fluid (the *serum*). The specific gravity of human blood varies, under physiological circumstances, between 1.045 and 1.075. It is less in women than in men, in children than in adults, and in pregnant women than those not pregnant. Its *capacity for heat* stands in direct proportion to its density. The *coagulation* of the blood may be divided into three periods. In from two to five minutes after its withdrawal, it becomes viscid and gelatinous on the surface. After seven to fourteen minutes, it has become a consistent jelly. After this time, a layer of thin, colorless, or pale-yellow fluid appears on the surface, which increases in quantity in the same degree that the red, jelly-like, contracting mass diminishes in volume. After from twelve to forty hours, the clot usually ceases to contract, and the serum is no longer pressed out. The fully-contracted clot has generally the form of the vessel, in which the blood has coagulated, in diminished proportion. Its lower part is of a darker, the upper of a brighter red color than the original blood. The blood of men coagulates more slowly than that of women. The clot of the former is usually more firmly contracted. Arterial blood coagulates sooner than venous. An abundant supply of oxygen hastens coagulation. By shaking, moving, twirling with sticks (or beating, as it is called), freshly-drawn blood forms, instead of a single consistent coagulum, small red flocculi and lumps of varying size and number. By the microscopical observation of the blood, we learn that it contains, besides a fluid holding substances in solution, morphotic, *i. e.*, solid, undissolved, peculiarly-shaped materials; and that the *liquor sanguinis* (*intercellular fluid, plasma*) is colorless, but the great majority of the suspended molecules colored. The colored molecules (*red blood-corpuscles*), which are of far more consequence than the colorless morphotic elements of the blood, form in man thick, circular, slightly biconcave discs, which consist of a colorless investing membrane, and red, or by transmitted light yellow, viscid contents. In some, one or more amorphous granules are occasionally met with. The blood-corpuscles of most of the mammals form likewise circular discs, except those of the camel, dromedary, and lama, which are elliptical and biconvex. Birds have long oval blood-corpuscles, elevated in the centre, and becoming thin at the margin. Those of the amphibia are oval and very convex. Human blood-corpuscles average $\frac{1}{300}$ of a Paris line in diameter. Those of the embryo are somewhat larger than those of the breathing animal. Those of most mammalia are somewhat smaller than those of man; while those of the amphibia are far larger (as much as $\frac{1}{72}$ of a line).

Fig. 13.



Red blood-corpuscles (human).

With the red blood-corpuscles there are found, in all blood, so-called *colorless corpuscles* (*lymph-corpuscles*), which are more spherical, much larger ($\frac{1}{200}$ of a line), and granular on the surface. They contain either one or several roundish, oval, or kidney-shaped nuclei. They are lighter than the red corpuscles, and hence remain suspended in the serum, or are generally collected in the upper part of the clot. The proportion of the colorless corpuscles to the red is as 1 to 400 in normal human blood. We find, with the microscope, besides the above-named corpuscles, no other substances, except a few fat globules, and now and then an epithelial cell.

The *liquor sanguinis* contains, together with other substances, *fibrin*, that material on which the coagulation of the blood depends. The clot consists of coagulated fibrin, which, in its separation, has entangled the blood-corpuscles and other morphotic elements. It is still well moistened with the serum.

The *serum*, which is gradually expressed by the contraction of the clot, has the same composition, whether the first or last drops of the expressed fluid be examined. Its specific gravity varies but little from 1.028.

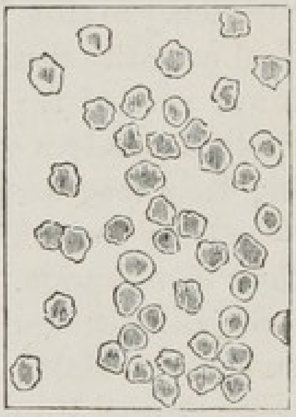
It is self-evident that the blood-corpuscles and their viscid contents must have a different composition from the intercellular fluid or the serum; but, from the ready diffusion of certain elements of the blood, these might have been expected to be equally distributed in the contents of the blood-corpuscles and the serum. This, however, is not the case. For the purpose of an easier comparison of these relations, we have placed, side by side, the composition of both, according to the best analyses hitherto obtained:—

1000 parts of blood-corpuscles contain—		1000 parts of liquor sanguinis contain—	
Water	688.00	Water	902.90
Solid constituents	312.00	Solid constituents	97.10
Spec. grav.	1.0885	Spec. grav.	1.028
Hæmatin	16.75	Fibrin	4.05
Hæmato-crystallin	241.07	Albumen	78.84
Cell-membranes	41.415		
Fat	2.31	Fat	1.72
Extractive matter	2.60	Extractive matter	3.94
Mineral substances (except iron)	8.12	Mineral substances (except iron)	8.55
Chlorine	1.686	Chlorine	3.644
Sulphuric acid	0.066	Sulphuric acid	0.115
Phosphoric acid	1.134	Phosphoric acid	0.191
Potassium	3.328	Potassium	0.323
Sodium	1.052	Sodium	3.341
Oxygen	0.667	Oxygen	0.403
Phosphate of lime	0.114	Phosphate of lime	0.311
Phosphate of magnesia	0.073	Phosphate of magnesia	0.222

The *physical properties of the blood-corpuscles* are not without influence on certain changes which the blood undergoes in different physiological and pathological circumstances. It must always be remembered, in considering these changes, that the blood-corpuscles are vesicles, never filled to distension with the red, viscid fluid;

and that, especially in the blood while circulating, endosmotic currents constantly take place between this red fluid and the intercellular fluid, which cause the vesicles sometimes to expand, sometimes to contract; and, consequently, that their specific gravity will vary according as more or less watery fluid has passed from the plasma into them. The last-named fact, viz: the variation in specific gravity, is an important cause of the different "tendency to sink" (Senkungsvermögen) of the red blood-corpuscles. In different specimens of blood, the colored particles show a very different inclination to sink, *i. e.*, so to settle below the level of the liquid, that a shallower or deeper layer of colorless fluid, free from blood-corpuscles, is formed from their surface upwards. The *specific gravity* of the blood-corpuscles will increase when relatively more water is abstracted from them than from the intercellular fluid, and decrease when, by the dilution of the latter, a large quantity of water is introduced into them. This abstraction of water may be effected either by evaporation or by the addition of small quantities of neutral alkaline salts, sugar, or gum. The blood-corpuscles may also increase in specific gravity when the salts and protein substances (hæmato-crystallin) are taken from them. This happens, *e. g.*, in the circulating blood after repeated bleedings. The hæmatin remains in the corpuscles in relatively greater quantity, and hence must increase their specific gravity (since hæmatin is so rich in iron).

Fig. 14.



Blood-discs shrivelled by the loss of water.

The blood-corpuscles are specifically lighter when they contain relatively much fat (in the form of fine granules); or when, on artificial dilution of the blood with water, they are distended with the latter.

Although the "tendency to sink" of the blood-corpuscles depends principally on their specific gravity, it is materially aided by another physical phenomenon, which we notice in them, namely, their property of clinging together by their broad surfaces, and thus forming *nummular rolls.* The blood-corpuscles are never "rolled" in blood recently drawn. This mode of arrangement generally takes place under the microscope, in consequence of the partial evaporation of the water. The increased facility of precipitation of the blood-corpuscles was formerly referred entirely to this property of clinging together; but, as they sink more readily on the addition of solution of sugar and gum, without clinging together, the "tendency to sink" cannot depend upon this property alone. This tendency of the red corpuscles to adhere together was formerly referred to a greater viscidity of the intercellular fluid, dependent upon a larger proportion of fibrin or albumen in the latter; but, independently of the fact that the corpuscles often possess a very great "tendency to sink" when the fibrin has been artificially abstracted, or when the intercellular fluid contains relatively less albumen (as in inflammatory blood), this view is physically incorrect; for, when the fluid is viscid, the particles suspended in it are less easily aggregated. If viscidity is the cause of the "rolling" of the corpuscles, it can lie only in their investing membranes. Carbonic acid, which disposes the red blood-cells to the roll-like arrangement, *appears* at least to loosen the cell-membranes of the corpuscles, and thereby make them more viscid. The roll-like arrangement may often, moreover, be a consequence of the increased "tendency to sink." It must, in other words, be regarded as a physical necessity that when the corpuscles sink, *i. e.*, accumulate in the lower part of the fluid, and thus approach each other, they must apply themselves with their broad sides to each other. The following facts may serve to prove the explanation here given of the "tendency to sink" of the blood-corpuscles, and find therein also their signification. The corpuscles of the blood of the horse are especially distinguished above those of all other animals by their tendency to sink. This decreases in the following animals in the order given: Horse, cat, dog, rabbit, goat, sheep, ox, bird, hog. The serum of the blood of the horse is, indeed, very viscid; but its corpuscles sink as rapidly in the serum of other animals, and those of other animals no more rapidly in the serum of the blood of the horse. The blood-corpuscles of the horse are deficient in fat relatively to those of other animals. The corpuscles of inflammatory blood sink more rapidly than those of healthy blood. The former is richer in carbonic acid, and a little poorer in albumen, than the latter. In defibrinated blood of inflammation, the corpuscles sink as quickly as in that which has not been robbed of this material. The blood of inflammation is, however, very rich in fibrin.

The degree of color which the blood as a whole exhibits depends, in great measure, upon the *shape of the blood-corpuscles*, and thus has its cause in physical circumstances. The lighter color of the blood is referred to the shape of the contracted blood-corpuscles, resembling concave mirrors; while it is assumed that the corpuscles which have been expanded by endosmosis, like convex mirrors, disperse the light more, and thus cause the color of the blood, as a whole, to appear darker. It accords with this, that all substances which abstract water from the blood-corpuscles, and thus render more observable their central depression, *e. g.*, all neutral alkaline salts, solutions of sugar, &c., which do not decompose the blood, produce in it a bright red to a light vermilion color; while by substances, such as water, ether, and dilute organic acids, which swell up the blood-corpuscles, and almost render them spherical, the blood becomes of a dark bluish red. That this formation of mirror-like forms, nevertheless, can only be of secondary importance as to the color of the blood, is proved especially by the fact that the blood of the amphibia, containing biconvex blood-corpuscles, which can never become concave, is also colored bright red by neutral salts of the alkalies and concentrated sugar solutions. The salts by means of which the blood of mammalia and birds, as also that of amphibia, assumes a vermilion color, are the following: Sulphates of potash and soda, nitrates of potash and soda, chloride of potassium, phosphate of soda, carbonate and bicarbonate of soda, ferrocyanide of potassium, borax, iodide of potassium, sulphocyanide of potassium, sal ammoniac, sulphate of magnesia, &c.—The *thickness and folding of the cell-membranes* of the blood-corpuscles must influence the color of the blood. If they are collapsed, the membrane will be thicker; if expanded, it will become very thin, and hence allow the coloring matter to shine through in its natural hue, which is a very dark-red; just as in a thin milk-glass a dark-red fluid still appears dark-red, but, in a thick one, light-red. On this account all substances which burst or dissolve the cell-membranes, render the blood dark-red, *e. g.*, acetic acid, the alkalies, &c. The coloring matter of the blood dissolves with its natural color in the intercellular fluid. The thickening, folding, and wrinkling of the cell-membranes, are especially visible in the blood-cells of the amphibia. We see with the microscope, in the blood of these animals, when rendered bright red by the above-mentioned salts, the blood-corpuscles so contracted that they resemble rumpled elliptical membranes, or folded and spotted fragments. According to some observers, oxygen appears to contract, carbonic acid to expand, the blood-corpuscles; and these deduce the lighter color of arterial and the darker of venous blood from these circumstances.—Colorless, solid substances, reflecting light more or less strongly, which are scattered among the blood-corpuscles, render likewise the mass of the blood of a brighter red. Hence the fatty blood of drunkards, or after an abundance of fatty food, and the blood of leuchæmia, so rich in lymph-corpuscles, appears of a brighter red; as also when milk, oily emulsions, or powdered gypsum, are added to the blood. The very dark-red solution of hæmato-crystallin becomes bright red as soon as crystals separate from it. In the microscopical investigation of the blood, a form of the corpuscles is often met with which has arisen in consequence of increased evaporation, or upon the artificial introduction of neutral salts of the alkalies; the corpuscles appear more isolated, flattened, jagged, indented, stellate, or quite distorted (p. 127). In recent blood, even when taken from sick persons, no such forms are to be found. Good microscopes exhibit clearly the varied involutions of the cell-membrane as the cause of these forms.

It would be erroneous to attribute the different coloring of the blood solely to different mechanical circumstances. It is easily demonstrated that chemical circumstances also effect changes in the hue of the blood-pigment itself, especially oxygen and carbonic acid. We have not yet been able to detect special combinations of the blood-pigment with oxygen or carbonic acid; but it is clear, from the following facts, that such combinations must exist. Arterial blood, or that which has been impregnated with oxygen, appears in thin layers, of a beautiful scarlet, from bright yellowish red to yellowish dun. Venous, or that which has been impregnated with carbonic acid, hydrogen, or nitrogen, in thin layers, appears purple; in extremely thin, green. The latter is, therefore, *dichroic;* the former not. As artificially prepared, hæmatin is dichroic or monochroic, according as acids or alkalies are added to it. The difference in hue effected by oxygen or carbonic acid, is probably not to be referred solely to mechanical relations. Blood, after such copious dilution that no red corpuscles are recognizable by the microscope, becomes always somewhat lighter colored in oxygen gas, and darker in carbonic acid gas. That these gases also combine chemically with other protein bodies is proved by the fact that a solution of the globulin of the crystalline lens is entirely precipitated by carbonic acid, and the precipitate is redissolved on the addition of oxygen. On the other hand, the metameric hæmato-crystallin, obtained by treatment with acetic acid and salts of the alkalies, exhibits the reverse reaction. It is precipitated from its solution by oxygen, and redissolved by carbonic acid. We shall, moreover, see further on, that a chemical absorption of oxygen, which depends solely on the contents of the blood-corpuscles, presents itself as a physical necessity. That a chemical influence is exercised on the part of diluted acids on the cell-membranes of the blood-corpuscles, scarcely requires mention; but those salts also, which at first produce a contraction of the blood-cells, and thus cause the blood to assume a lighter hue, gradually decompose the cell-membranes; so that the blood-corpuscles are not only altered in their shape, but, after a longer or shorter time, are entirely destroyed; as a natural consequence of which the previously light-red color of the blood passes into a deep dark red. The sulphates and nitrates of the alkalies maintain the vermilion color of the blood for some time; but, with carbonates of the alkalies and sal ammoniac, it very soon passes into a dark red. Another peculiar physical property of the blood-corpuscles is that, in filtering the blood through paper, the greater part of them pass through the filter; a property, nevertheless, which they lose when concentrated solutions of salts, especially sulphate of soda, or nitrate of potassa, are added to the blood. The blood-corpuscles, however, even after the addition of these salts, soon collect together in masses upon the filter, become dark red, and then pass through the filter. If oxygen is introduced into the liquid on the filter, it is somewhat longer before the blood-corpuscles pass through. The chemical constituents of the blood-corpuscles, and the proportions in which they are combined, have been already (p. 126) detailed.

The *cell-membranes*, which previously were erroneously held to be fibrin, or deutoxide of protein, when isolated, form in the moist state a whitish-gray adhesive mass, which swells up to a jelly in acetic acid and diluted alkalies; does not dissolve in solution of nitre, even after prolonged digestion, at 98°.6; contains no sulphur, and reacts with nitric and hydrochloric acids as a protein body. If acetic acid or diluted alkalies be added to recent blood, it becomes almost dark red and gelatinous, or else may be drawn out in mucus-like threads; the corpuscles are no longer to be seen under the microscope; the cell-membranes here are not dissolved, but give rise to the sizy condition of the blood by their distension. By the addition of solution of chloride of sodium or of iodine, the membranes may again be made visible, but the blood-corpuscles themselves are destroyed. The substance of the cell-membranes is best prepared by first washing the hæmato-crystallin obtained from the fluid of the clot (which contains many cell-membranes entangled among the crystals) with water containing alcohol, until nitrate of silver no longer gives any reaction, and then treating with distilled water. The hæmato-crystallin is thus dissolved, and the membrane substance remains behind. It must then be freed from fat by alcohol and ether. That this substance of the cell-membranes has not a fixed composition, results from the two following facts. In the first place, in every kind of blood, the addition of water, or ether, or acetic acid, affects the blood-corpuscles very unequally, so that some disappear by the addition of a little water, but others remain unaltered even after the introduction of a great quantity. The blood-corpuscles of the blood of the hepatic veins are distinguished from those of all other vessels by the circumstance that they cannot be made to vanish wholly by the addition of water, but form a considerable sediment in the diluted blood. On account of the imperfection of the methods of quantitative determination, the normal *relation between the moist blood-cells and the intercellular fluid* is not established exactly; yet in the blood of adults, on an average, 51.2 per cent. (varying from 47.2 to 54.2) of moist corpuscles are found. The blood of women, especially in pregnancy, contains a smaller proportion, and this proportion continually diminishes after repeated losses of blood and other fluids. Among the animals the blood of swine is richest in corpuscles, while that of the amphibia contains relatively few. Very lately the enumeration of the blood-corpuscles has been attempted, and in a cubic millimetre[1] of healthy human blood from 4,600,000 to 5,055,000 corpuscles have been found. The so-called dry corpuscles were previously determined (see under Analysis of the Blood), and were found on the average to form 13 per cent. of healthy blood.

Hæmatin and globulin were formerly held as the principal constituents of the viscid contents of the blood-corpuscles. This globulin was held to be identical with the albuminous substance of the crystalline lens of the eye, but this is not the case; to adduce but one difference, the globulin of the crystalline lens is entirely precipitated from its watery solution by a stream of carbonic acid; the

[1] A millimetre is about equal to 0.47 of a line.

solution of the contents of the blood-cells is not. The globulin is not crystallizable; while, on the contrary, the protein body contained in the blood-cells is distinguished from all similar substances by its crystallizability. This substance is properly formed from the protein substance of the blood-corpuscles, after it has been subjected to the influence of oxygen, carbonic acid, and light. It is worthy of remark, that this substance shows in the blood of different animals, together with great similarity in other respects, different crystalline forms and solubilities. We know, thus far, of prismatic, rhombohedral, and hexagonal hæmato-crystallin. In the moist blood-corpuscles there is contained 18 to 26 per cent. dry hæmato-crystallin; in the whole blood from 9 to 12 per cent.

The insoluble ferruginous substance, which is described in organic chemistry as *hæmatin*, is not found as such in the blood, but is a product of the transformation of the actual blood-pigment. It is contained in the soluble form in the blood, and cannot be separated perfectly by any means from hæmato-crystallin, and presented pure in the soluble condition. If it may be assumed that the soluble blood-pigment, which adheres so closely to hæmato-crystallin, contains 6.93 per cent. of iron, as the artificially prepared hæmatin does, it may be calculated that the blood-corpuscles of an adult man contain 16 to 17 per cent. of it. According to some observations, it appears as if in all conditions which are accompanied with an excess of water in the blood, hæmatin exists in relatively greater quantity in the blood-corpuscles.

A not unimportant part of the *fats* of the blood is contained in the blood-corpuscles. Their quantity amounts to 2 or 3 per cent. of the moist corpuscles. They consist of margarin, olein, margarate and oleate of potassa, cholesterin and glycero-phosphate of potassa. According to some determinations, more fat is found in the cells of venous blood than in those of arterial. Besides the organic substances named, the most accurate quantitative analyses show that other substances, of which the composition is not known, exist in the blood-corpuscles, viz: the so-called extractive matters.

In reference to the *mineral constituents* of the blood-corpuscles, the above table of the composition of the blood (p. 126), taken from the best analyses, shows that, in the blood-corpuscles, the *phosphates* and the *combinations of potash* are in great excess over the chlorine and sodium combinations. The blood-corpuscles of arterial blood are always richer in salts than those of venous blood. Those of the hepatic vein are especially rich in them. The *iron* of the ash of the blood-corpuscles belongs only to the hæmatin.

In the blood-corpuscles, finally, the *gases* of the blood are especially contained. This is seen from the fact that whipped blood, which still contains nearly all of its corpuscles, possesses very considerable powers of absorption of gases, while the serum scarcely absorbs more of them than water. The gases in question are oxygen, carbonic acid, and nitrogen. Whipped blood will absorb 1½ times its volume of carbonic acid, but only 15 per cent. by volume of oxygen. Nitrogen appears not to be more largely absorbed by the blood than by water. The combination of these gases with the blood is somewhat loose, as in vacuo the greater amount can be again extracted from the blood. Moreover, one kind of gas is in great measure expelled by another. Nearly equal quantities of nitrogen are found in venous and arterial blood. In arterial there is only relatively more oxygen than in venous; for, in both kinds of blood, there are contained considerable quantities of gases which may be extracted by the air-pump. According to some observations it has been found that in arterial blood the proportion of oxygen to carbonic acid was as 6 : 16; in venous as 4 : 16. In the blood of calves, oxen, and horses, were found 10 to 12.5 per cent. of oxygen, and 1.7 to 3.3 per cent. of nitrogen, by volume. On the other hand, in arterial blood, 66 per cent.; in venous, 78 per cent., by volume, of carbonic acid, were found. That these gases are contained in the blood, and especially in the blood-corpuscles in a chemical combination, although a loose one, there is no longer any doubt. If the oxygen were, *e. g.*, only mechanically absorbed, the blood, *i. e.*, its water, could only take up 0.925 per cent. by volume, while we find, as related, from 10 to 13 per cent. in the blood. The quantity of gases taken up must here also, as in water and other liquids, be proportional to the pressure under which they stand; but this, also, is not the case. We have finally learned to recognize, in the principal substance of the blood-corpuscles, hæmato-crystallin, an organic material, which possesses a remarkable affinity for these gases, and in which, also, one gas can expel the other. Such loose combinations are not unheard of in chemistry. Carbonate and phosphate of soda absorb considerable quantities of carbonic acid (forming bicarbonate of soda). The carbonic acid thus combined may be driven out either by other gases, as by oxygen,

&c., or by greatly diminished atmospheric pressure; a property which the globulin of the crystalline lens, as we saw above (pp. 112 and 132), shares with these salts. That other gases enter into fixed chemical combinations with individual constituents of the blood, and particularly with the contents of the blood-corpuscles, which cannot be so readily dissolved by other indifferent gases, is self-evident to us; but there are some gases in which very active manifestations of affinity are not otherwise to be noticed, which combine so firmly with the components of the blood-corpuscles, *e. g.*, carbonic oxide and several carbohydrogens, that the previous nature of the blood can in no way be restored. These gases color the blood almost black, destroy the blood-corpuscles, and disintegrate the hæmato-crystallin; at least a pure solution of the latter loses by these gases not only its crystallizability, but also many of its other properties.

In whipped blood there are also found certain morphological elements, which have been called *fibrinous flakes.* They do not consist, however, of fibrin, but show, chemically, more resemblance to horny substance; they are mostly epithelial cells, partly derived from the inner coat of the bloodvessels, partly from a foreign source —*i. e.* epithelial fragments of the cuticle of the observer, which have fallen into the blood. The accumulated fragments of the cell-membranes of destroyed blood-corpuscles have also occasionally been taken for them.

As the chemical constitution of the morphotic components of the *colorless blood-corpuscles* agrees, as far as known, entirely with that of the mucous corpuscles and pus-corpuscles, we shall consider these more closely in histo-chemistry, among "Cytoid Corpuscles." The number of them in the blood, even in physiological circumstances, is very different. We find them much increased after large bleedings often repeated, in great quantities in the blood of the hepatic and splenic veins, as also in the blood in leuchæmia and pyæmia.

Among the chemical constituents of the intercellular fluid, fibrin presents itself most prominently, on account of its spontaneous coagulation. As the chemical properties of blood-fibrin are known through organic chemistry, we shall occupy ourselves here especially with the mode of coagulation of this substance in freshly drawn blood. The form of coagulation is best investigated microscopically by placing between the slide and cover-glass a drop of liquid free from blood-cells, from blood the corpuscles of which have sunk somewhat below the surface before its gelatinizing. Almost immediately there may be seen in the field several molecular granules, from which extremely fine, straight fibres very soon arise, extending like radii from each point, but not forming regular stellate masses as in crystals; these fibres elongate gradually over several points, and cross each other repeatedly, so as finally to resemble a tangled spider's web; this network becomes constantly thicker, so that the colorless corpuscles imbedded in it can scarcely be recognized. As fibrin, when examined in exsiccated drops of blood, has a lamellar appearance, many observers are of the opinion that in coagulation it separates in the form of lamellæ, and that its fibrillated appearance depends merely on a duplication of the lamellæ. It is not yet exactly known what maintains the fibrin in solution in the blood while circulating, and what disposes it to separate in the solid form after being drawn; but it is probable that by the access of atmospheric air—*i. e.* of its oxygen—such a change takes place in the dissolved fibrin, that it becomes insoluble in the alkaline liquor sanguinis. The spontaneous coagulation of the fibrin in the blood is delayed by the presence of an excess of carbonic acid, and by the addition of dilute solutions of sulphates, nitrates, hydrochlorates, carbonates, or acetates of the alkalies; by concentrated solutions of these salts it is wholly prevented. As fibrin, in coagulating, always incloses morphotic elements, especially colorless corpuscles, it has not yet been possible to present it chemically pure. In the coagulation of the blood, various modifications show themselves under different physiological and pathological circumstances; thus, the period within which it commences or is completed, the *period of coagulation*, is in the first place somewhat various. Various causes influence this. *Violent agitation* of the blood, produced by shaking or stirring, hastens the separation of the fibrin. Free access of *atmospheric air*, or *oxygen*, has the same effect; hence blood coagulates quicker in shallow vessels than in deep ones, as also when it trickles slowly from a vein than when it flows freely in a stream. *Carbonic acid* delays coagulation; hence, in cyanosis and inflammatory processes, the blood coagulates slowly. *A watery condition of the blood* hastens coagulation; but the addition of large quantities of water to the blood, after it has been drawn, delays it. Thus the watery blood which we always find in women, but especially in anæmia, coagulates much more slowly than the blood of men or healthy persons. How far the salts which have been mentioned above influence the period of coagulation in diseased blood, is not yet precisely ascertained. One fact remains, the addition of *solutions of albumen, casein, or sugar* to the blood, retards its coagulation. The influence of *temperature* has not been very closely investigated; we only know that, when blood is frozen before or during coagulation, after thawing, it coagulates as if it had not been frozen. The *quantity of fibrin* in the blood is probably without influence on the period of coagulation. Why, finally, the blood does not coagulate in the corpses of those struck by lightning, hanged, or dead of asphyxia or narcotic poisons, but, on the contrary, very speedily in the plague and those poisoned by the bite of the viper, is as yet unexplained.

The *consistence of the blood-clot* is also very different; this is not founded in any chemical difference of the fibrin, but depends on several mechanical conditions, principally upon the relative proportions of the blood-corpuscles to the fibrin; thus, if the number of the corpuscles is small as compared with the quantity of fibrin, the latter contracts more closely; if the blood-corpuscles are much in excess, a soft coagulum is formed. Hence the lower part of every clot is softer, the upper more consistent; hence the clot of chlorotic patients is small and solid, that of plethoric, soft and voluminous. Excess of water, also, in the blood, always produces a soft, often gelatinous, clot, as is proved by the artificial addition of water to the blood, as well as by experience in hydræmic blood. Carbonic acid, and salts which retard coagulation, generally produce a softer condition of the clot; from oxygenated, bright-red blood, a thick, elastic coagulum is formed; from that of cyanotic and asphyxiated persons, rich in carbonic acid, a very soft, gelatinous one. The *shape of the clot* formed by coagulation is dependent on the form of the vessel in which the process takes place; but there are some other circumstances which modify this. The clot is, namely, very often contracted relatively more on the surface than in the middle and lower part; it often has also on the surface a layer, of variable thickness, of compact fibrin (the so-called *inflammatory crust, buffy coat*), with which there is generally associated a concavity of the upper surface, a cup-like depression with raised margin. The opposite case is when, besides the clot, a sediment of red corpuscles is formed. These phenomena depend upon the relation of the period of coagulation of the fibrin to the settling of the blood-corpuscles. If the corpuscles sink below the surface of the fluid before the fibrin begins to separate, the upper part of the coagulated fibrin will contain no red corpuscles (hence appearing whitish gray), and will contract more firmly than the under corpuscle-holding portion (hence the cup-shaped depression with raised margin). On the other hand, if the blood-corpuscles have but little tendency to settle, on account of the rapid coagulation of the fibrin, if they do not form themselves into rolls, they are partly pressed out of the clot by the contraction of the fibrin, and form the above-mentioned red sediment. The formation of a buffy coat is also favored, when the above conditions are present, by several circumstances—as, *e. g.*, the form of the vessel in which the blood coagulates; in a tall, narrow vessel, a buffy coat is often formed from blood which exhibits none in a broad, flat vessel. Further, the quantity of blood-corpuscles is not without influence; blood containing few of them (that of pregnancy, chlorosis, and of the second and third bleedings) forms a crust much more readily than that containing an excess (*e. g.* in plethora). A *large proportion of fibrin*, moreover, influences the formation of the crust; but this consideration is of secondary importance. The blood generally forms a crust in diseases of an inflammatory character; the venous blood of healthy horses constantly exhibits it; the arterial also, but smaller. The quantity of fibrin in healthy blood of man varies but little from 0.3 per cent. We find a constant increase of it in all inflammations, accompanied by fever, which may rise to 1.3 per cent.; it is most observable in acute articular rheumatism; in no disease is there found constantly an important diminution of fibrin. Arterial blood usually contains more fibrin than venous; its quantity is smaller in the blood of the portal vein, very small in that of the splenic vein, while it is wholly wanting in that of the hepatic veins.

The *serum*, after separation from the clot, occasionally contains, especially in certain diseases, a small quantity of undissolved particles in suspension, which give it a milky or slightly opalescent appearance; these particles consist either of fat-molecules, or of fine granules of precipitated albumen poor in salts, or of colorless blood-corpuscles. The proportion of *water* in the serum stands generally in direct ratio to the proportion of water in the whole blood, and especially to that of the blood-corpuscles; where the proportion of water in the serum is considerable, the number of the blood-corpuscles usually is diminished; hence the solid residue of the whole blood is generally much reduced under such circumstances; on the other hand, the physical law follows, that a very watery serum necessitates also an increase of water in the blood-cells. The serum of adult males contains about 90.5 per cent. of water; on the average, that of women, especially during pregnancy, contains somewhat more. All external and internal circumstances of the animal organism, which are associated with considerable *loss of fluid*, diminish the quantity of solid constituents in the blood, and hence an increased proportion of water is produced; the same must be the case after deprivation of food, or disturbed nutrition; hence the blood becomes more watery in most diseases, except in the first stage of typhus fever, measles, scarlet fever, and cholera. The serum of the blood of the *arteries* contains more water than that of the *veins;* among the latter, that of the *portal* vein is especially rich in it, while that of the *hepatic* vein contains less even than that of the arteries. The blood of the amphibia contains more water, that of birds less, than that of the mammalia.

The principal constituent of the blood-serum is *albumen*. This is the substance from which all other protein substances, and probably all the nitrogenised tissues in the animal economy are formed. The quantity of albumen in normal blood varies between 6.3 and 7.0 per cent.; in normal serum between 7.9 and 9.8 per cent. In most *diseases* the albuminous contents of the serum are more or less diminished; they have been found increased only in intermittent fever and cholera. During digestion the proportion of albumen in the blood also increases considerably. *Arterial* blood-serum contains less albumen than *venous;* that of the *portal* vein has a still smaller proportion, while, on the contrary, that of the *hepatic* veins is very rich in it. Human blood contains, on an average, more of this substance than that of most mammalia.

Whether *casein* is a constant element of normal blood-serum has not been determined by the investigations hitherto made. At all events, a substance exists in the serum which has great resemblance to casein, and hence has been called serum-casein; but it may, with equal propriety, be taken as an albumen deficient in alkali and salts. This serum-casein is, according to some observers, sensibly increased in the blood-serum of pregnant women, and in that of the placental vessels.

The *fats* of the serum consist less of stearin, margarin, and olein, than of stearic, margaric, and oleic acids, and cholesterin; what was previously known as serolin, is a mixture of the crystallizable part of the fats named. In the ethereal extract of the serum the crystallizable fats preponderate, while those of the blood-corpuscles are more oily and yellow-colored. Phosphoretted substances, soluble in ether, which exist in the blood-cells, are wanting in the serum. The proportion of fat in the blood-serum is somewhat variable, but careful determinations of it are wanting. During *digestion*, the blood becomes constantly richer in fat. In *diseases*, the ordinary fats appear to diminish, while the cholesterin increases. The blood-serum of *women* is, on the average, richer in fat than that of *men*. The blood of the *arteries* contains less fat than that of the *veins;* among the latter, that of the *portal* vein is the richest in it.

Grape-sugar is also a constant constituent of the blood-serum. The quantity of it, however, under ordinary circumstances, is extremely small; thus, in the blood of the ox, there has been found only 0.0007 per cent. After the use of amylaceous or saccharine *food*, its quantity may be increased so as to amount to 0.5 per cent.; in *diabetic* patients, whose blood always contains much sugar, more than 0.05 per cent. is seldom found. The blood of the *portal* vein contains only traces of sugar, while that of the *hepatic veins* abounds in it.

[The origin of sugar in the liver is deduced from the fact first observed by M. Cl. Bernard, that the blood of the hepatic veins is very rich in sugar, while that of the portal vein (during the digestion of animal food) contains little or none of this principle. The tests employed by him for its determination were fermentation with yeast, Trommer's, and a third, the tartrate of copper and potassa, which is very delicate, and has the advantage of ready applicability. It has, however, been asserted by M. Figuier, that sugar does exist in small quantities in the blood of the portal vein after the ingestion of purely animal food; that it is carried to the liver, and there stored up for distribution according to the wants of the system. His memoir on the subject was referred by the *Académie des Sciences* to a committee of investigation, who reported that a substance was found in the portal vein which reduced the oxide of copper, but did not undergo fermentation with yeast, and hence its saccharine character could not be considered as proved. M. Figuier, however, maintains that another substance, as yet unknown, which is present in the portal blood, prevents the fermentation, and that, on its removal, by means of nitric or sulphuric acid, fermentation takes place readily. This has not yet been reported upon. Meanwhile, M. Bernard has announced the formation of sugar in the liver from a substance found in its parenchymatous tissue. His experiments were as follows: A healthy dog, which had been fed exclusively on meat for some time previously, was killed seven hours after a meal; the blood of the portal vein contained no sugar, while that of the hepatic showed an abundance. A strong current of water was passed through the portal vein for forty minutes until it flowed from the hepatic vein free from all traces of sugar or albumen. A portion of the liver, on being boiled with water, yielded no trace of sugar; but, after standing for twenty-four hours, the rest of the liver contained it in nearly normal quantity. He next took a fresh liver, and having separated as far as possible the parenchymatous portion of the liver from the bloodvessels and nerves, he extracted the former with alcohol, so as to remove every trace of sugar. The residue, after filtration, was thoroughly desiccated and tested for sugar without success: it was then moistened with distilled water, and allowed to remain at the ordinary temperature for twenty-four hours, when sugar was found abundantly. The formation of sugar from a nitrogenised material in the liver, and the source of that found in the serum, is thus placed beyond doubt.—J. C. M.]

Urea must also be considered a normal constituent of the blood; its quantity is however so small that exact quantitative determinations of it have hitherto been impossible.

Hippuric acid, *creatin*, and *creatinin*, have also been recognized as normal constituents of the blood.

It is not improbable that the serum contains a peculiar yellow *coloring matter*, but this has not been proved with certainty.

Biliary coloring matter and acids often occur in diseased blood, even when there is no decided lesion of the liver; in healthy blood, however, these substances are never found.

Hypoxanthin is found in the blood in very small quantities; it occurs in larger quantities in the blood of the splenic vein, as also in the blood generally in leuchæmia.

Uric acid has hitherto been found with certainty only in diseased blood—especially in arthritis.

Actual *glutin* has as yet been detected only in the blood of leuchæmia.

Formic, *acetic*, and *lactic* acids may perhaps be contained in very small quantities in normal blood (as the first exists so abundantly in the sweat, and the last in the muscles); but thus far they have only been detected in the blood of the splenic vein, and in that of leuchæmia.

The blood of most animals usually emits, when warm, an *odor* peculiar to almost every species; this occurs especially on the admixture with it of 1½ vols. of sulphuric acid; this is most undeniable in the blood of the goat, sheep, and cat; the chemical nature of these odoriferous principles is not yet ascertained, but they probably belong to the volatile fat acids.

Among the *mineral constituents* of the serum, *chloride of sodium* predominates (averaging 61 per cent. of the ash); next to this stands *carbonate of soda* (28.9 per cent.); the proportion of *chloride of potassium* in the ash is very variable (but averaging about 4 per cent.), as also that of *phosphate of soda* (about 3 per cent.); the quantity of sulphate of potassa which is found depends mostly upon the manner of incineration. We find altogether, on the average, 0.85 per cent. of salts in the serum; that of the blood of men contains more salts than that of women, and that of adults more than that of children. In violent inflammations, the serum-salts have been found much diminished, and even still more so in cholera; on the contrary, in acute exanthemata, in typhus, dysentery, Bright's disease, and especially dropsy, or hydræmia, considerably increased. Arterial blood-serum is somewhat richer in salts than venous; that of the portal vein contains more, again, than the arteries. After repeated bleedings, more salts are found in the serum of the parts of the blood last drawn than in the first.

Carbonate of ammonia is found in the blood only in severe illnesses, and especially associated with the set of symptoms which has been called uræmia; and almost constantly in the blood of cholera patients.

Silicic acid has hitherto been found only in the blood of fowls.

For the *analysis of the blood*, the well-known means afforded by analytical chemistry are not sufficient. It is especially necessary in the investigation of the blood, to examine the blood-corpuscles separated from the intercellular fluid; but these molecules are separable from the liquid of the blood neither by filtration nor any other mechanical means. We must hence seek to estimate them indirectly. As the blood-clot usually contains all the corpuscles, and presses out the greater part of the pure serum, the idea suggested itself of analyzing both parts separately, and calculating all the water found in the blood-clot as belonging to the serum. As it was not possible to estimate directly the water still included in the clot, it was assumed that the fluid which permeated the blood-corpuscles with all its constituents (ascertained by special analyses of serum), was serum. When, then, the solid constituents belonging to the water (as this was derived from the serum), and also the fibrin were subtracted from the solid residue of the blood-clot, it was thought that the quantity of the solid constituents of the blood-corpuscles was ascertained in the number thus found. This constitutes the before-mentioned dry blood-corpuscles of the earlier analyzers, who found, on the average, 12.5 to 13 per cent. of them in normal blood. Independently of this method being wrong in principle, since the blood-corpuscles themselves do not and cannot contain actual serum within themselves, the amount of error is not so constant that such analyses are capable of comparison; for, *e. g.*, with the same quantities of blood-corpuscles the clot contains sometimes more, sometimes less real serum, and thus there is subtracted from the solid residue of the blood-clot an entirely accidental quantity of the solid constituents of the blood-cells, standing in no relation to the actual proportion. The attempt has been made, in various ways, to improve this method, but it still remains unreliable, because its principle is wrong. From the knowledge that the blood-corpuscles passed less readily through the filter after the action on the blood of sulphate of soda or nitrate of potassa, a means of determining the quantity of the dry residue of the blood-corpuscles was thought to have been attained in the application of a saturated solution of Glauber's salts (1 vol. of blood mixed with 8 vols. of the solution). But entirely independent of the fact that we seldom succeed in filtering off the blood cells in this way without some of them passing through the filter, and also that in the blood of many animals, or in diseases, no such separation is effected by this salt, we thus determine only several coagulable constituents of the blood-corpuscles (for the corpuscles saturated with the salt-solution can only be separated from the salts by a second solution and coagulation), and lose all the salts and uncoagulable organic matters of the blood-cells. Of late, other ways have been devised to obtain at least indirectly approximative determinations of the amount and composition of the corpuscles in the blood. As from the comparison of the analyses of the clot and the serum of the same blood it is evident that in the solid residue of the clot there are more potassium compounds and phosphates than chlorine and sodium compounds, while the serum contains almost exclusively the latter, it may be assumed that an amount of serum corresponding to the sodium or chlorine is contained in the clot, and we may thus proceed to the estimation of the constituents belonging to the blood-corpuscles. But as in all probability the blood-corpuscles are not entirely free from sodium and chlorine, the estimation cannot be supported on this ground alone with entire certainty. It has also been endeavored to ascertain, by micrometrical determinations, the amount of the watery contents of the blood on the one hand, and, on the other, the volume of the serum contained in the blood-clot. It was thus found that the blood-corpuscle loses under the microscope, by drying, about 68 to 69 per cent. of its volume, and hence contains 32 to 31 per cent. of solid matters; and also that in 100 vols. of firmly contracted blood-clot, about 20 vols. of serum are still contained; hence, four-fifths of the volume of the blood-clot would belong to the blood-cells. Any one acquainted with this kind of microscopical and volumetrical determination will not deny that these can lay no claim to great confidence; but, by combining all three of these modes of determination, we may hope to find an approximative value for the serum still contained in the clot, and thus for the quantity and constituents of the blood-corpuscles. By means of the calculations based upon these determinations it has been established that the first of the above-mentioned methods may be applied in the direct analyses of the blood; the number of dry blood-corpuscles, thus obtained, must be multiplied by 4 to determine very nearly the amount of recent blood-cells, and hence that of the serum inclosed in the blood-clot. When the amount of serum thus contained is known, it is of course easy to calculate the constituents belonging to the blood-corpuscles. A method of analysis of the blood has been projected lately, founded upon an enumeration as exact as possible of the [blood-corpuscles] contained in a given volume of fresh blood, and a similar enumeration of blood, diluted with a certain quantity of serum, together with comparative analyses of both liquids. It is easily conceivable, that if we could add to the blood a soluble substance which merely dissolved in the serum, and incapable of endosmose, could not penetrate into the blood-cells, we should have hit upon the simplest and safest way of ascertaining the amount of the serum contained in the clot; for it would only be necessary, after noting the quantity of the substance added, to determine the proportion of this substance in the serum on the one hand, and in the blood-clot on the other, in order to know how much serum was still contained in the clot;

after the subtraction of this number, and the quantity of fibrin, we would have the quantity of moist blood-cells. We have, in fact, flattered ourselves from time to time that we had found this substance, but hitherto we know of no material to which the cell-membranes of the blood-cells are impenetrable, and probably there is none which absolutely forbids endosmotic currents between the cell-contents and the intercellular fluid.

Analytical chemistry teaches the modes of determining the other constituents of the blood. We only remark here briefly that what is obtained as fibrin, either by whipping the blood, or by washing the finely-chopped clot, is never pure fibrin, but always contains colorless blood-cells and remains of colored cells; and, also, that albumen cannot be precisely determined from the alkaline blood-serum, unless this fluid has previously been neutralized or slightly acidulated by dilute acetic acid.

With regard to the difference of constitution of the blood in different physiological circumstances, the following may be looked upon as established.

As to the difference of *sex*, the following holds good. The blood of women is somewhat lighter red than that of men. It is specifically lighter, with sulphuric acid develops a less intense sweaty odor, contains more water, and fewer blood-corpuscles; as, consequently, the serum predominates in the blood of women, it contains more albumen and fixed fats than that of men. The serum of women's blood contains less salts than that of men's. On the other hand, in the blood of women, as a whole, more salts are contained than in that of men. During *pregnancy*, the blood is of a darker hue, has a less specific gravity, as it contains more water, and is poorer in blood-corpuscles, than that of non-pregnant women. Fibrin is only relatively increased, hence the smaller clot with a superficial fibrinous layer. The serum contains less albumen; the so-called serum-casein is increased. The blood of *children* is rich in solid constituents, especially in blood-corpuscles; poorer in fibrin and salts, and richer in extractive matters, than that of adults. In *old age* the blood becomes poorer in solid constituents, especially in blood-corpuscles and albumen. Cholesterin is said to increase in it.

During *digestion*, the blood becomes richer in solid elements; the colorless cells, especially, increase; the fibrin usually coagulates more slowly; it is richer in fat, hence the serum is often cloudy;

the blood-corpuscles, albumen, fat, and salts, likewise, are on the increase. After *long abstinence*, *depraved nutrition*, or *excessive loss of fluids*, the blood has a somewhat analogous composition; the blood-corpuscles decrease; the serum becomes more watery, poorer in albumen, and other organic constituents, but richer in salts. By many experiments the proposition has been established that *the loss of albumen from the blood is replaced by corresponding quantities of salts.* Among the *mammalia* the *omnivora* contain most blood-corpuscles, and, consequently, their blood is richest in iron and the phosphates. It also contains most fibrin and solid constituents of the serum, but less salts than the blood of other dietetic classes. The blood of *carnivora* is richer in blood-corpuscles and fat than that of *herbivora.* The blood of *birds* is as rich in blood-corpuscles as that of omnivora, and contains more fibrin and fat, but less albumen, than that of mammalia. The blood of cold-blooded animals is poorer in blood-corpuscles, and richer in water, than that of all other vertebrata.

As regards the differences of the blood of different vessels, the following is ascertained: In the red cells of *arterial blood* there are fewer solid constituents, and especially less fat, than in those of venous blood; on the other hand, relatively more hæmatin and salts. The liquor sanguinis of arterial blood contains more fibrin and water; on the other hand, relatively less albumen, and absolutely less fat and extractive matters, than that of venous blood. The blood of the *portal vein*, compared with that of the jugular vein, is poorer in blood-cells and in solid constituents generally. The blood-corpuscles often appear, under the microscope, granular, distorted, and jagged; are richer in hæmatin, and poorer in hæmato-crystallin; containing, however, twice as much fat as those of the jugular vein. The quantity of fibrin is less, while it contains much fat. The serum contains far less albumen; but, on the contrary, much more fat, extractive matters, and salts; at most, only traces of sugar. The blood of the *hepatic veins* contains by far more solid constituents than that of any other vessel. It is very rich in blood-corpuscles, colorless as well as colored. The latter are but little changed by water; they are poorer in hæmatin, fat, and salts. The liquor sanguinis of this blood contains no fibrin, less albumen and fat, and far less saline matter, than the blood of other vessels; on the other hand, it contains so much extractive matter, and relatively so little water, that its solid constituents are found to be higher than those of any other blood. It is also distinguished by its large proportion of sugar (see p. 140). The blood of the *splenic vein* is, on the average, somewhat more watery than that of the jugular vein. It contains numerous colorless blood-corpuscles of various sizes and shapes, and very little fibrin. This blood is, however, especially distinguished by containing lienin, hypoxanthin, two ferruginous pigments, acetic, formic, and lactic acids, and iron dissolved in the liquor sanguinis. *Menstrual blood* contains no fibrin, and relatively few solid constituents (16 per cent.). The blood of the *placental vessels* contains little fibrin and albumen, but relatively much serum-casein.

Inflammatory diseases always give rise to a more or less important augmentation of fibrin. This usually increases with the grade and duration of the inflammation; the blood-corpuscles generally diminish in a small degree; the albumen of the serum is lessened, especially when there is considerable exudation; the salts remain nearly the same; the fats, especially cholesterin, increase slightly. In *acute exanthemata*, the blood-cells diminish, the serum becomes denser, its salts increasing more than the organic matters. In so-called *plethora*, the blood-corpuscles are increased, the fibrin normal, the albumen slightly above the normal mean. In *chlorosis*, the blood forms, on coagulation, a small firm clot, often with the buffy coat, together with clear serum; the blood-corpuscles more or less diminished; the composition of the liquor sanguinis usually normal. In *dysentery*, the blood becomes poorer in corpuscles; the fibrin and also the salts increase, while the albumen diminishes. In *cholera*, the blood becomes excessively thick and glutinous; the blood-corpuscles are relatively increased, and their salts diminished; the serum poorer in water and salts, and relatively richer in albumen. It also generally contains urea in appreciable quantities. In *Bright's disease*, the blood assumes the character which it usually does, as said above, after excessive loss of the fluids (in so-called *anæmia*); urea is often found much increased in it; a portion of this sometimes is changed into carbonate of ammonia (in so-called *uræmia*). In *yellow fever*, as in cholera, a great deal of urea has been found in the blood. In *typhus fever*, during the first eight days, the blood is found as in plethora, afterwards as in anæmia. In *puerperal fever*, the diminution of the blood-corpuscles is usually very considerable; the fibrin is (when peritonitis accompanies it) much increased, but gelatinous and soft, generally forming a crust; the solid constituents of the serum much diminished; the extractive matters increased. Occasionally bile-pigment is found in such blood, and not unfrequently free lactic acid. In *pyœmia*, the fibrin is diminished, the colorless cells much increased. In *leuchœmia*, the blood is pale red, often with whitish streaks, too rich in colorless cells, and, on coagulation, but little alkaline serum separates. It contains glutin, albuminous, ferruginous, and phosphoretted substances, hypoxanthin, formic, acetic, and lactic acids. Of the composition of the blood in *carcinoma*, nothing further is known than that, according to some observers, the fibrin is much increased. *Diabetic blood* has the same composition as normal blood, except its large content of sugar. *Scorbutus*, *tuberculosis*, *scrofulosis*, *chronic rheumatism* and *arthritis*, are such vague descriptions of pathological states that no especial value is to be placed on the analyses of blood accomplished in such conditions.

THE CHYLE.

This animal fluid is, during digestion (especially after partaking of fat), almost milk-white; in the fasting state, only opalescent, often yellowish white to pale reddish in color, of feeble odor and insipid taste, slightly alkaline in reaction. Like the blood, the chyle coagulates in nine or ten minutes after being withdrawn from the animal body; the coagulum, which contracts fully in two to four hours, is very small relatively to the serum, very soft, often merely gelatinous; the yellow coagulum usually becomes of a light-red color in the air. The chyle serum remains always cloudy and opalescent, becomes clearer by ether, is often clouded by acetic acid; on being boiled, it does not deposit a dense cheesy coagulum, but merely becomes milk-white from the suspended molecules of coagulated albumen.

Quantities of chyle for chemical investigation are best obtained from the thoracic duct by opening the cavity of the chest immediately upon killing the animal (which should have eaten several hours previously), and tying the duct at its point of discharge into the subclavian vein; from the carefully prepared thoracic duct a large quantity of chyle is thus obtained, as free as possible from blood.

The chyle is very rich in *morphotic* elements. We find in it principally fine molecular granules, aggregated masses of granules, or nucleus-like formations, cytoid corpuscles with one or several nuclei (chyle-corpuscles), and fat-globules; colored blood-corpuscles are very rarely found in the chyle of the thoracic duct. The chemical constituents of the chyle are almost the same as those of the blood. The fibrin of chyle usually contracts but little, remains gelatinous, and hence is more easily soluble in salt solutions than the densely contracted blood-fibrin; its proportion is far less than in the blood. The albumen of the chyle is richer in alkali; on this account it does not coagulate in flocculi and masses, is partially precipitated by acetic acid, and on evaporation of the partially coagulated fluid films are formed on the surface. Its quantity in chyle-serum is much less than in blood-serum. *Casein* is maintained to be a constituent of chyle-serum, but this is not proved. The proportion of *fats* which are only partially saponified in the chyle, is very various, depending on the description of the food. *Sugar* is only to be detected after amylaceous diet, and then only in traces. The *constituents of the bile* do not pass as such, at least normally, into the chyle. The residuum of the chyle contains more so-called *extractive matters* than that of the blood-serum. The chyle is very rich in alkalies, which are combined partly with albumen, fatty acids, and lactic acid, partly with phosphoric acid and chlorine. Sulpho-cyanogen compounds, sulphates, and sal ammoniac, are not to be detected in the chyle. Whether or not iron is contained in the chyle serum is still in dispute. The *mineral constituents* of the solid residue of the chyle form about twelve per cent., of which nine or ten per cent. are soluble salts.

The influence of the food upon the composition of the chyle is shown as follows: after fasting, or insufficient food, the chyle is somewhat poorer in solid constituents, and especially in fat. After animal food, if it be fatty, it becomes milk-white from the fat. As the chyle collected from the intestinal villi in the vessels of the mesentery comes into close contact with the blood-fluid, it undergoes, on its way to the thoracic duct, various modifications by the interchange of its constituents with those of the blood, which are, however, unfortunately only to be detected by the microscope. Fibrin makes its appearance in the chyle first in the vessels of the mesentery; after the receptaculum chyli, the proportion of albumen and solid constituents generally increases, while the free fat disappears partially, some of it being saponified, some passing into the increasing morphotic elements. The *quantities* of chyle which enter the blood within a given time can be determined or estimated only in the most uncertain manner. Direct determinations have been attempted by opening the thoracic duct in the neck of living or just-killed animals, and collecting the outflowing chyle, and estimates presented, based upon a comparison of the albuminates, or fats absorbed, with the proportions of these substances in the chyle. According to the latest experiments, it is assumed that the quantity of fluid passing from the thoracic duct into the subclavian vein in twenty-four hours, is as great as the entire amount of blood in the body, *i. e.*, one-fifth of the weight of the latter.

THE LYMPH.

This fluid is colorless, or slightly yellowish, usually somewhat opalescent, of a feeble, saltish, insipid taste, and alkaline reaction. It coagulates from 4 to 20 minutes after its withdrawal from the lymph vessel, forming a gelatinous, quivering, colorless coagulum, which contracts very gradually, so that the clot becomes inconsiderable relatively to the serum. The lymph which has mostly been used in chemical investigations, has been such as flowed out spontaneously in consequence of wounds. It is most readily obtained from frogs, by incising the skin of the upper part of the thigh and dissecting off a part of it. Of *morphotic elements* there are found in the lymph, besides fat-globules, nucleus-like formations, and especially cytoid corpuscles (the so-called lymph-corpuscles); only in the lymphatics of the spleen and the lymph of starving animals have blood-corpuscles been found. The *chemical constituents* of the lymph coincide almost exactly with those of the blood, after subtracting the substances peculiar to the red-corpuscles. The quantity of *fibrin* in the lymph is very small compared with that in the blood, as also the quantity of *albumen* is relatively less; that of the *salts* relatively more. On the whole, the lymph contains far less solid constituents than the liquor sanguinis. *Fat* is generally contained saponified in the lymph, but in small quantity. The *extractive matters* are contained in greater quantity in the lymph than in the blood-serum; among them *urea*, *lactic acid*, &c., lie concealed. It is also worthy of remark that *ammoniacal salts* have been detected with certainty in the lymph, as also sulphates pre-formed in considerable quantities.

TRANSUDATIONS.

We embrace, under this head, all those animal fluids which, as they have to pass through series of cells, present themselves as elements of the blood which have been extravasated immediately from the capillaries in the fluid state. They are distinguished from the *secretions* in the narrower sense of the word by containing only the constituents of the liquor sanguinis, while the secretions contain either elements peculiar to themselves, or certain matters accumulated which exist only sparingly elsewhere; and from exudations by being free from blood-corpuscles, and subject to no morphotic developments. The transudations are poured out normally and abnormally in the parenchymata of organs, in the open and closed cavities of the animal body, and even upon the cuticle. Thus there belong to this class the secretions of all serous membranes, the aqueous humor of the eye, the liquor amnii, the secretion of wounds (when free from blood-cells), the contents of the vesicles formed by blisters, &c. The passage of water and some of the constituents of the liquor sanguinis through the walls of the capillaries is to be regarded as the result of a mechanical necessity, occasioned by the *penetrability of the walls of the capillaries*, by the *rapidity of the movement of the blood* in them, and by the *physical and chemical constitution* of the blood flowing through the capillaries. According to the differences in the above-named causes, the transudations will also have a different composition; they, however, contain the same chemical constituents as the liquor sanguinis, only in different proportions. Their *physical properties* hence agree in general with the latter fluid; whether normal or abnormal and in excess, they are colorless, transparent, of insipid slightly saltish taste, alkaline reaction, and always of less specific gravity than the liquor sanguinis. *Morphotic constituents* are rare in the transudations; epithelial cells, molecular granules, and cytoid corpuscles, are merely accidental constituents in them. Red blood-corpuscles cannot well pass into a transudation without partial laceration of the capillaries; if they are found, we have no longer the simple process of transudation to deal with. The entire liquor sanguinis as such never passes into the transudations; as in the permeation of the capillary walls by the fluid, one constituent of the liquor sanguinis passes more readily than another, and water the most readily of all, the consequence must always be that the transudation will contain far less of solid constituents than the liquor sanguinis. As, then, animal membranes are penetrated more easily by the soluble salts and so-called extractive matters of the liquor sanguinis than by albumen; and, again, by albumen more easily than by fibrin, we always find in the transudations more salts, relatively to the albumen, than in the liquor sanguinis, and fibrin only in extremely small quantities, or not at all.

Fibrin, which is wholly wanting in normal transudations, occurs in those excessive secretions of serous membranes which have been termed *hydrops fibrinosus*. It forms generally a loose gelatinous coagulum, and is otherwise identical with blood-fibrin; its quantity in the transudation is always far less than in the liquor sanguinis. Like the fibrin, the albumen of transudations does not differ from that contained in the blood; but a portion of the albumen of transudation is often precipitated by acetic acid, and only imperfectly separated by boiling, so that, on evaporation of the fluid, casein-like films form on the surface. We know that these peculiarities belong to the albuminate of soda; they, therefore, prove merely that there is a more basic albuminate contained in the transudation than in the blood. The quantity of albumen in the transudations is exceedingly various; it is even wanting in the aqueous humor, in the liquor amnii, in the fluids of the ventricles of the brain, and of the spinal marrow. It has been attempted to ascertain determinate causes for this difference in the proportions of albumen in the transudations. In the first place, it appears that the *quantity of albumen depends on the system of capillaries* from which the transudation has arisen. This proposition is, indeed, established upon but few investigations; but the facts presented indicate that, under similar conditions, different capillary systems allow different quantities of albumen to pass through. The fluid of the ventricles of the brain contains accordingly least albumen (about 0.5 per cent.), that of the peritoneum much more (1.0 per cent.), and that of the pleura the most (1.8 per cent.). It is not hence to be inferred that, under different circumstances, the quantity of albumen of the transudation from one set of capillaries is always restricted to the same figure; but only that, when under similar conditions excessive transudations take place from several serous membranes, this proportion is shown between the quantities of albumen in the transudations of the different capillary groups. Another proposition which may be drawn from the facts thus far presented is, that *the slower the current of blood in the capillaries, the richer is the transudation in albumen.* Thus, *e. g.*, more albumen is found in the peritoneal transudations, when they depend upon large tumors, than when a lesser disturbance of the circulation in the abdomen is occasioned; for instance, by disease of the liver, with contraction of its parenchyma, &c. Thus, also, more albumen is found in the transudation in acute than in chronic hydrocephalus.

The proportion of albumen in the transudation is also always dependent upon the proportion of albumen in the blood. The poorer the blood in albumen, the less the quantity of albumen in the transudation; hence, in Bright's disease, when the blood is deprived of so much albumen by the kidneys, the transudations become very deficient in this substance. All dropsical fluids which depend upon disturbances in the current of the blood are, on this account, richer in albumen than those depending upon hydræmia, *i. e.*, an excessively watery condition of the blood. True *casein* has not been as yet detected in the transudations. It has been already stated that the *extractive matters* are contained in larger quantity in the transudations than in the corresponding liquor sanguinis: it is also to be remarked that older transudations, as in hydrops saccatus, usually contain far more of these substances than fresh transudations. The extractive matters are, however, very variable in quantity in the transudations. They contain but little more of saponifiable and saponified fats than the corresponding liquor sanguinis; but the group of capillaries, from which the transudation has arisen, appears also to influence its amount of fat; at least the fluids transuded from the capillaries of the ventricles of the brain, the pericardium, and the subcutaneous areolar tissue, are very deficient in them. *Cholesterin* generally occurs in larger quantities in these fluids than the fats and salts of fat acids. Occasionally (particularly in hydrocele) such quantities of cholesterin are found in old transudations that the fluid resembles an emulsion of cholesterin crystals. The *resinoid acids of the bile*, as also *bile-pigment*, are found in transudations only when associated with hepatic derangements. *Sugar* is found principally in normal transudations in diabetes; but the liquor amnii also usually contains this substance. *Urea* is always found in transudations, as it is more easily diffused than the salts of the blood: it has even been found in the aqueous humor. It is, of course, to be expected that it would exist in greater amount in the transudations in Bright's disease, in which it is found in appreciable quantities in the blood. It is probable that, in the transudations, hippuric acid, creatin, creatinin, &c., also exist, but this has not been specially proved: creatin has been found only in the liquor amnii. Lactates, also, have not been detected with certainty in normal transudations. It has been already mentioned that, among the constituents of the liquor sanguinis, the (soluble) *salts* transude most easily; and that, on this account, they are found most abundantly in the transudations in proportion to the organic constituents; but their quantity in the latter is always less than in the liquor sanguinis, for the simple reason that the water of the blood transudes more readily than these soluble salts. Watery blood is, as shown above, always richer in salts than normal blood. The richer the blood is in salts, the more of them are found in the transudations; but their proportion in the latter is always somewhat less than that in the liquor sanguinis. This rule has but one exception, viz: when a large portion of the constituents of the blood, especially albumen (in Bright's disease), pass off by the kidneys; for then the quantity of salts in the solid residue of the transudation may exceed that of the organic matters.

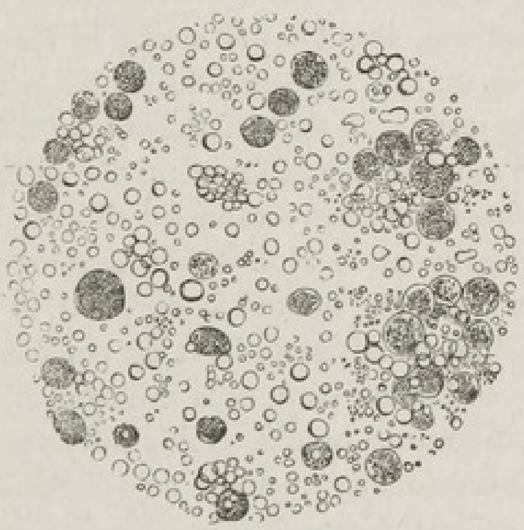
Whether the secretions of the intestinal capillaries, as they appear after drastic cathartics or in cholera, are to be reckoned among the simple transudations, is very questionable, as different physical laws appear to be here in force; for the composition of the liquor sanguinis stands in inverse proportions here to that of the transudation, as compared with the above-mentioned transudation processes. That is, while we saw the transudations taking place, as the blood became at the same time more watery, richer in salts, and poorer in albumen, we find here that the blood becomes much poorer in water, poorer in salts, but much richer in albumen.

In the transudations, as in the intercellular fluid of the blood, the chlorine and sodium compounds predominate over the other soluble salts of the blood. The transudations of the choroid plexus of the ventricles of the brain alone form an exception to this; in these, the phosphates and potassium compounds prevail; the fluid of the ventricles is, hence, not to be reckoned among the transudations (in the narrower meaning of the term). Ammonia salts are not to be detected in normal and recent transudations; but, when urea is contained in the blood and transudations, a little ammonia is also found usually. Like all animal fluids, without exception, the transudations also contain gases, carbonic acid, oxygen, and nitrogen, in solution, although in small quantities.

THE MILK.

The milk of all the mammalia is white (sometimes with a slight tendency to bluish, sometimes to yellowish), slightly translucent, odorless, of a weak sweetish taste, and mostly alkaline reaction; specific gravity between 1.028 and 1.045. It is well known that, when milk stands at rest for some time, a yellow layer abounding in fat separates on the surface, while the fluid below it becomes bluish-white, and specifically heavier. Milk does not coagulate by boiling, but forms on its surface a film of coagulated casein mingled with fat-globules. If it is brought into contact with the mucous membrane of the calf's stomach (called rennet) for some time, at a moderate temperature, it coagulates, whether alkaline or acid in its reaction. Human milk always has an alkaline reaction; that of

Fig. 15.



Fat globules and colostrum-corpuscles of human milk.

carnivora, acid; that of herbivora, generally, alkaline (in the cow, horse, and sheep, after being fed in the stall on green fodder, the milk has been noticed to become acid). It presents itself under the microscope as a clear fluid, in which an innumerable quantity of fat-globules, the so-called milk-globules, appear in suspension; the size of the latter varies usually between 0.0012 of a line and 0.0018 of a line, while some are larger, some smaller. That these fat-globules are surrounded by a special cell-membrane, may be concluded partly from their becoming much distorted under the microscope when a little acetic acid is added to the milk, and partly from the fact that the milk does not lose its emulsive character on being agitated with ether alone; while, when a little caustic potassa (which dissolves the cell-membrane) is also added, it becomes transparent and almost as clear as water by agitation with ether (which then takes up all the fat). The *colostrum-corpuscles, corps granuleux*, irregular conglomerations of fat-granules, held together by an amorphous, albuminous substance of 0.0063 of a line to 0.0232 of a line in diameter, without nuclei and without special cell-membranes, occur not only in the colostrum (up to the third or fourth day after delivery, occasionally even to the twentieth), but always occur when the milk secretion is disturbed by any pathological condition. Epithelial cells, mucous corpuscles, fibrinous clots, blood-corpuscles, infusoria (*Vibrio bacillus*), and byssus (blue milk), are rare admixtures, purely accidental, or caused by pathological affections of the mammary glands.

The chemical constituents of the milk are the following:—

Of *casein*, there is found in the normal milk of women 3.1 to 3.5 per cent.; in colostrum, about 4 per cent.; in the milk of the cow, 3 to 4 per cent.; in that of the goat, 4.5 to 6.3 per cent.; in that of the ass, only 2 per cent.; in that of the bitch, 8.3 to 13.6 per cent. After animal food more casein is found in the milk than after vegetable diet. The *fats* have been examined thoroughly only in cow's milk. The pure milk fat is almost colorless, or very slightly yellowish, solidifies after being melted at 80°, but, in so doing, rises in temperature to 85°; it consists of about 68 per cent. of margarin, 30 per cent. of olein, and 2 per cent. of a mixture of fats, which, upon saponification, or becoming rancid, yields butyric, caproic, caprylic, and capric acids (occasionally vaccinic acid is formed instead of butyric and caproic acids). According to later investigations, the solid fat of butter, which was previously regarded as simply margarin, consists of four different neutral fats, which yield, by saponification, four solid fat acids, differing from each other by C_4H_4, viz: myristic acid, $C_{28}H_{28}O_4$; palmitic acid, $C_{32}H_{32}O_4$; stearic acid, $C_{36}H_{36}O_4$; and butic acid, $C_{40}H_{40}O_4$. In the milk of women, from 2.5 to 4.3 per cent. of fat is found; in that of cows, on the average, 4.5 per cent.; in that of mares, 6.95 per cent.; in that of asses, 1.25 per cent.; in that of sheep and goats, 4 per cent.; in that of bitches, 11 per cent.; in the colostrum of women, 5 per cent.; in that of cows, 2.6 per cent. It is a remarkable fact that the portions of milk drawn at first from the breasts or udders are much poorer in fat than those flowing afterwards. That the nature of the food has an influence over the proportion of fat in the milk, results from several experiments, but is not specially demonstrated. It is further established that in diseases the proportion of fat in the milk decreases. *Lactin* is found in the milk of women from 3.2 to 6.2 per cent.; in that of cows, 3.4 to 4.3 per cent.; in that of asses, 4.5 per cent.; in that of mares, 8.7 per cent.; in that of goats and sheep, 4.3 per cent. The milk of bitches contains, under animal diet, often only traces of lactin. The colostrum of women's milk contains about 7 per cent. of it. The *salts* of the milk consist principally of chlorides of sodium and potassium, and phosphates of the alkalies, lime, and magnesia, besides the alkali which is combined with the casein. Sulphates and ammonia salts are wholly wanting in the milk. In the ash of milk, the amount of insoluble phosphates preponderates over that of all the soluble salts. In women's milk there are contained 0.04 to 0.09 per cent. of soluble salts; in cow's milk, together with 0.21 per cent. of soluble, 0.28 per cent. of insoluble salts; in that of bitches, under animal diet, 0.45 per cent. of soluble, and 0.57 of insoluble salts. *Lactic acid* is never found in alkaline milk. The acid reaction of some kinds of milk may often (*e. g.* in that of carnivora) depend upon the acid phosphates of the alkalies. *Albumen* has been detected only in inflammatory affections of the mammary glands. The presence of albumen cannot be concluded from the coagulation of milk by heat; for the contents of the lactiferous ducts out of the period of suckling, the colostrum of cows, and the milk of bitches, deposit, on heating, a coagulum which is by no means identical with albumen. *Urea* is only found in the milk in Bright's disease. It is proved that *iodide of potassium* may pass into the milk; no reliable investigations have been presented as to other substances.

With reference to the *analysis* of the milk, it is only necessary to remark that it is not sufficient, for an exact determination of the amount of fat, to evaporate the milk and extract with ether, as the latter never exhausts all the fat from such a solid milk residue. On this account, the method is to be commended of acting upon the milk, previously to evaporation, with a certain quantity of sulphate of lime; this has, at the same time, the advantage of precipitating the casein, and avoiding, in the evaporation of the milk, the otherwise unavoidable bubbling and spirting; the residue also dries much more quickly. That the constitution of body, the temperament, the nourishment, and other external circumstances, are of decided influence upon the quantity of milk secreted, scarcely needs mentioning. According to several experiments, a healthy nursing woman is able to discharge in twenty-four hours, from both breasts, about 1,300 grammes [or nearly 2 lbs. 14 ozs.] of milk. A cow affords, on the average, 6 kilogrammes of milk [or nearly 13 lbs. 4 ozs.] in twenty-four hours. Hence, a nursing woman secerns of milk, during twenty-four hours, 22 grains for every 1,000 grains of her weight; a cow only 10.4 grains.

THE SEMEN.

The seminal fluid, with which the secretion of the prostate is usually mingled, forms a mucous, viscid, opalescent, colorless mass, becoming slightly yellowish on drying, is of peculiar odor, considerably heavier than water, neutral, or slightly alkaline. When recent, it is gelatinous, but after some time becomes liquid. It forms with water a slimy sediment; alcohol coagulates it, but a boiling heat does not. It is obtained usually from the vas deferens or the seminal vesicles of animals while in heat; but the quantities thus collected are only sufficient for microchemical investigations. For chemical researches of the semen, the fluid expressed from the testicles of animals has been made use of. The most peculiar *morphotic elements* of the semen are the so-called *spermatic filaments*, spermatozoids; they have, in different animals, nearly similar, although distinguishable, forms: they consist of a round, oval, or pyriform head, from which proceeds a long, gradually tapering filament. In human spermatozoids, the head has a breadth of 0.0007 to 0.0013 of a line, and a length of 0.0019 to 0.0025 of a line; the filament, a length of 0.018 to 0.020 of a line. The spermatozoids are with difficulty destroyed by fermentation; they are dissolved only by concentrated solutions of carbonates of the alkalies; they consist of a protein substance, which leaves, on incineration, a large quantity of ash very rich in phosphates; besides this, they contain about 4 per cent. of a soft, buttery fat. Besides the spermatozoids, we find in the semen the following form-elements: epithelia, prostatic and mucous corpuscles, and finely-granular pale molecules, with sharp contours, the seminal granules of the size of 0.0016 to 0.0100 of a line. The fluid surrounding these form-elements, which is in great measure derived from the glands of Cowper, the seminal vesicles, and the prostate, gelatinizes after its emission; the gelatinizing substance, *spermatin*, resembles mucus more than fibrin; it does not coagulate by boiling, by drying becomes insoluble in water, is dissolved by diluted alkalies, and precipitated again by concentrated alkalies; it is precipitated by acetic acid, but redissolved in an excess; it is soluble in concentrated nitric acid. Among the *salts* of the semen, phosphates of lime and magnesia are found to preponderate; besides these, we find much chloride of sodium, and also phosphates of the alkalies. In the *recognition of semen* in doubtful cases, the microscope is most useful, as the spermatic filaments are preserved tolerably long in the urine and on being dried; by carefully moistening the dried semen, scraping it from the tissue on which it is found, and agitating it in water, unchanged spermatic filaments are always found with the microscope. *Seminal stains* upon linen or other fabrics are also distinguished from all similar spots by becoming tawny yellow when moderately heated for one or two minutes.

THE FLUIDS OF THE OVUM.

By the fluids of the ovum we understand here only the fluids of the unincubated or undeveloped ovum—*i.e.* the yolk and the albuminous layer which surrounds the yolk, especially of birds. (Notice is elsewhere taken of the fluids of the developed ovum, the liquor amnii and liquor allantoidis, the vernix caseosa, and gelatin of Wharton—Transudations, Urine, Secretion of the Skin, Mucus.)

The yolk has been minutely investigated only in fowls and fishes; it forms a soft, thick, slightly translucent, sometimes yellowish-red, sometimes sulphur-yellow fluid, without smell, of feeble but peculiar taste; when mixed with water, it forms a white emulsive fluid, restores reddened litmus, hardens on boiling to an easily pulverized mass, is coagulated by cold alcohol, gives to ether, on being agitated with it, only a reddish, amber-colored fat, while a white, viscid mass subsides. Under the microscope, there are seen among the extremely fine granules, too small for measurement, yolk globules (*Dotterkügelchen*) and *fat globules*, of various sizes; the latter are distinguished generally by their less intensely yellow color. The *yolk globules* are inclosed by a membrane, which appears as if strewed over with granules. When the yolk fluid is acted upon by sal ammoniac or other salts of the alkalies, the granules suspended in it disappear entirely, leaving glistening, sharply defined fat-globules, together with the distorted yolk cells, which have become oval, cucumber, or spindle-shaped; a finely granulated membrane is still recognized in the latter. Diluted acetic acid also distorts the yolk-cells, without, however, dissolving the suspended molecular granules. In the eggs of fishes and amphibia there are also found by the microscope the so-called yolk laminæ, generally of a quadrangular shape, often in layers. These are not fat, as they are insoluble in alcohol and ether; are stained yellow by nitric acid; in other acids, swell up and fall into several pieces. So far as we at present know, the spherical cell-like bodies of the yolk consist mainly of fat, and contain especially phosphoretted fat (glycero-phosphoric acid?) and yolk-pigment.

The quantity of the cell-membranes of the yolk globules amounts to about 0.5 per cent. of the yolk. The fine molecular granules of the yolk fluid are nothing more than casein poor in alkali, which is readily dissolved in salts of the alkalies. Their quantity amounts to about 14 per cent. of the yolk fluid. Albumen, containing but little alkali, is really in solution in the yolk fluid—to the extent, however, of only 3 per cent. The mixture of casein and albumen contained in the yolk was formerly called vitellin (see p. 111). The fats of the yolk have not as yet been sufficiently examined; they consist principally of margarin and olein; with these another body presents itself, which, from its high melting point and crystalline form (rhombic plates), is usually held to be cholesterin, but it does not appear to be fully identical with the latter; besides this, a viscid, gelatinous substance has been separated, *lecithin* and *cerebrin*, also not sufficiently studied; from the latter substance the glycero-phosphoric acid detected in the yolk may be formed. The quantity of all the substances which may be extracted by ether from the yolk residue forms about 30 per cent. of the yolk fluid. The pigments of the yolk have not yet been sufficiently investigated; we only know that a yellow and a red pigment exist in it, and that the one or the other contains iron. Among the *mineral substances* of the yolk the potassium compounds and phosphates predominate; chlorine and sodium are found in the yolk ash only in very minute quantities. The ash contains 67 to 70 per cent. of phosphoric acid alone; hence the phosphates contained in the yolk must be monobasic. Of inorganic matters, 1.5 per cent. are also contained in it. The proportion of water in the yolk of fresh eggs is somewhat variable; it ranges from 48 to 55 per cent. The eggs of fowls contain, on the average, 15.2 grammes of yolk and 23.9 grammes of white. The eggs of fish which do not possess a coat of white contain the same constituents as those of fowls, and in nearly the same proportions.

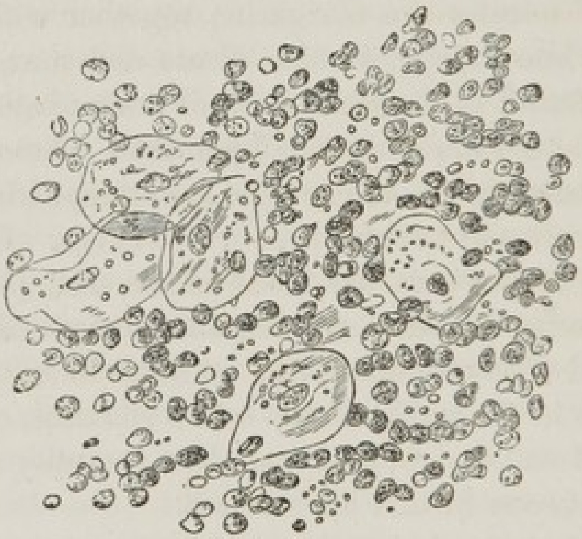
The white (albumen) of the egg of fowls is by no means amorphous under the microscope: besides chalazæ, and perfectly structureless basement membrane, there are found here and there corpuscles projecting in three or four points, or aggregations of extremely fine needles. The cell-membranes are the principal occasion of the gelatinous condition of the white of the egg. The *albumen* of the white of eggs is, in great measure, combined with soda; it amounts to nearly 12.5 per cent. of the fresh white of egg. The aggregations of needles are margarin; together with this, olein is found in the white of egg, as also oleate and margarate of soda. *Grape sugar* is found in the white both of unincubated and incubated eggs; its quantity amounts to 0.5 per cent. Among the *mineral constituents* of the albumen, the soluble salts preponderate; while in the ash of the yolk the reverse proportion exists. Of chlorides of the metals over 50 per cent. are found in the ash; phosphates exist only in small quantities, as also potassium-compounds; the soda is partly combined with carbonic acid. A little silica is found in the white as well as in the yolk. Fresh white contains, on the average, 0.66 per cent. of mineral substances. The quantity of water in the white ranges between 82 and 88 per cent.

MUCUS.

This fluid, proceeding from the so-called mucous membranes, forms in the normal state a viscid mass, capable of being drawn into threads, and consisting of a pellucid, cohesive fluid, and a great number of morphotic elements, principally epithelial cells. Even normal mucus exhibits many differences, according to the mucous membrane from which it is derived, both with regard to its morphotic elements and its chemical reaction.

The epithelial cells of mucus belong, according to the histological nature of the secreting surface, to the pavement, cylinder, or ciliated epithelium. Their amount is so great in normal mucus that the intercellular fluid can hardly be distinguished, to say nothing of its being separated from them. (Under the Horny Tissues of the Animal Organism we shall speak of the chemical nature of the epithelia.) *Mucous corpuscles*, cytoid molecules, resembling the colorless blood-cells and pus-cells, occur in all normal mucus, although often very sparingly. They increase in even slight irritations of the mucous membranes, and become so numerous in greater (the so-called catarrhs) that the mucus appears, under the microscope, to be almost wholly composed of them. (We shall examine more closely their chemical nature under "Exudation," in considering the cytoid corpuscles.) *Coagula of fibrin* and *blood-corpuscles* are found in the secretion only in exudatory (croupy) inflammations of the mucous membranes. There are often found in mucus *granular masses* and

Fig. 16.



Mucus and pus-corpuscles, epithelial cells, and blood-discs, from vaginal mucus.

granular cells (so called *inflammation-globules*), especially in catarrhs or croupy inflammations of the air-passages. Fat-globules are seldom found in mucus. Molecular granules are found in mucus, especially in diseases which, like tuberculosis, cancer, typhus, interfere with the entire tissue-metamorphosis of the body. From the glandular organs, which discharge upon the surfaces of mucous membranes, different species of cell-formation pass into some kinds of mucus. Vibriones and microscopical fungous growths occur accidentally in stagnant mucus.

The principal peculiarities of mucus are due to a substance dissolved or swollen up in it, MUCOSIN, *mucin*, a substance as yet but little known, chemically speaking, since the mucous fluid can only seldom, and then in abnormal cases, be obtained free from epithelial cells and other formations. This mucosin, which sometimes dissolves entirely in water, at others only swells up, does not coagulate by heat. Alcohol causes it to separate in flocculi or threads, which, however, resume their previous properties on being washed with water. It is precipitated by acids, even by dilute acetic acid, but is redissolved in concentrated acids. The differently proportioned combinations with alkali, in which mucosin is found, may occasion the differences of its properties: thus its being separated from some mucus in threads by water may depend upon the withdrawal of its alkali. Albumen is not contained as such in normal mucus, but occurs whenever the mucous membrane becomes inflamed. Fat is but slightly contained in normal mucus, but occurs in great quantity in catarrhal conditions. The mucus of the various mucous membranes reacts *sometimes acid*, *sometimes alkaline*. The normal reaction is so much the less to be ascertained, as probably the alkali in the one case, and the free acid in the other, depend upon foreign admixtures. Among the *mineral constituents* of mucus, chloride of sodium predominates; together with this, there are found in the ash principally carbonated alkalies (the bases of which were combined with the mucosin), and some phosphates and sulphates of the alkalies, as also earthy phosphates. The salts of mucus amount to about 0.7 per cent. Mucus contains 88.2 to 95.6 per cent. of water.

THE SALIVA.

The saliva is not only a mixture of the secretions of the different salivary glands, but the secretion of the oral mucous membrane also actually belongs to it. This *mixed saliva* is hence to be distinguished from the secretions formed by the individual glands. It is a cloudy, slightly opalescent fluid, viscid, and capable of being drawn into threads, without smell or taste. After standing some time, a grayish-white precipitate separates, which consists of pavement epithelia and some mucous corpuscles; its specific gravity varies in man from 1.004 to 1.006; its reaction is normally alkaline. From man, pure saliva is best obtained by strongly depressing the lower jaw, and irritating the gum with a feather; during the transient choking that ensues, the saliva comes from the mouth in jets. It is best obtained from fasting animals, by holding before them their favorite food, while the mouth is at the same time turned aside. The *secretion of the parotid*, which can only be obtained from artificial or spontaneously arisen salivary fistulas, is as clear as water and colorless, without odor or taste, does not draw into threads, of a spec. grav. varying between 1.0061 and 1.0088, of decidedly alkaline reaction. The sum of the solid constituents is somewhat variable: in that of man there have been found from 1.4 to 1.6 per cent.; in that of the dog, 0.46 per cent.; in that of the horse, 0.7 to 1.1 per cent. The principal organic constituent of the secretion of the parotid is a substance, SALIVIN, *ptyalin*, combined with potassa, soda, or lime, which has much resemblance to an albuminate, but is by no means identical with it. It is a gelatinous substance, soluble in water, not coagulable by heat. Its solution, containing alkali, is precipitated by basic acetate of lead, bichloride of mercury, and tannic acid, but not by alum, sulphate of copper, and other metallic salts. This substance is combined in part with lime, which it yields to carbonic acid; hence the parotid secretion, originally as clear as water, becomes cloudy in the air, like lime-water. Together with this material, another organic substance is found, which is soluble in alcohol and water, and is also precipitated by tannic acid, but not by alum. A potash-salt of one of the *volatile acids* belonging to the butyric acid group, is found in this saliva. *Sulphocyanide of potassium* is usually, but not always, contained in it. In the ash of the parotid secretion there is contained much chloride of potassium and chloride of sodium, not a little carbonate of lime, and small quantities of phosphates.

The *secretion of the submaxillary glands* is a colorless, clear, very viscid fluid, without smell or taste; specific gravity of that of the dog 1.004; reaction less strongly alkaline than that of the parotid secretion; it contains the same constituents as that just described, only with less lime combined with the organic matter. The solid residue of this secretion has been found to be 0.855 per cent.

The *secretion of the oral mucous membrane* is very viscid and adhesive, cloudy, colorless, generally frothy, rich in epithelial cells, of alkaline reaction, containing about 1 per cent. of solid residue, of which 0.62 per cent. is organic matter.

In human *mixed saliva* there are found 0.35 to 1.00 per cent. of solid constituents; in 100 parts of the solid matter there are found about 38 per cent. of mineral constituents, principally chlorides of sodium and potassium. Abnormal constituents occasionally occur in it—*e. g.*, *iodide of potassium* constantly after the use of iodine; occasionally, also, the constituents of the *bile* pass into the saliva; *sugar* very seldom does. Whether actual *albumen* is ever found in it, remains still doubtful. *Mercury* passes into the saliva only when mercurial salivation has occurred, in consequence of its introduction into the organism in great quantities. In an abnormal state, the saliva has an *acid* reaction, as also commonly in the fasting state; after the reception of food, especially of an acid, spiced, or indigestible kind, it usually becomes alkaline. It is most commonly found acid in irritations of the primæ viæ, and in diabetes mellitus. The nature of this free acid must, at present, remain undecided.—The concretions which are occasionally met with in the excretory ducts of the salivary glands, the so-called salivary calculi, consist mainly of carbonate of lime, some phosphate of lime and magnesia, and a little organic matter.

As regards the *quantity of saliva secreted within a given time*, it was previously assumed to be, in an adult man, 3,334 to 4,877 grs. in twenty-four hours; later experiments, on men and on animals, make these figures appear too small; according to these, 23,151 grs. may be assumed as the mean quantity secreted by adults in twenty-four hours. The amount of the salivary secretion is very different in every little period of time, as the more abundant or sparse flow of saliva into the oral cavity is dependent on very different causes. Dry and hard food induces a more abundant flow of saliva; that which is moist and soft, on the other hand, affects the salivary secretion but little. Movement of the lower jaw—hence chewing, speaking, singing—increases the secretion. Acid, aromatic, and pungent substances have the same effect. The secretion of saliva lasts, moreover, for some time after the use of nourishment. The more saliva is secreted and swallowed or ejected, the poorer it becomes in solid constituents; the organic materials diminish more than the mineral.

The *function* of the saliva is as much mechanical as chemical. It, especially the parotid secretion, serves not only to moisten thoroughly the dry articles of the food, and thus render them accessible to the other digestive fluids, but also, particularly the mucous secretion of the submaxillary glands, to render the morsels slippery, and so to aid in deglutition. By its mucous nature, finally, the saliva may be useful in introducing atmospheric air to the stomach and alimentary canal, by means of the froth formed in chewing. Like the mechanical, the chemical function of the saliva is various.

Its most striking and important property, in this respect, is its *capability of changing starch into sugar in a very short time*, whether it be alkaline or acid in its reaction. It is worthy of remark that the secretion of the parotids does not possess this power, either individually or when mixed with the mucus of the mouth; that of the submaxillary glands, also, does not possess it alone, but does when mixed with the mucus of the mouth. Hence the parotid secretion is without influence on the formation of sugar from starch; *the amylum ferment arises only by the union of the secretion of the submaxillary glands and the mucus of the mouth.* It was believed that a *salivary diastase—i. e.* a simple chemical body—would be detected, which causes the transformation of starch into sugar in mixed saliva; but we have not as yet succeeded in this. This capability of saliva to affect the amylacea must not be overrated, as results from the following facts: the secretion of saliva bears no relation whatever to the proportion of starch in the food, but is rather in an inverse ratio to its degree of moistness; the flow of saliva is very small after the swallowing of thoroughly moistened amylacea (*e. g.* when boiled, or rendered pasty). Further, many animals which swallow their food without chewing possess only rudimentary salivary glands. In the contents of the stomach we often find very little sugar, occasionally none, after the use of amylaceous food. Nature has, finally, produced in the pancreatic and intestinal fluids far more powerful means for the conversion of starch into sugar in the intestine. The saliva exerts no transforming power upon other carbohydrates, as cane-sugar, gum, and cellulose, as also on gluten; nor upon the protein bodies, or gelatin, or gelatin-yielding substances. Whether the *alkalinity* of the saliva really exercises such great influence upon the acids brought into the stomach, or formed there, as has been ascribed by some to it, must be determined by more exact experiments. A so-called *dynamical operation* has also been ascribed to the saliva—*i. e.* it was thought that it acted as a stimulus to the stomach, by means of which a more abundant secretion of gastric juice was obtained, and the process of digestion very materially assisted. Direct experiments upon animals have not confirmed this opinion. Finally, so-called *passive functions* have been attributed to the saliva, in virtue of which it supported the sense of taste, favored the expression of the voice, cleansed the mucous membrane of the mouth, and, to a certain degree, quenched thirst.

THE GASTRIC FLUID.

The gastric fluid, when pure, is clear, liquid, colorless (at most slightly yellowish), of a feeble, peculiar smell, and slight salty and acid taste; a little heavier than water, of very acid reaction, does not coagulate on boiling, but does slightly on neutralization by an alkali. Like most acid fluids, the gastric juice does not pass readily into putrefaction. Morphotic elements are but rarely found in it; they consist partly of unaltered cells of the gastric follicles, partly of their nuclei, and partly of a fine molecular matter. The gastric juice may be obtained pure, excepting the constant admixture of some saliva, by allowing dogs, in which artificial fistula has been induced, to feed on easily-chewed bones, opening the fistula in the course of five to tĕn minutes, and filtering off the mucous flakes and particles of the food from the fluid which escapes. If we wish to investigate the gastric juice free entirely from the saliva, the œsophagus, or at least the salivary ducts, must be tied. Formerly animals were caused to swallow a sponge fastened to a string; after some time the sponge was withdrawn by means of the string, and the fluid expressed. Afterwards it was usually obtained by killing animals shortly after eating, and collecting the fluid from the contents of the stomach. The gastric juice, when filtered, contains but few solid constituents: in that of a woman there has been found (after the abstraction of hydrochloric acid) 0.517 to 0.562 per cent.; in that of the dog, 1.05 to 2.07 per cent.; in the solid residue there are contained about 63 per cent. of organic and 37 per cent. of inorganic matters.

The organic substances of the gastric juice are not yet sufficiently known. We only know that an organic material is contained in it, to which principally the gastric juice owes its property of dissolving and changing into uncoagulable substances (*peptones*) the protein bodies. This substance, PEPSIN, is closely related to the protein bodies; it does not coagulate by heat, but loses its digesting powers, and is precipitated by bichloride of mercury, lead salts, alcohol, and tannic acid. Together with this substance, there is also found, in the gastric fluid, an organic substance soluble in water and alcohol. The free acid of the gastric fluid is partly hydrochloric, partly lactic acid. The latter is often wholly wanting in that of carnivorous animals. The quantity of free muriatic acid amounts, on the average, to 0.35 per cent., that of the free lactic acid, to 0.45 per cent. of the fluid. In that of a woman there was found, in gastric fluid containing saliva, 0.022 per cent., and, at another time, 0.018 per cent. of free muriatic acid (without lactic acid). In the gastric fluid, which is obtained shortly after the partaking of food, free muriatic acid is usually wholly wanting; free acid is then found, but this consists generally of lactic and butyric acids (arising principally from the bread and meat). Among the *mineral constituents* of the gastric fluid the chlorine compounds predominate. Besides chloride of sodium, there are found small quantities of chloride of ammonium, chloride of calcium, and chloride of magnesium, together with traces of chloride of iron. Phosphate of lime is found only in very small quantities, while phosphates and sulphates of the alkalies are not to be detected. Under peculiar circumstances, several substances may pass into the gastric fluid as *accidental constituents*, e. g., iodide of potassium, ferrocyanide of potassium, iron salts, urea. *Artificial gastric fluid* is the name given to the fluid obtained by treating the glandular membrane of the stomach with dilute muriatic acid. It possesses the chief peculiarity of the natural gastric fluid of changing coagulated protein bodies into soluble substances.

With reference to the *amount of gastric fluid secreted*, by several experiments on dogs these have been found to secrete, in twenty-four hours, $\frac{1}{10}$ of the weight of their body. According to this, an adult human being would, in twenty-four hours, discharge about $14\frac{1}{10}$ lbs. of fluid into the stomach. According to several direct observations on a woman, as much as one-fourth of the weight of the body has been found to be secreted as gastric fluid.

The *function of the gastric fluid* is evident from the above-named property of dissolving protein bodies and substances containing or yielding gelatin, and changing them into easily-resorbed peptones. This power is destroyed by boiling, by saturation of the free acid, by sulphurous and arsenious acid, by alum and most metallic salts. It is much restricted by saturating the gastric fluid with salts of the alkalies, or other soluble compounds. The place of the muriatic and lactic acids may be partially supplied by other strong mineral acids, but not by other organic acids. 100 grains of recent gastric juice are capable of dissolving 3 to 5 grains of coagulated albumen. On the non-nitrogenised articles of food, *i. e.*, the fats and carbohydrates, the gastric fluid has no effect. It moreover interferes with the action of the saliva upon amylum, at least so far that raw starch is not changed in the stomach into sugar, although boiled starch is. The gastric fluid is not sufficient for the solution of all the protein bodies requisite for the nourishment of an animal; this results not only from the fact that a large portion of the protein bodies eaten leaves the stomach undigested, but also from the following consideration: A dog needs daily, for the perfect maintenance of all the physiological functions, 50 grains of flesh (containing 10 grains of albuminates) for every 1000 grains of its weight; it secretes, however, only 100 grains of gastric juice, which, as before mentioned, is capable of dissolving at the utmost one-half of the albuminates of the flesh; hence other fluids must also flow into the intestinal contents which are capable of dissolving the protein bodies, for the gastric juice is deprived, in the duodenum, of its free acid, and with it of its power of digestion, by the bile and pancreatic fluid. In man, moreover, according to the few exact observations made, less of the albuminates seems to be digested in the stomach than in dogs.

THE BILE.

The bile of most animals forms, when discharged from the gall-bladder, a mucous fluid, capable of being drawn into threads, of a green or brown color, bitter taste, peculiar odor, which often resembles musk, especially on being warmed; its specific gravity ranges about 1.02; it is usually slightly alkaline, often quite neutral, very rarely acid even in disease. Bile containing mucus putrefies readily; when free from mucus, with difficulty, or not at all. Recent human bile can, of course, only be obtained from the corpses of criminals immediately after execution. In order to study the proportions of the biliary secretion and its influence upon digestion, &c., biliary fistulas have been established by tying the biliary duct, and allowing the punctured gall-bladder to unite with the external edges of the wound. Every kind of bile contains two important constituents, one or several resinoid, and one coloring matter. The *resinoid acids* are not entirely identical in all kinds of bile; in that of most of the mammalia, glycocholates and taurocholates of the alkalies are found mingled in different proportions. In the bile of the dog there has been found only taurocholate of soda. The resinous acids of the bile of swine are peculiar; these are also paired partly with glycin, partly with taurin, but differ from the before-mentioned acids in composition by 2 equivs. of CH (see page 90). These acids form in most bile at least 75 per cent. of the solid residue. The *bile-pigment* occurs in the bile of different animals in two modifications, a brown and a green—the latter appears to be a product of the oxidation of the former; but these substances have been as yet too little investigated to allow us to express a decided opinion. The peculiar changes of color which the brown pigment especially undergoes by the action of nitric acid, are well known. The quantities of the pigment have not been even approximatively determined.

A never-failing constituent of bile is *cholesterin*, which is probably dissolved by the taurocholate of the alkali, and hence is seldom found separated in the crystalline form. Free fats, which are also held in solution by the taurocholate of alkali, as also fatty salts of the alkalies, are very common constituents of the bile; in the solid residue of human bile, 27 to 30 per cent. of fats, fat acids, and cholesterin have been found.

Among the *mineral constituents* of the bile, chloride of sodium, as usual, preponderates; with this there are found some phosphate and carbonate of soda, phosphates of lime and magnesia, with traces of iron and manganese. No sulphates of the alkalies are found in fresh bile, as also no ammoniacal salts. It is worthy of remark that the bile of marine fishes contains almost solely potash salts, while that of herbivorous mammalia yields only soda salts.

The bile owes its property of drawing into threads principally to its content of mucus; there are intermixed in the abundant mucous fluid relatively few cells of cylinder-epithelium. Normal human bile contains, on the average, 14 per cent. (ranging between 10.2 and 17.7 per cent.) of solid constituents; that of the ox 10 to 13 per cent.; that of the swine 10.6 to 11.8 per cent. The organic constituents of human bile amount to about 90 per cent.; that of most animals contains less organic constituents as opposed to the mineral substances, occasionally only 86 per cent.—The bile of most of the carnivora is yellow or yellowish-brown—that of herbivora green; but the yellowish-brown bile becomes green by long retention in the gall-bladder (after long deprivation of food), hence the pigment undergoes an oxidizing process in the gall-bladder. It also becomes more concentrated by a prolonged delay in the bladder; *e. g.*, in the dog and cat the recent secretion of the liver contains 5 per cent. of solid elements, while the bile from the gall-bladder contains 10 or even 20 per cent. *Albumen* is found in the bile in the embryonic state, occasionally in fatty liver, in Bright's disease, and in abscesses of the liver. *Urea* occurs in the bile in uræmia, hence principally in cholera and Bright's disease. In bile which has stagnated for a long time in the bladder, in consequence of disease, sediments are not seldom found, which may be recognized under the microscope as greenish and brownish stalks, sausage-shaped molecules, or minute crystals arranged in rows; this substance has been named *bilifulvin.* There are often found among these, ruby-red to yellowish-red rhomboidal crystals, which resemble the *hæmatoidin* found elsewhere only in old extravasations of blood; the rod-like molecules are also transformed by exsiccation of the bile, or treating it with ether, into crystals perfectly resembling hæmatoidin. The solid constituents of the bile are usually increased in the following diseases: in cardiac affections and abdominal diseases, which delay the current of the blood in the large veins, also in cholera, in which all the animal fluids become thicker by the loss of water. The bile is, on the other hand, usually more watery after violent inflammations, in dropsical affections, typhus, tuberculosis, and diabetes; in these conditions, the proportion of water in the bile appears always to stand in a certain relation to that in the blood. *Biliary concretions*, which are so often found in the gall-bladders, especially of elderly persons, are generally of two kinds. One contains a smaller or larger nucleus of chalky pigment, but consists mainly of cholesterin; the latter is sometimes deficient, and the concretion consists wholly of the pigment compound. Another species of biliary calculi is dark green or black, contains the pigment in a different modification, is also very rich in lime, but almost free from cholesterin. Biliary calculi, which consist mainly of carbonate and phosphate of lime, are very rare.

By careful investigations of the quantity and constitution of the bile flowing in a given time from biliary fistulas (artificially produced in animals), the following results have been obtained as to the *amount of the secretion of the liver:* In different animals, the ratio presents itself that in the cat 1000 grains secrete in twenty-four hours 14.5 grains of bile (with 0.816 grain of solid constituents); in the dog, the same weight secretes 20.0 grains (with 1.0 grain solid const.); in the sheep, 25.42 grains (with 1.34 grains solid const.); in the rabbit, 137.8 grains (with 2.47 grains solid const.); in the goose, 11.78 grains (with 0.816 grains solid const.); and in rooks, 72.1 grains (with 5.256 grains solid const.). These results, however, are to be regarded only as approximative, as other experiments have afforded very important deviations from them. The secretion of bile is constant, but increases and decreases according to the period of digestion. In the third hour after the reception of food, it increases, and continues so to do until the thirteenth or fifteenth hour; from this time, it rapidly sinks, so that by the twenty-fourth hour it is about as great as at two hours after the reception of food. In prolonged abstinence, the quantity of bile secreted diminishes continually, so that in cats, *e. g.*, after ten days' fasting, it is reduced to one-fourth of the quantity of the secretion afforded in the twenty-fourth hour after the last meal. The biliary secretion is further increased in proportion corresponding to the *amount of food taken;* the *description of food* is also of influence on the amount of the biliary secretion. Animal food causes, according to numerous experiments, a more abundant secretion of bile than vegetable; other experiments have meanwhile given an opposite result. Thus, according to several observations, only 18.58 grains of bile to 154 of fresh meat were secreted from a dog, and 20.7 grs. to 154 grs. of bread one day old. It is to be remarked, however, that the bile under animal diet contains 3.056 per cent. of solid constituents; under bread diet only 2.639 per cent. Abundance of fat, added to the ordinary diet, increases considerably the secretion of bile; on the other hand, exclusive feeding on fat has so little influence on it that no more bile is secreted than during fasting. The partaking of *carbonate of soda* diminishes considerably the biliary secretion. By the use of *calomel* it is increased; but this is by the bile becoming more watery. No more solid constituents than usual are secreted. *Febrile diseases* lessen the biliary secretion.

The *function of the bile* has always been variously interpreted; it has been attempted in many ways to explain its influence especially on the digestive process. An undeniable, and certainly not a secondary function of the bile is to neutralize the acids of the gastric juice, which enters the duodenum with the digested food. The contents of the duodenum, it is true, always react acid; but, instead of the muriatic and lactic acids, the resinous, quickly-decomposing acids of the bile occur in the intestine. The bile has no special power of solution over the chyme; it must, however, dissolve some of the chyme constituents by means of the water which is poured abundantly into the intestine by it, while some of the biliary constituents become insoluble. The bile prevents, in a certain degree, the *putrefactive decomposition* of the contents of the intestine; when bile is not poured into the intestine, the excrements and contents of the large intestine usually smell excessively bad. It has always been maintained that the bile possessed the power of dissolving fat. Although this power is limited, it is by no means to be wholly denied; it has been proved by direct experiment as regards one of the constituents of bile, taurocholic acid. Nevertheless, the solvent power of the bile over neutral fats is so small that it would not be nearly sufficient actually to dissolve all the fat, the resorption of which in the intestines is proved; and yet the well-known fact that greasy stains may readily be removed by bile indicates significantly enough that this animal fluid must exercise an influence upon the movements of fat in tissues. More recently, direct observations have confirmed the opinion that a change in the relations of adhesion between oily fluids and membranes moistened with water is occasioned by bile. Thus, oil rises in capillary tubes moistened with bile considerably higher than in dry tubes, or those moistened with water; fat passes through membranes saturated with bile much more easily than through those moistened with water. While the influence of the bile upon the absorption of fat may be explained in this way, the following facts prove that without its assistance but very little fat is actually absorbed. In animals whose bile, by means of biliary fistulas, is diverted wholly externally, it is found that as much of the albuminates and carbohydrates are absorbed as in uninjured animals; but it is otherwise with the fats. A small portion of these is absorbed when the access of the bile to the intestine is prevented; but the quantity of fat then absorbed is 2½ times less than when the bile flows freely into the intestine. In the dog, for every 1,000 grains there are absorbed 0.5 to 0.6 of a gr. of fat, while in the same case, on exclusion of the bile, only 0.1 of a gr. is absorbed. The chyle of dogs fed upon fat contains over 3 per cent. of fat, while in those with biliary fistula, after feeding on fat, only fat acids are found to the amount of 0.8 per cent. In another instance, there was found in the chyle of a dog with fistula of the gall-bladder, which consumed much flesh, only 0.2 per cent. of fat; in that of an uninjured, healthy dog, which had not very fat flesh, on the contrary, 3.2 per cent. The importance and mode of operation of the bile on the absorption of fat are, therefore, placed beyond doubt by these experiments.

That *the formation of the bile* takes place in the liver is proved by the following facts: In frogs in which the whole liver has been extirpated, not a single actual constituent of the bile was to be detected in the blood; icterus does not occur in any disease which attacks the parenchyma of the liver, and thus suppresses the secretion of bile; in the blood of the portal vein not one of the actual constituents of the bile is found preformed. During the slow passage of the blood through the liver, it undergoes such important modifications (compare the blood of the portal and hepatic veins) that a mere filtering off of certain constituents of the blood through the liver (as of the urine through the kidneys) is not to be thought of.

THE PANCREATIC FLUID.

The secretion of the pancreas is a colorless, clear, slightly viscid fluid, without taste or smell, of tolerably strong alkaline reaction, coagulates on being heated, as also by the addition of alcohol or mineral acids. The specific gravity is somewhat variable, as, according to the duration of digestion, sometimes more, sometimes less solid constituents are contained. *The concentration of the pancreatic fluid stands in inverse ratio to the quantity of the secretion afforded in a given time.* Thus, there are found in the pancreatic fluid of the dog from 1.62 to 11.56 per cent. of solid constituents. The pancreatic juice passes into putrefaction, after a few hours, at a moderate temperature in the air; starch is transformed into sugar by it, in a few minutes, and neutral fats decomposed into glycerin and the corresponding fat acids. In order to collect pancreatic fluid, no other mode is applicable, than that of forming a fistula of the duct of Wirsung, which will discharge upon the surface. The principal constituent of the pancreatic fluid is an albuminous substance, which is not perfectly identical either with albumen or casein. This substance coagulates on being heated, is precipitated by alcohol, but the precipitate remains, even after long washing with alcohol, soluble in water; it is precipitated by acetic acid, but gradually dissolves in an excess, on being warmed. About 78 per cent. of this substance is found in the solid residue of the pancreatic fluid. Besides a buttery fat, there is also found in it an organic substance in small quantity, which is soluble in alcohol. The *mineral substances* of the pancreatic fluid consist, principally, of chloride of sodium, phosphates of the alkalies and earths, sulphates of the alkalies, and carbonate of lime. The experiments instituted upon animals with regard to the *amount of the secretion*, have resulted as follows: 1,000 grains in the dog secrete, in 24 hours, about 35 grains of fluid. During the period of digestion (in ruminants, after the chewing of the cud), the secretion attains its height. The quantity of the fluid secreted is independent of the volume of the pancreas. Prolonged fasting, vomiting, and mechanical effects, lessen the quantity of fluid secreted; ingestion of solid food, and especially of drink, augments it considerably. The *function* of the pancreatic fluid, in digestion, may be twofold, according to the above-mentioned properties, namely: to change starch into sugar, and to decompose the fats, so as to render them absorbable. That it actually performs the former in digestion, has been placed beyond doubt, by numerous experiments. The pancreatic fluid possesses this property in a much higher degree than the saliva; it is operative even at a low temperature; neither bile, nor gastric juice, nor free acids, interfere with this function of the fluid. It is also the property of this fluid to decompose the neutral fats; it loses this as soon as it comes in contact with free acids, as, *e. g.*, with those of the gastric fluid; hence the pancreatic fluid cannot serve, principally, to decompose the neutral fats in the intestine; and we find, in fact, neither in the chyme, nor in the chyle of the lacteals, considerable quantities of fat acids, but always a preponderance of the neutral fats. After the conduction externally of the pancreatic fluid, the fat taken with the food is absorbed in the same quantities as when this fluid flows freely into the intestine. As the pancreatic fluid is entirely changed or reabsorbed before it reaches the middle of the small intestine, it is not to be presumed that in the ileum, where the contents often begin to react neutral or alkaline, the neutral or alkaline fluid is still able to decompose the fats.

THE INTESTINAL FLUID.

This liquid, which is secreted from the bottle-shaped glands of the alimentary canal (follicles of Lieberkuhn, and of the large intestine), is colorless, capable of being drawn into threads, and of alkaline reaction; its morphotic elements are granular cells, cell-nuclei, and, occasionally, some fat and cylinder-epithelium. The intestinal fluid, after being filtered, contains, on the average, 3.2 per cent. of solid constituents; it does not coagulate on boiling, is not clouded by acetic acid. Alcohol precipitates from it an organic substance, which redissolves in pure water; its solution is precipitated neither by mineral acids nor bichloride of mercury, but by acetate of lead.

The intestinal fluid, free from bile and pancreatic fluid, is obtained, partly, by tying a knuckle of intestines, from which the contents have been pressed out as much as possible, or from intestinal fistulæ in animals, whose bile and pancreatic fluid have been conducted externally, by the formation of fistulæ. The quantity of intestinal fluid, as a whole, secreted in a given time, cannot be accurately determined; but it has been observed, that fluid is poured into the small intestines most abundantly five or six hours after the time of the meal; and that after the reception of drink, the quantity increases very much. The intestinal fluid serves, as regards its function, as a complement to the digestive fluids, the gastric and pancreatic fluids, which become inoperative towards the middle of the small intestine; it possesses not only, as the latter of these does, the power of rapidly changing starch into grape sugar, but also of dissolving (notwithstanding its alkaline reaction) and rendering absorbable flesh and other protein bodies. In tied knuckles of intestine, into which starch or paste has been introduced, all the starch is transformed into sugar at the end of three hours, and in great measure absorbed. Pieces of meat or coagulated albumen disappear from such knuckles after six to fourteen hours.

CONTENTS OF THE INTESTINES.

The contents of the intestines, even after the use of tolerably simple articles of diet, consist of a mixture of undigested, undigestible, and already changed or decomposed substances, with which are mingled constituents, partly undecomposed, partly already metamorphosed, of the digestive fluids. The reaction of the intestinal contents is different, according to the part of the intestinal canal from which they are taken, and to the species of food partaken of. The contents of the stomach always redden litmus in the normal state, whatever may have been the kind of food used; those also of the duodenum, notwithstanding the influx of the bile and pancreatic juice, react acid, but far less intensely; in the jejunum a slightly acid reaction is still met with, while the contents of the ileum are neutral or alkaline, the latter especially near the cæcum. After exclusively animal diet, the acid reaction usually disappears a little below the duodenum, and alkaline reaction soon occurs; after the reception of vegetable food, the acid reaction often extends beyond the middle of the small intestine, and after the use of sugar it reaches even to the cœcum. The contents of the large intestine react alkaline, as a rule, but it not seldom occurs that the external parts, or those near to the mucous membrane, react alkaline, while the internal parts exhibit a strongly acid reaction. It cannot be doubted that the acid reaction of the gastric contents depends principally upon the free acid of the gastric juice, whether this be muriatic or lactic acid; the acid which we find in the duodenum has the same source, but there the freed and still undecomposed bile-acids may also occasion the reaction. The free acid which we find in the small intestine after abundant saccharine and amylaceous food, is lactic acid, according to direct experiments. In the cœcum and colon a genuine butyric acid fermentation often takes place; hence the acid reaction of the internal portions of their contents. That the alkaline reaction, where it occurs, arises mainly from the alkaline digestive fluids, it is scarcely necessary to mention; occasionally in the colon this may be caused by the development of ammonia. On account of the rapidity of their absorption but few soluble substances can be extracted from the intestinal contents; we meet with sugar most frequently, which arises merely from the amount of starch in vegetable food. Even in the cœcum sugar is often found. In the watery extract of the contents of the small intestine, whether the food has been animal or vegetable, we meet with *coagulable protein-bodies;* as these are mostly changed by digestion into soluble non-coagulable bodies (peptones) by digestion, and as the coagulable substance of the pancreatic fluid speedily disappears from the intestine, and these coagulable substances are found in the intestine even after non-nitrogenised diet, it is more than probable that this albumen occurs in consequence of endosmotic currents from the blood. *Dextrin* and veritable *peptones* are detected only in very minute quantities. In the alcoholic extract of the intestinal contents there are found, besides sugar, the free acids, and their salts with the alkalies, the *constituents of the bile.* In the duodenum and near to it the conjugate bile-acids may be detected; the further we proceed in the small intestine the less we find of these; but in their place choloidic acid and dyslysin occur; in the large intestine we find but few products of metamorphosis, more substances soluble in ether, which yield with sulphuric acid and sugar the well-known bile reaction, and finally small quantities of taurin. According to special researches, half of the bile poured into the bowels is decomposed before reaching the middle of the

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small intestine. Fat is often found in the whole tract of the alimentary canal, especially after animal diet; when the food is very abundant in fat, it often passes into the excrements. *Cholesterin* may likewise always be detected in the intestinal contents, although in very small quantities. The bile-pigment gradually undergoes in the intestinal canal the same changes which we have noticed in it in the putrefaction of the bile. The yellow color of the excrements depends upon entirely altered bile-pigment. The constituents of the intestinal contents which are insoluble in neutral menstrua consist partly of the cell-formations arising from the digestive fluids, partly of undigested or undigestible remnants of the food. The *starch-granules* are smaller the further they have penetrated in the intestinal canal; often we find merely their envelops, like loose laminated vesicles. *Muscular fibres* present themselves in all stages of transformation; we often find in the colon, unaltered primitive muscular bundles, then smaller parallelopipedon-like pieces on which the transverse striation is still evident, generally to be recognized only by a fine parallel punctation; then instead of transverse only longitudinal striæ occur; finally a hyaline mass remains which is only to be recognized as the rudiment of muscular fibre by a parallel grouping of some prominent points. Fragments of bones are often found in dogs in the different parts of the intestinal tract. Yeast-cells occur very frequently after the use of baked food. After a vegetable diet, nearly all the morphotic elements of the structure of plants may be recognized; the chlorophyll-cells remain quite unaltered, the parenchyma-cells occasionally isolated; spiral vessels, especially in the excrements, often as if prepared. The *gases* which are found normally or abnormally in the stomach and intestinal canal, have their source partly in the atmospheric air mingled in chewing and moistening with saliva the food, partly in the decomposition of the intestinal contents. Hence the differences in composition which show themselves in the gas obtained from the different portions of the intestines. In the mixture of gases contained in the stomach, we find a little oxygen, a good deal of carbonic acid, with nitrogen and traces of hydrogen; in the small intestine the oxygen has disappeared, but much hydrogen and carbonic acid are present; these have evidently arisen from decomposition; part of the carbonic acid may also be derived from the blood. In the colon, where the processes of decomposition commenced in the ileum not only continue but become more intense, still larger accumulations of gases take place. Here there are added to the carbonic acid and nitrogen considerable quantities of carburetted hydrogen with small quantities of sulphuretted hydrogen.—With regard to the intestinal contents in the fœtus, they are of course different according to the portion of intestine from which they are obtained. In the *small intestine* of the human fœtus (after five months) there is found a light yellow mass of neutral or slightly acid reaction, consisting mainly of epithelial formations and mucus (89 to 96 per cent. of the solid residue); the ethereal extract of this mass consists of oleic and margaric acids and a little saponifiable fat; in the alcoholic extract there are found traces of resinous bile-acids and bile-pigment. A considerable amount of chlorides of the alkalies is also met with and a substance resembling casein. The contents of the *colon* of the fœtus of 7 to 9 months are very similar to the *meconium* discharged after birth; they form brownish-green, almost black, tolerably compact masses, without odor or peculiar taste, readily putrefying in the air. Meconium, like the contents of the large intestine, is generally of a slightly acid reaction, seldom neutral; it contains principally cylinder-epithelium (appearing green under the microscope), mucus and fat, with much cholesterin; neither bile-acids nor bile-pigment are to be detected, as also no substance precipitable by heat or acetic acid.—The contents of the intestine are often discharged by vomiting, and then exhibit not seldom characteristics which we do not find in normal intestinal contents. That vomit consists of undigested and half-digested articles of food mingled with the fluids of digestion, it is hardly necessary to mention. It results of course from this, that the longer after the reception of the food the vomiting takes place, the more changed it will be. The transformations which the matters vomited exhibit may be normal or abnormal, *i. e.*, we may recognize the usual forms of change in the simplest articles of diet which are found in normal digestion, or other products of an acid fermentation. If the vomiting takes place a good while after the reception of the food, so that the contents of the duodenum are also discharged, we find not only the animal, but also the vegetable substances changed. The food has, however, generally undergone abnormal alterations; the starch and the sugar formed from it are subjected to various processes of fermentation; at one time lactic acid, at another acetic acid is formed, while butyric acid frequently occurs; occasionally these carbohydrates are transformed into a colorless ropy mass.

The different degree of alteration of the secretion separated by the diseased mucous membrane of the stomach, may be the cause of the differences in the processes of fermentation, the results of which we find in vomit. Besides the yeast fungus, which is not rare in vomit, microscopic algæ occasionally present themselves; they form films which consist of a greater or less number of four-parted cells (measuring $\frac{1}{300}$ to $\frac{1}{500}$ of a line in diameter); they resemble bundles tied with strings, and were originally called *sarcina ventriculi*, but are probably identical with the *Merispomedia punctata* of Meyen, and the *Gonium tranquillum* and *glaucum* of Ehrenberg. They are not characteristic of any particular affection of the stomach. *Excessively watery fluid substances* are often vomited, without any food having been previously taken. Sometimes this fluid arises merely from the saliva which has gradually accumulated in the stomach; it then often reacts alkaline. Frequently, however, vomiting of a watery fluid occurs which reacts strongly acid; the nature of its free acids has not yet been thoroughly investigated. The *rice-water* discharges, which are vomited in cholera, are of feeble but nauseous odor, and deposit white flakes of mucus and epithelium. The fluid contains but few organic substances in solution, principally chloride of sodium and a little sulphate of alkali. In the commencement of the disease, it contains free butyric and acetic acids; when the vomit is free from remains of food, *urea* is found in it if the reaction be acid or neutral; when it is alkaline, as is usual when uræmia occurs, *ammoniacal salts*, especially carbonate of ammonia, present themselves. *Albumen* is found but sparsely in the acid fluids, more abundantly in the alkaline. *Biliary matters* may generally be recognized in vomit, by the green color of the mass. *Blood* is not always to be recognized in vomit by its red color, and the presence of the blood corpuscles; matters resembling coffee-grounds, or of a chocolate color, are often vomited when the blood has remained some time in the stomach; but even then we always find rudiments of blood-corpuscles, and an abundance of iron on incineration of the mass. *Sugar* is frequently found in vomit; it occurs especially in diabetic patients. *Fat* is not seldom found in vomit. After what has been said already as to the contents of the colon, it is scarce necessary to remark that the solid excrements, the *fæces*, consist more or less of the indigestible remains of food, cellular tissue of plants, tendons, membranes, primitive muscular bundles, &c., that they contain only traces of altered constituents of the bile, with an abundance of epithelial cells, mucus, &c.

The disagreeable odor of the excrements seems to depend in great measure upon decomposed bile and mucus; their reaction is generally acid but very often alkaline or neutral. Normal human excrement contains about 25 per cent. of solid constituents (varying from 7 to 31 per cent.). An adult discharges on the average about 5 oz. 5 drs. of fæces (varying between 2 oz. $7\frac{1}{2}$ drs. and 10 oz. 15 drs.) daily, hence about 1 oz. $5\frac{1}{2}$ drs. of solid constituents (from 9 drs. to 2 oz.). The solid excrements contain on the average very few soluble salts; while dried human fæces afford nearly 6.7 per cent. of *mineral constituents*, we find among these only 1.54 parts (23 per cent.) of soluble salts. It is only when the food passes with abnormal rapidity through the alimentary canal, that great quantities of salts are discharged with it by the rectum. In the excrements, as a rule, the magnesia preponderates over the lime, *i. e.*, the lime salts seem to be more readily absorbed in the intestine than the magnesia salts, hence the ratio in the excrements of the magnesia to the lime, is generally as 1: 2 or $2\frac{1}{2}$, while far more lime is contained in the food: lime and magnesia are combined with phosphoric acid in the fæces of man and the carnivora. Ammonio-phosphate of magnesia is a constituent of the fæces (when of neutral or alkaline reaction), easily recognized by the microscope; this salt arises not only from the amount of magnesia in the food, but also from the decomposition of mucus especially in the diarrhœa of typhus, cholera, &c. A little silica is almost always found in the excrements, either as sand or as the skeletons of insoluble vegetable tissues. Unaltered constituents of the bile are found only when the contents pass rapidly through the intestines, as in catarrhal diarrhœas, after saline purgatives, &c. Taurin is always found in the excrements. The latter are free from bile when the biliary duct is closed; they then are of a dirty whitish gray, of a very nauseous fetid odor, and contain more fat than usual. The *bright yellow semi-fluid excrements of sucking children* contain a great deal of fat, much coagulated and still undigested casein, bile-pigment so little altered as still to afford the well-known play of colors with nitric acid, as also bile-acids which give the usual reaction with sugar and sulphuric acid; epithelial cells also are not wanting. The excrements are sometimes *green*, after bile has been poured abundantly into the intestine, especially when much free acid also exists there, hence usually in the icterus of new-born infants. The color arises from the bile-pigment; together with this are found slightly modified bile-acids. The grass-green stools after the use of calomel are well known; we find in them sulphuret of mercury, from which the color may in part arise by its fine subdivision; more unaltered bile, however, is found in such excrements than usual. After long-continued use of iron-preparations or ferruginous mineral waters, the excrements often become black or green; the color depends here upon the proto-sulphuret of iron. If the albuminate of the protoxide of iron is dissolved in caustic potassa, and sulphuretted hydrogen introduced, an intense steel-green fluid with sulphuret of iron in suspension is obtained. The excrements also appear green after the use of indigo, black after partaking of whortleberries, light yellow after the use of rhubarb, gamboge, or saffron. The excrements in consumption are sometimes found to contain more *fat* than usual. *Sugar* is occasionally found in the fæces of diabetic patients. The stools are found to be black, chocolate colored, or tarlike, when *blood* is contained in them, and this arises from the upper part of the intestinal canal; so also the semi-liquid, green excrements which are observed occasionally in typhus and other diseases, depend upon blood, which is easily recognized by the microscope. Soluble *albumen* is found in the stools in dysentery, typhus, and occasionally also in Bright's disease, and in cholera. The greatest quantities of epithelial cells are found in the dejections in cholera. *Cytoid corpuscles* are very numerous in the excrements in catarrhal diarrhœas, in dysentery, and occasionally in typhus and cholera. *Hyaline mucus* is observed in the excrements in catarrh of the large intestine; it arises from the follicles of the colon, and contains round or oval, pale, or granular cells and cell-nuclei. *Fibrinous exudations* occur in the fæces in follicular ulceration, and in dysentery. The *intestinal concretions* which are observed more commonly among the herbivora, consist mostly of phosphate of magnesia, ammonia, and carbonate of lime. *Bezoars* are the intestinal concretions of different animals belonging to the genus of goats or gazelles, and consist partly of *phosphate of magnesia and ammonia, and phosphate of lime*, partly of *lithofellic acid*, and partly of *ellagic acid.*

THE SEBACEOUS SECRETIONS.

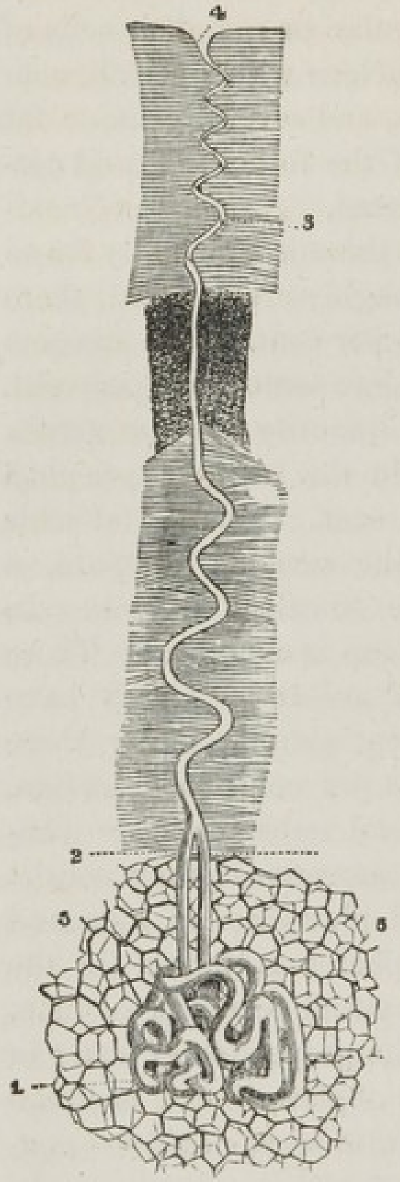
We consider here not only the secretion of the sebaceous glands which are distributed over the whole skin, but also that of the Meibomian glands, and the ceruminous glands of the ear, the smegma præputii, castoreum, and the vernix caseosa. All these secretions contain more or less morphotic elements, especially small-celled epithelium from the glands of the skin; usually epithelial cells from the cuticle are mingled with them. There are found besides in these secretions, especially in the Meibomian secretion and ear wax, peculiar, oval, angular or roundish cells of $\frac{1}{200}$ to $\frac{1}{140}$ of a line, which, with a pale nucleus with nucleoli, contain small, dark, sharply defined granules, and several genuine fat molecules. In inflammatory irritations of the follicles, cytoid corpuscles (mucous or pus-corpuscles) are secreted. Among the chemical constituents of the sebaceous secretions there is constantly found a *protein-substance*, which has not been thoroughly investigated; there are contained of it in the vernix caseosa, 4 per cent., in the smegma præputii, more than 5 per cent., in Canadian castor, 5.8 per cent. *Neutral fats* are present in considerable quantity; in the vernix caseosa there were found 47.5 per cent., in the smegma præputii 52.8 per cent., in Canadian castor 8.2 per cent. Volatile fat-acids do not exist in these secretions. In the smegma præputii, a little *cholesterin* is found, in castor, the so-called *castorin*. In the preputial secretion, a little ammonia-soap is contained. There are found in castor, especially, *resinoid substances* which have not been thoroughly examined: in recent genuine castor, there were found 67.7 per cent., in Russian, 64.3 per cent., in Canadian, 41.34 per cent. of them. Soluble mineral substances are contained only in small quantities in these secretions: they consist of chloride of sodium, sal-ammoniac, and phosphate of soda and ammonia; the quantity of earthy phosphates is larger (in the vernix caseosa, 6.5 per cent., in the preputial secretion of man, 9.7 per cent.). As is almost self-evident, the proportion of water in these secretions is very variable. A trace of *phenylic acid* is found in castor. *Hippuric acid*, and frequently also *benzoic acid*, are contained in the preputial secretion of the horse, and in castoreum. In the latter there is found much sulphate of lime, in the smegma præputii of the horse, carbonate and oxalate of lime.

THE SWEAT.

This fluid, as it collects in drops on the skin of one perspiring, is colorless, tastes salty, has a peculiar odor, is poor in solid constituents, and, when recent, always reddens litmus. For the investigation of the sweat, the necessary material is generally obtained by extracting with water that which is absorbed by clean sponges or cloths;

or by expressing it when the latter are very damp. In order to collect larger quantities of sweat, the best plan is to inclose the arm in an air-tight apparatus of glass, gutta percha, &c. *Epithelial cells*, in great abundance, are usually mingled with normal sweat, so that it appears quite cloudy, almost milky, when collected in large quantities.

Fig. 17.



Vertical Section of the Skin, showing the Structure of the Sweat-glands.—1. Convoluted tubule or tubules lined with the excreting cells, and imbedded in the subcutaneous adipose tissue, 5. 2. Duct of the gland passing through the cutis vera and rete Malpighii, and becoming spiral in the cuticle, 3.

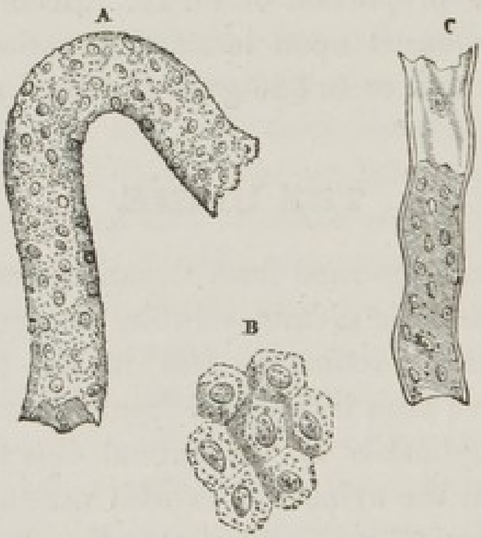
Of *solid constituents* the sweat contains, according to the experiments of different observers, 0.5 to 2.2 per cent., that is, of those which do not volatilize on evaporation. Among these the *chlorides of sodium and potassium* predominate, constituting more than half of the solid residue. *Phosphates of the alkalies* are not found in the sweat; so also *ammonia and ammoniacal salts* never occur in it when recent, but are formed by the decomposition of its nitrogenised constituents; ammoniacal alkaloids are not found even in offensive alkaline sweat. The *earthy phosphates*, and *oxide of iron*, which are found constantly in the ashes of the sweat, can only depend upon the epithelial cells mingled with the sweat. That the *fat* of the sweat does not arise only from the sebaceous follicles, but is secreted from the sweat-glands, results from the fact that a little fat is always found even in the sweat of the palm of the hand, which, as is well known, contains no sebaceous glands. The most important constituents of the sweat are the *volatile acids*, among which *formic acid* preponderates; the quantity of *acetic acid* is less, and that of *butyric acid* least. Whether metacetonic and caproic acids exist in it is still uncertain. *Lactic acid* is not contained in the sweat, but a peculiar nitrogenised acid, $C_{10} H_8 NO_{13}$ is said to have been found in it. *Urea* probably also occurs in that of healthy individuals in small quantities; it is certain that in uræmia much urea is contained in the sweat, especially of the face. Whether albumen, uric acid and sugar exist in it, is not yet established by reliable observations. The coloring matters which in rare cases are observed in the sweat, are wholly unknown. But few substances pass more or less readily into the sweat; benzoic and cinnamic acids very readily, tartaric acid less so, and iodide of potassium, still less. Salicin quinine, and lactin could not be found again in the sweat. Together with the liquid secretion, a *separation of gases* by means of the sudoriparous glands is observed, especially of nitrogen and carbonic acid; the proportion between the two gases is very variable, but it appears that usually 1 vol. of nitrogen is exhaled for every 2 vols. of carbonic acid. The researches hitherto made, have not led to exact results as to the *amount of the secretion from the skin;* but it appears to stand to the exhalation from the lungs, in about the proportion of 7 : 12. According to very uncertain calculations, based upon loose observations, an adult in a vapor bath appears to secrete 386 grains of fluid sweat.

THE URINE.

The urine is a fluid, secerned from the animal organism by means of the kidneys, containing certain soluble, nitrogenised substances, and salts which have become useless in the metamorphosis of animal tissue, or have been introduced from without into the animal body, but are inapplicable to the animal functions. It follows hence, of course, that the urine will exhibit various modifications in its physical and chemical properties, according to the external and internal circumstances of the organism. Normal human urine has usually the following characters: it is of a light or dark-amber-yellow, perfectly clear and transparent, of a bitter salty taste, and feebly aromatic smell, is heavier than water (yet normally not more than 1.03), and reddens litmus perceptibly. In clean vessels the urine does not readily decompose; after standing in repose, it usually deposits a slight cloudiness of mucus; by longer standing it not only becomes not alkaline, but its acid reaction increases (*acid fermentation of urine*); yellow or reddish crystals are then deposited, appearing rhombic under the microscope. Later, often only after several weeks, but especially at a higher temperature, with a large proportion of water and abundance of mucus, the urine becomes covered with a thin, fat-glistening or iridescent film, fragments of which sink to the bottom; dirty yellowish-white flakes mingle with the mucous sediment, the color of the urine becomes paler, and its reaction alkaline (*alkaline fermentation of urine*). It begins to develop a disagreeable ammoniacal odor; in the mucous whitish-gray sediment, white granules and colorless prismatic crystals highly refractive of light, become visible.

Of *morphotic elements*, pavement epithelium, especially from the bladder, is most commonly found in the urine; it occurs in large quantities only in vesical catarrh, especially that occurring in scarlatina. *Mucous corpuscles* are generally to be found in the mucous cloud of urine which has stood for some time. In vesical catarrh, pyelitis, gonorrhœa, and diseases of the prostate, the mucous corpuscles often increase so as to render the urine cloudy and milky.

Fig. 18.



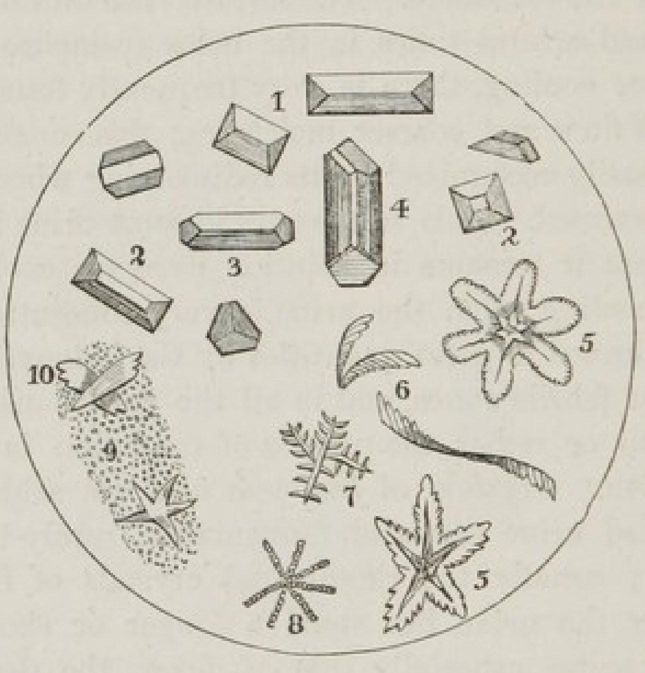
A. Portion of a secreting canal from the cortical substance of the kidney. B. The epithelium or gland-cells more highly magnified (700 times). C. Portion of a canal from the medullary substance of the kidney. At one part the basement-membrane has no epithelium lining in it.

Only in pathological urine are those *bottle-shaped or cylindrical bodies* to be found, which arise from the tubuli uriniferi; three species of them may be distinguished; first, those which consist of the epithelial coat of the tubules of Bellini, in which the small cells with their nuclei appear as if grouped in a honeycomb form; they are observed in the commencement of Bright's disease, and in the desquamative stage of erysipelas and scarlatina. The second species of cylinders consists of recent exudation, generally granular in appearance, in which more or less blood and pus-corpuscles may be recognized. A third form of these cylinders resembles hyaline tubes, which are often hard to recognize on account of their transparency; they are coagula of pure fibrin.

Spermatic filaments are found in the urine most abundantly after pollutions or coition. *Blood-corpuscles* are found plentifully in the urine, in inflammations of the uropoietic organs; and only under similar circumstances are larger fibrinous clots to be found. A species of *thread-like fungus*, not unlike the mycoderma cerevisiæ, but considerably smaller ($\frac{1}{280}$ to $\frac{1}{330}$ of a line), is found not only in urine which has stood some time, but occasionally in that recently discharged, as when, in vesical catarrh, decomposition of the urine commences within the bladder; *vibriones* and *monads* are found under similar circumstances. The *sarcina ventriculi* of Goodsir has also been found several times in the urine (compare p. 180). In the urine after cooling, there is very frequently found a sediment apparently of finer and coarser molecules; this consists of *urate of soda*, and is easily recognized by its redissolving when the urine is moderately warmed. This salt occurs in most urine in such small quantities, that it remains in solution even on cooling; it only appears on cooling when the urine is very concentrated, or when the salt is excreted in great quantities by the kidneys. It is hence found in most febrile states, and in all the conditions under which the respiration, or rather the process of oxidation in the blood is interfered with. Crystals of *free uric acid* are seldom found in recently voided urine (the acid fermentation rarely takes place in the bladder); usually the rhomboidal crystals of free uric acid separate after the urine has stood a longer or shorter time; in pathological urine, especially that of fever, the deposit of such crystals takes place in two or three hours. *Urate of ammonia* is not found alone as a constituent of a urinary sediment; usually there are mingled with it mucus, crystals of the triple phosphate, and amorphous molecules of phosphate and carbonate of lime, as it only occurs in urine, when the latter has undergone the alkaline fermentation; it is hence generally formed out of the organism; but in vesical catarrh of long standing, and especially in paralysis of the bladder, it is met with in recently voided urine. It may be recognized by the naked eye in the sediment as white, opaque granules; under the microscope, it has the appearance of dark brown, scarcely translucent globules, beset here and there with fine needles.

Crystals of *phosphate of magnesia and ammonia* (triple phosphate) occur only in neutral and alkaline urine. The octohedral crystals of oxalate of lime occur not seldom in the urine; it is not improbable that the oxalic acid is formed from other substances in the acid fermentation of the urine; at least, oxalate of lime is often visible only after the deposition of crystals of uric acid; true sediments, however, of oxalate of lime often appear in the urine, *e. g.*, in rachitis, after epileptic convulsions, in the convalescence from typhus (in the latter, generally with slight catarrh of the bladder). Among the most rare of the spontaneous deposits in the urine is *cystin*, which contains much sulphur, and appears in six-sided plates. On what pathological processes the appearance of this substance in the urine depends, is entirely unknown. Of the *chemical*

Fig. 19.



Crystals of the triple phosphate. 1, 2. Prismatic formation in various positions, 3, 4. The same, slightly modified. This form occurs usually in the alkaline fermentation of urine; while the stellar and foliate crystals, 5, 6, 7, are produced when ammonia is added to recent urine. 10, Urate of ammonia.

constituents in solution in the urine, *urea* is far the most important. That the excretion of this substance by the urine is subject to very important variations, has already been remarked (p. 65). It should also be remembered that the kind of food, and next to this the quantity of water simultaneously secerned, have great influence over the amount of urea which is excreted. With regard to the latter circumstance, experiments on men and animals have proved that an increased secretion of water is accompanied by an increased discharge of urea. Thus, *e. g.*, with 1000 grains of urine on an average, 33 grains of urea are discharged in 24 hours, with 2000 grains, about 42 grains, and with 3000 grains, about 50 grains. The specific gravity of the urine hence stands in a certain proportion to its content of urea, or to the amount of urea excreted in a given time. Thus when the specific gravity of human urine = 1.0135, in which 1.5 per cent. of urea are contained, 42,135 grains of urine are discharged in 24 hours; when the spec. grav. = 1.027 with a per centage of 3.75 of urea, only 16,592 grains of urine are discharged. The influence of diet upon the amount of urea excreted is more important, and has been more thoroughly investigated. By numerous experiments upon men and animals, the following relations have been placed beyond doubt. After the use of meat and other nitrogenised food, the whole of the nitrogen contained in it is not excreted in the shape of urea; if the nitrogenised food is sufficient for the restoration of the organic elements which have become effete, $\frac{1}{3}$ of the nitrogen which is taken up is discharged in other ways and means than by the formation of urea; only $\frac{2}{3}$ of the nitrogen absorbed appears in the urine as urea. If more nitrogenised food is taken, a perceptible increase of urea takes place in the urine; the deficit of [nitrogen in the] urea remains, absolutely considered, constant; but in relation to the amount of urea excreted, it may amount to $\frac{1}{6}$, $\frac{1}{8}$, or even $\frac{1}{50}$. A part of the nitrogenised food taken up also often remains in the body, and is there applied to the formation of cells and tissues; hence, in such cases, still less urea is found than was to be expected from the quantity of nitrogenised material consumed.

That urea is excreted constantly in the urine during abstinence from food, is a fact conceded on all sides; it is worthy of remark, however, that the excretion of urea which, in the absence of nitrogenised food, arises from the consumption of the constituents of the organs, becomes considerably less when non-nitrogenised articles of diet, *e. g.*, fat or starch, are partaken of.—As after the reception of protein bodies, so also after partaking of gelatin, the quantity of urea in the urine is rapidly augmented, but always in direct proportion to the amount of the gelatin taken in, *i. e.*, nothing is retained from gelatin in the body; without being applied to the redintegration of the organic elements, it is decomposed in the blood, so that urea passes into the urine as a product of its disintegration. An accelerated movement of the blood, or so-called febrile excitement, whether caused by certain medicinal substances, or by division of the par vagum on both sides, is followed, according to several observations, by an abundant excretion of urea; a retarded movement of the blood, on the other hand, is accompanied with a diminution of the amount of urea separated.

Uric acid which, as mentioned above, is generally found combined with soda, occurs in human urine normally only in small quantities, averaging about 0.1 per cent. In 24 hours an adult voids 7.7 to 13.9 grains of uric acid. Its quantity in the urine is much less dependent upon the nature of the food taken, than upon the internal conditions of the organism. In all cases where the nutrition is interfered with, by disturbed digestion, diseases of the organs of respiration, in all febrile movements, the quantity of uric acid increases in the urine. It occurs only in small quantities in the urine of carnivorous mammalia, in that of herbivora, not at all; it is found abundantly in the urine of serpents, birds, and insects. The urine of calves while sucking, contains no hippuric acid, but uric acid and allantoin. *Hippuric acid*, which has lately been artificially prepared from chloride of benzoyle, and glycin-oxide of zinc [$C_4 H_4 NO_3 . Zn O$], is principally contained in the urine of herbivorous mammalia, and occurs constantly in the urine of man, under vegetable or mixed diet. It is found in human urine in quantities hardly greater than uric acid. Its relative amounts in pathological conditions are almost wholly unknown; it is found in diabetic urine as constantly as in normal. After the use of benzoic acid the quantity of hippuric acid is considerably increased. *Cynuric acid*, the chemical composition of which has not hitherto been exactly ascertained, has only been found in the urine of the dog in very small quantities. *Creatin* and *creatinin* are integral constituents of the urine; but exact quantitative determinations of them have not been made. *Formic acid* presents itself occasionally in the urine of healthy individuals, although in very small quantities. *Lactic acid* is not found in normal human urine, but occurs very soon when the process of oxidation in the blood is interfered with; hence in disturbances of digestion, respiration, nutrition, and, therefore, in all febrile conditions; it must not, however, be forgotten that lactic acid is developed in the urine by the acid fermentation. In the urine of herbivorous animals, it occurs especially after stall-feeding. *Extractive matters*, *i. e.*, materials not yet accurately examined chemically, occur in very variable quantities in the urine; they increase considerably in diseases. It is worthy of remark that children void in 24 hours far more extractive matters, relatively to their weight, than adults; thus a child excretes about 0.35 of a grain, for every 1000 grains of its weight; an adult, however, only 0.15 of a grain.

During abstinence, the extractive matters appear in greater quantity in the urine, so that their absolute amount exceeds that of the absolute amount of the urea. The *oxide of omichmyle* belongs at present to these extractive matters, as a substance not yet thoroughly investigated. Not less unknown are the *coloring matters* of the urine. Notwithstanding the attention which the latter have received, both when normal and abnormal, neither in a chemical nor diagnostic aspect have they obtained any particular interest. *Chloride of sodium* and *chloride of potassium* are found in large quantities, so that an adult excretes, in only twenty-four hours, nearly 162 grains of chlorine. It is found most largely at mid-day (not immediately after dinner-time), at night considerably less, towards morning somewhat more. Bodily exercise increases the excretion of chlorine; most diseases, even a slight indisposition, diminish it. Even when no chlorine compounds are received from without, chlorine is always excreted, combined with a metal of the alkalies. When a great deal of chlorine is received from without, more than usual is secreted soon by the kidneys, but not all; the rest must leave the organism in some other way. The diminution, or even the entire disappearance of chlorine in the urine, is principally observable in diseases accompanied with the secretion of large exudations, *e. g.*, in acute dropsy, acute Bright's disease, acute tuberculosis, in violent diarrhœas, in cholera, typhus, and especially in pneumonia. *Sulphates* are found constantly in the urine, although in very variable quantities. An adult discharges, on the average, in twenty-four hours, 31.4 grains of sulphuric acid, *i. e.*, 0.32 grains for each 1000 grains of his weight. During the period of digestion, the quantity of sulphuric acid excreted increases, at night it diminishes, and reaches its minimum during the morning. Only very violent bodily exercise or psychical excitement increases the excretion of the sulphates. Fasting does not diminish it in the first twenty-four hours. Sulphates of the alkalies, taken pure, are entirely excreted during the next eighteen or twenty-four hours. Observations are still wanting which might lead us to safe results as to the variations in the excretion of sulphuric acid in diseases. *Acid phosphate of soda* is also contained in normal urine, and gives rise principally to its acid reaction; together with this, phosphate of lime and of magnesia are constantly found in no small quantity. An adult discharges by the urine in twenty-four hours, on an average, 49.4 to 80.2 grains of phosphoric acid (0.64 of a grain to 1000 grains of weight). After the ingestion of food, the quantity of phosphoric acid excreted rises materially; considerably more is excreted at night than in the morning. After partaking abundantly of protein bodies, the quantity of phosphates excreted is much increased, during fasting much diminished. As to the variations in the amount of phosphoric acid in the urine in diseases, no harmonious results have as yet been obtained; this much only seems certain, that, in acute affections of the nerve-substance, the phosphates are found in greater quantities in the urine. From an adult about 15.4 grains of earthy phosphates are excreted in twenty-four hours; but this amount is liable to very great variations, according to the nature of the diet. In the urine of small children and of pregnant women, the quantity of phosphate of lime often diminishes materially; in the latter (especially from the sixth to the eighth month of pregnancy) occasionally so much so that no lime can be detected. In normal human urine, the proportion of phosphate of lime to phosphate of magnesia is likewise somewhat variable, but on the average $= 15:7$. Traces of *iron* and *silicic acid* are usually found in the urine. *Gases* are also dissolved in the urine, especially carbonic acid and a little nitrogen. The *free acid* of the urine is subject obviously to numerous variations. That discharged by an adult in twenty-four hours corresponds to about 35.5 grains of oxalic acid. During the period of digestion, the quantity of free acid in the urine is a medium one; during the night it reaches its maximum, and during the morning hours, its minimum.

The quantity of water in the urine, even under physiological circumstances, is extremely different. Unfortunately, exact experiments are yet wanting by which the influence of each individual physiological moment upon the amount of the excretion of water by the kidneys, might be ascertained. According to the experience of the majority of observers, after the use of very large quantities of water, more than usual solid constituents appear to be excreted with the urine. In about six hours, the superabundant quantity of water taken up is again discharged. After considerable addition of water to the blood, *e. g.*, by injection into the veins, the urinary excretion is by no means correspondingly increased. After the cold bath, water is separated by the kidneys in the largest quantity. Shortly after a meal, absolutely and relatively less water and more solid constituents are secreted by the urine. That the description of the stools, and a more or less abundant transpiration (which again depends upon the external temperature, the degree of humidity of the atmosphere, bodily exercise, &c.), are of important influence upon the excretion of water, is self-evident; but the amount of consequence of each operating moment is not yet ascertained by exact investigations.

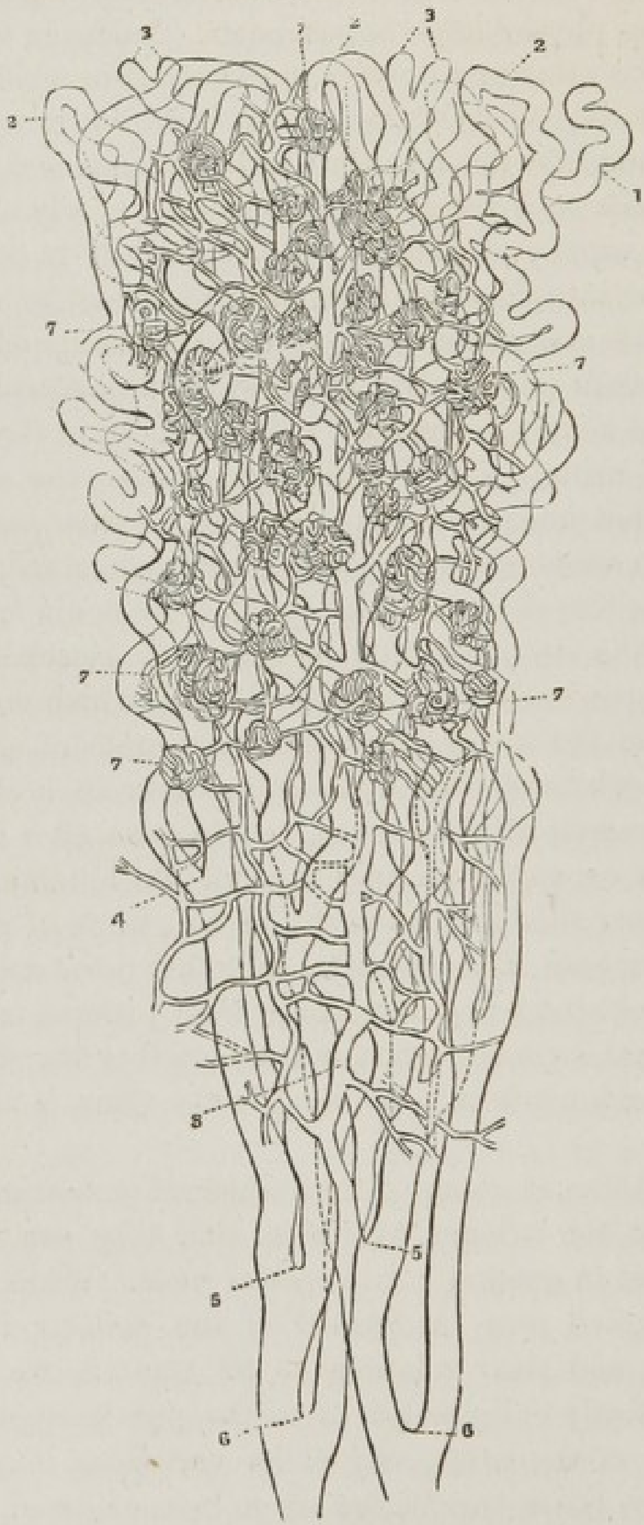
Many substances accidentally or purposely introduced into the organism pass unaltered into the urine; others undergo changes, and others do not pass into it at all. In general, it may be assumed, that those substances only (not belonging to the articles of food) pass into the urine which are easily soluble in water, and enter into no insoluble compounds with the constituents of the animal body, and which, moreover, are not readily oxidizable or decomposable. Hence nitrates, chlorates, borates, carbonates, and silicates of the alkalies, chlorides, bromides and iodides of potassium and sodium pass unaltered into the urine; while, *e. g.*, sulphuret of potassium is oxidized, and appears in the urine as sulphate of potassa. Many substances which form insoluble compounds with animal matters, especially with albuminates, only occur in the urine when introduced into the body in large quantities; to these belong, *e. g.*, all the salts of the metals. Many organic substances undergo in the animal organism the same changes which are capable of being produced by various oxidizing processes; the products of oxidation then show themselves in the urine, *e. g.*, as in the case of salicin. Some are fully oxidized to carbonic acid and water, and hence cannot be detected by their products of decomposition in the excretions, *e. g.*, mannite, quinine, &c. Although oxidation of the materials ingested generally takes place, we sometimes meet with deoxidations of highly oxidized substances; thus, ferricyanide of potassium appears in the urine as the ferrocyanide. Sulphocyanide and ferrocyanide of potassium, baryta-salts, and ammonia-salts pass unchanged into the urine, as also most of the organic acids. Tannic acid is, however, changed into gallic; benzoic and cinnamic pass into hippuric; uric acid is decomposed into urea, oxalic acid, carbonic acid, and water. The neutral salts of the alkalies, with the vegetable acids, re-appear in the urine as carbonates, on account of which the urine speedily becomes alkaline after their reception. *Quinine* and *urea* pass unaltered into the urine; on the other hand, anilin, thein, theobromin, allantoin, alloxanthin, amygdalin, asparagin, and phlorrhizin are not again detectable in the urine. Salicin is transformed in the organism to saligenin, salicylous and salicylic acids, which appear in the urine. Coloring and odoriferous matters in general pass unchanged, or slightly modified, into the urine. The following substances do not reappear: camphor, resin, inflammable oil, musk, alcohol, ether, cochineal, litmus, chlorophyll, and the coloring principle of alkanet. The rapidity with which many substances, hurrying through the animal organism, appear in the urine, is very different; yet, as a rule, it is the greater the more soluble and indifferent to the animal substances the material is. Iodide of potassium often appears in the urine after four to ten minutes.—The time is as various during which a substance may remain in the organism: on an average, it is the less the more soluble and indifferent the substance is; it stands, therefore, in a direct ratio to the rapidity of its passage into the urine.

In diseases, *abnormal constituents* occasionally occur in the urine; they are—

Albumen.—This enters the urine from the blood, first when the circulation of the blood in the capillaries of the kidney is disturbed, as happens in diseases of the heart or lungs, or tumors in the abdomen; also by a greater degree of wateriness of the blood, hence usually accompanying dropsy; also in renal catarrh and Bright's disease, whether this be accompanied with the phenomena of uræmia or not.—*Casein*, which was believed to have been found in chylous urine, has not yet been detected with scientific accuracy.—*Fat* is found only in very small quantities in the urine, often not at all; it is most commonly met with after the use of very fatty articles of diet. Isolated fat-globules appear not seldom in the urine in diseases accompanied by rapid wasting, especially in the so-called chylous urine. In Bright's disease, especially when the fatty metamorphosis has commenced in the kidneys, fat-globules are frequently found in the tubular casts, and also suspended free in the urine.—Under physiological circumstances, *sugar* very rarely passes into the urine so as to be recognizable; it has been found after the ingestion of large quantities of saccharine food; it must, however, be remembered that sugar decomposes very rapidly in the urine, and hence is probably often decomposed in the bladder, or undergoes transformations during the chemical treatment. It may thus pass from the kidneys into the urine much more often than it is detected chemically. According to experiments upon animals, sugar appears to pass in normal conditions into the urine only when it is accumulated in the blood to the extent of 0.4 to 0.5 per cent. In diabetes mellitus, sugar passes into the urine when the blood contains far less sugar than in the just mentioned physiological experiments. Besides in diabetes, sugar is found in the urine occasionally in disturbed or suddenly checked secretion of milk, in Bright's degeneration of the kidneys, and when the circulation of the blood in the renal capillaries is delayed.—*Bile-pigment* and *bile acids* occur in the urine in nearly all varieties of icterus; it is worthy of remark that occasionally in pneumonia the bile acids pass into the urine without bile-pigment being found with them.—*Butyric acid* occurs but rarely and in small quantities in the urine.—*Ammonia salts* are not found in healthy recent urine; they are formed, as a rule, in the acid, and especially in the alkaline fermentation of urine; in acid pathological urine, the occurrence of ammonia is not unusual—*e. g.*, in typhus, measles, scarlatina. In alkaline urine, ammonia is almost constantly contained, for the alkaline reaction either depends directly upon ammonia formed in consequence of the decomposition of the urea, especially in vesical catarrh; or upon carbonates of the alkalies, which soon cause decomposition of the urea; hence ammonia, urate of ammonia, and ammonio-phosphate of magnesia always occur in herbivorous animals, which excrete alkaline urine, and in man after the ingestion of carbonates or vegetable acid salts of the alkalies, when they render the urine alkaline (see above, p. 187, urate of ammonia and ammonio-phosphate of magnesia). Whether *nitric acid* can appear in the urine without being introduced from without, is still doubtful; it is certain, however, that the assertion that after the reception of ammonia-salts nitric acid is found in the urine, is founded upon a mistake.

So many different external and internal conditions influence the amount of the urinary excretion, that they can be reviewed entirely neither in general nor in special cases. While an approximative conception may be formed of the remoter influences of the excretion, and their relations to its amount, we are still by no means perfectly enlightened as to the proximate conditions of the excretion of the urine, and of its variations in amount. In reference to the latter, two factors are to be considered, namely, the mechanical conditions for the passage of the urine through the kidneys, and the constitution of the blood. We have already mentioned that when the current of blood in the capillaries is retarded, albumen occurs in the urine; it certainly depends upon the rapidity

Fig. 20.



SMALL PORTION OF KIDNEY, SHOWING ITS STRUCTURE.—1, 2, 3. Tubuli urinifera terminating in loops or cœcal extremities. 4, 5, 6. Convergence of the tubules in the medullary portion. 7, 7. Corpora Malpighiana, supplied from an arterial twig, 8, and connected with a venous capillary plexus surrounding the tubules.

of the circulation in the finer renal vessels whether more or fewer solid constituents pass from the Malpighian tufts into the canaliculi contorti. As the vessels leading from the Malpighian bodies have a smaller diameter than those forming the bodies, an increased pressure must take place upon the walls of the former, by means of which the excretion of urine is probably occasioned; by the vessels surrounding the canaliculi contorti the water is again absorbed from the urine contained in the latter, the urine thus becoming more concentrated. It has also been proved, by direct experiment, that the lateral pressure in the arterial system of the kidneys exerts a powerful influence upon the urinary excretion; when the tension of the blood in these vessels is raised, it increases; in the reverse case, it diminishes. Since in the canaliculi contorti the fluid excreted gives up water to the blood again, it is explicable why rapidly excreted urine is watery, and that slowly excreted concentrated, and why the urine never exceeds a certain degree of concentration. That the tension in the circulatory system depends upon nervous influence, &c., it is scarcely necessary to mention. Thus, direct experiments have shown that by excitement of the vagi nerves the tension of the arterial system is diminished, and consequently the excretion of urine is diminished.—The relation of the character and composition of the blood to the urinary excretion has been less carefully investigated, although it is obvious that the more excretory urinary constituents there are contained in the blood, and the more watery the blood is, the more urine must be excreted. The quantity of urine voided daily by an adult man may vary from 8,500 to 54,000 grains; on an average, from 18,500 to 23,150 grains are voided. For 1000 grains of weight, an adult discharges, on the average, 401.3 grains; a child, 725.5 grains. The quantity of urine excreted is usually greatest after partaking of the midday meal; at night it decreases, and rises again in the morning hours. Though the different proportion of water is the principal cause of these variations in the whole quantity of the urine, the amount of solid constituents thus excreted is also liable to considerable variation, according to the quantity and nature of the food taken; from 617.4 to 1234.7 grains of solid matters may be discharged by an adult in twenty-four hours by the urine. As principally nitrogenised excretory products and salts of the alkalies pass into the urine, it is readily seen that nitrogenised food, and hence animal diet, will effect an increase of the solid constituents of the urine; and that, moreover, a more active metamorphosis of tissue, which takes its course principally in the nitrogenised tissues of the animal body, must be of influence upon the amount of this factor. If the tissue-metamorphosis is less, as in most diseases, far less solid substances will be excreted by the kidneys. Further, if the blood is poor in albuminates, and abundant in salts, the solid normal constituents of the urine are materially diminished, as is proved by observations on Bright's disease, as also by direct experiments with injections of salts into the blood. The quantities, also, of *mineral constituents* excreted with the urine are subject to very great variations, viz: between 108 and 355 grains in twenty-four hours, averaging about 231.5 grains. If we examine the constitution of the urine according to different *physiological categories*, we find as follows:—

The urine of *women* is richer in water, and poorer in salts and in urea, than that of men; especially is this the case during pregnancy; as watery urine becomes alkaline much more easily than concentrated, the urine of pregnant women readily undergoes the alkaline fermentation; on account of its content of mucus, it often froths, and forms, on its upper surface, in its decomposition, a film, previously called *kyestein*, consisting of triple phosphate and fungus, and formerly regarded as peculiar to the urine of pregnant women.

As regards the urinary excretion, at different periods of life, the same holds good, as of tissue metamorphosis in general. Men in the prime of life, in whom the metamorphosis is most active, secern most urine-constituents. If the quantities of urine excreted, however, are compared with the bodily weights, nearly twice as much is discharged by children as by adults. No differences have been detected (at least with certainty) in the nature of the chemical constituents of the urine, with regard to the period of life. Sufficient has already been said as to the influence of digestion, and of the articles of diet.

Besides what has been already stated under the abnormal constituents of the urine, but little is to be said, with certainty, as to the composition of the urine in diseases. As the condition of the nutritive processes is generally reflected in it, it will have, in diseases, a constitution corresponding to the pathologically modified tissue-metamorphosis. We need here only refer to the urine in fever, and those conditions of debility accompanied by this or that disease, which we call anæmia, &c. The *urine of fever* is generally of a deeper tinge, dark yellow, reddish, or reddish-brown, of greater specific gravity, somewhat stronger odor, and very acid reaction. Far less urine is excreted, in equal periods, in fever, than in the healthy state; it appears only to be more concentrated, as the separation of water, by the kidneys, is relatively much more decreased, than that of the solid constituents. In the urine of fever, we find, very constantly, a relative and absolute diminution of the inorganic salts, and an increase in uric acid. The diminution of the salts concerns especially the chloride of sodium, which often disappears entirely in exudative inflammations. Urea is relatively diminished, the extractive matters somewhat increased, and lactic acid may be detected. The *urine of anæmia* is pale, of feebly acid reaction, becomes readily alkaline, the organic constituents much diminished; the salts, on the other hand, at least relatively, increased. All that is necessary has been said already, concerning diabetic urine, that of Bright's disease, &c. With reference to the urine of animals, the following holds good: The *urine of the swine*, the only omnivore which has hitherto been accessible for observation, is, usually (*i. e.*, under the well-known vegetable mast-feeding), clear, almost odorless, evidently alkaline, effervesces with acids, becomes cloudy on boiling, while the bicarbonates of the alkalies are changed into carbonates; it contains neither hippuric nor uric acid, nor ammonia salts, traces merely of phosphates, but together with urea (about 0.4 per cent.), salts of sulphuric acid, and chlorides of the alkali-metals, there are contained in it lactates of the alkalies. The *urine of the carnivora* is clear, very light yellow, of unpleasant odor, disagreeable bitter taste and acid reaction, easily becoming alkaline. Uric acid is often not to be detected, or exists only in traces. When carnivora are fed with vegetables, the urine becomes cloudy, alkaline, and altogether like that of the herbivora. The *urine of the herbivora* is yellowish, cloudy, of a disagreeable odor, alkaline; contains, besides urea, hippuric acid, lactates of the alkalies, and carbonates of the alkalies and earths, oxalate of lime, but few phosphates, and no uric acid. When herbivora are fed upon purely animal food, the urine takes on the same peculiarities as that of the carnivora. Hence the urine of calves while sucking shows a different composition from that of those which are fed; it resembles the fluid of the allantois of the fœtal calf. Such calves' urine is clear, almost colorless, odorless, of strongly acid reaction, containing uric acid, and especially allantoin, besides urea, but no hippuric acid; its content of phosphate of magnesia and potash salts is considerable, while that of phosphates, sulphates, and soda salts is very small. The *urine of birds*, as also that of *serpents*, consists almost solely of acid urates, a little urea, and phosphates of the earths. The urine of *frogs* is fluid, contains urea, common salt, and a little phosphate of lime. *Tortoises* void a clear urine, sometimes slightly acid, sometimes slightly alkaline, containing urea, acid urates, hippurates, always a little fat, phosphates and sulphates, chloride of sodium and chloride of potassium. The red excrements of *butterflies* consist almost entirely of acid urates of the alkalies; those also of most beetles and caterpillars contain uric acid. Guanin is found in the excrements of several of the lower animals.—With respect to the *urinary concretions*, their composition is somewhat various; but it may be asserted, in general, that they contain principally the same constituents which we have already described as found in the urinary sediments, and hence that their origin corresponds nearly with that of the sediments. The great majority of calculi are formed by the commencement of the above-mentioned processes of fermentation within the bladder, an agglomeration of mucus, which occurs in consequence of the vesical catarrh so frequently causing, or accompanying these processes, forming the foundation layer or nucleus of the concretion. It is to be ascribed to the ready crystallizability of free uric acid that the acid fermentation of urine, especially, disposes to the formation of calculi; hence, also, we find more commonly the nuclei of the concretions consisting of uric acid crystals, than the whole concretions composed of it. Since, by the concretion, when once formed, or by so-called gravel, an irritation is excited in the mucous membrane of the bladder, which is followed by a more violent vesical catarrh, by the mucus, thus abnormally secreted, the alkaline fermentation is very soon set up within the bladder; the consequences of which are that crystals of triple phosphate and urate of ammonia deposit upon the concretions of uric acid, already formed, molecules of phosphate of lime being intermingled in greater or less quantity. It is not to be wondered at, that these substances are mingled, in calculi, in the most varied proportions; for when the urine is, *e. g.*, only neutral, the triple phosphate is deposited, without any urate of ammonia. A certain mixture of *phosphate of lime*, and *phosphate of magnesia and ammonia*, gives rise to the so-called *fusible calculus*. *Oxalate of lime* is not usually contained in the calculi, which consist principally of free uric acid; urinary concretions are found, especially the mulberry-like, which consist principally of oxalate of lime. Their origin has not been satisfactorily ascertained as yet. The calculi consisting of cystin and those of xanthin are very rare; their origin cannot, at present, be surmised.

HISTOCHEMISTRY.

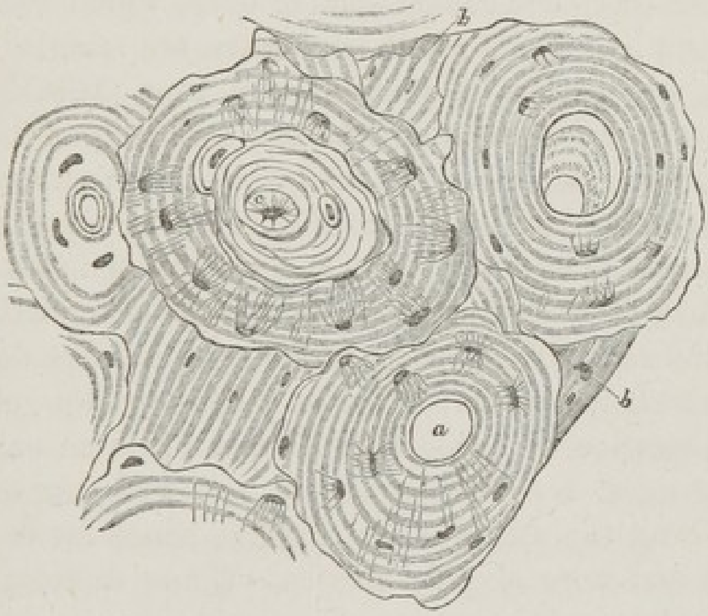
SCIENCE OF THE ANIMAL TISSUES.

The chemical investigation of the animal tissues presents in many respects still more difficulties than that of the animal fluids. These lie partly in the fact that most of the tissues are very intimate comminglings of different substrata which cannot be separated from each other mechanically; and partly, that all tissues are alike insoluble in the ordinary indifferent menstrua, and undergo such important modifications by the more active solvents, that their original constitution can hardly be guessed at. Hence, but little progress has been made in the knowledge of even the simpler animal tissues. The only method which can lead to a more exact acquaintance of the constitutions of tissues, and has already so done in part, is to cause the operation of different chemical reagents upon the simple tissues under the microscope, in order to ascertain the chemically homogeneous tissue-elements. Microchemistry has already rendered important services to Histology, as the true composition of certain tissues (*e. g.* horn, &c.) was first recognized by means of it. In physiological chemistry it affords us in a measure the key with which to open the approach to a rational investigation of the composition of animal tissue; for while it allows us to separate the chemically homogeneous from the chemically different, it often gives us the means to institute a chemical separation on a large scale, and thus subject the individual elements of tissue to a pure chemical investigation. Macrochemical analysis must follow the microchemical. Although histochemical investigations hitherto have not led to many general propositions and theories, a proposition has been established that the chemical nature of the tissue or of the important tissue elements always corresponds with their function. Although we know not yet what causes render this or that substratum of tissue available for one purpose and not for another, we see that analogously constituted substances are deposited only in analogously constituted tissues. In considering the tissues chemically, a circumstance must not be overlooked which is usually ignored by pure histology, viz: the character and composition of the fluid saturating the tissue. If not proved, it may at least be supposed that this fluid materially affects the physiological function of the tissue concerned, or is influenced by it. Closer investigations of some of these fluids of the tissues have not only presented us with their material difference from the liquor sanguinis and the simple transudations, but also opened up many interesting physiological points of observation.

OSSEOUS TISSUE.

The osseous substance of vertebrata is pierced with various cavities and canals, which in fresh objects are filled with nutritious fluids of different kinds, and when dried contain the non-volatile constituents of their previous contents. The largest of these cavities visible to the naked eye, are the large *medullary cavities* in the centre of the long bones, and the *cellular spaces* of the spongy bones and parts of bones, as also the so-called *foramina nutritia* through which vessels and nerves enter the bones. A second tubular system of the proper bone-substance, is the so-called *medullary canals*—canals of Havers; which, from 0.01 to 0.05 of a line in diameter, traverse reticulately especially the compacter parts of bones, and discharge after frequently anastomosing with each other, partly in the great medullary cavity of the long bones and the cellular spaces of the spongy, partly upon the surface of the bones next to the periosteum. The bone substance surrounding these cavities is pierced by still a third group of finer canaliculi; these are the so-called *bone corpuscles* and *ductuli chalikophori*. They are filled with air in dried bones, and hence appear black under the microscope; by means of these elongated lens-shaped bone corpuscles (*lacunæ*, *bone cavities*) 0.01 of a line long, 0.004 of a line broad, and 0.003 of a line thick, and their innumerable prolongations (ductuli), the substance of the bones becomes exceedingly porous. The marrow fills not only the great medullary cavity, but extends also into the cellular spaces of the articular portions and of the spongy bones; but not into the Haversian canals. While a little cellular tissue and some bloodvessels, together with the peculiar medullary substance, compose the medulla, bloodvessels and the nerves accompanying them enter into the canals. The bone-corpuscles and their prolongations are not filled with lime-salts, as was previously supposed, but with a liquid, of the chemical nature of which nothing is as yet known; they are also not simple excavations in the bone, but are surrounded with a peculiar membrane. The bone-substance lying between the cavities just described, is by no means a perfectly homogeneous mass; a number of concentric rings, which are true lamellæ of 0.002 to 0.005 of a line thick, are recognized around the bright spot (lumen) of

Fig. 21.



Transverse Section of Compact Bone, showing the ordinary Appearances.—*a*. Haversian system. *b, b*. Interstitial laminæ. *c*. New Haversian system within an older one.

each Haversian canal (in good transverse sections). Another system of these lamellæ runs parallel to the external and internal surface of the bone; besides these, there are found isolated groups of these lamellæ between the lamellæ of the Haversian canals. These laminæ again are not homogeneous; for in them we find an innumerable quantity of pale granules (of about 0.0002 of a line in diameter). The different morphotic elements of osseous tissue cannot at present be very closely investigated chemically; we only know that while the fundamental substance of bone consists of a mixture of cartilaginous substance (gelatin-yielding material) and lime-salts, the membrane lining the bone-corpuscles and their prolongations consists of an albuminoid substance insoluble in boiling water. That the granules which may be recognized in the free bone laminæ consists of phosphate of lime, is very doubtful.

The chemical investigations with reference to bone-substance have only extended to the ascertaining the proportion of the principal constituents to each other, in the different portions of the skeleton, under different pathological and physiological conditions. All the bones of the vertebrata contain, besides cartilage substance, which constitutes the principal part of all the organic matters, greater or less quantities of *fat*, and *albuminoid substances not yielding gelatin*, arising partly from the bloodvessels of the bones, and partly from the membrane already mentioned which lines the minute bone cavities. The inorganic constituents of bone, which usually constitute more than half of the whole bone-mass, are mingled in various proportions, and consist of phosphate of lime ($3CaO.PO_5$), which always exists in preponderating amount, carbonate of lime, a little fluoride of calcium, and phosphate of magnesia. An apparently constant amount of sulphates of the alkalies in the bone-ashes of reptiles and fishes is worthy of notice; with this exception, in the bone-ashes of most animals there are found but few soluble salts, such as chloride of sodium and carbonate of soda, which are probably derived from the fluids which permeate the bones. *Bone-cartilage*, obtained by prolonged digestion of bones with diluted nitric or muriatic acid, forms when moist a somewhat elastic, yellowish, translucent substance, retaining the shape of the original bone; on drying, it becomes hard and very slightly brittle. When sufficiently treated with acid, it leaves only a trace of ash; its atomic constitution is exactly the same as that of the gelatin resulting from it by boiling. In pathologically altered bones, it is always found of the same character and composition as in those that are healthy. In some fossil bones only, does it behave as gelatin resulting from boiling. The *fat* of the bones can only belong in the least degree to the basis substance, as the fatty bone medulla does not enter the Haversian canals; only in pathologically rarefied osseous tissue are large amounts of fat deposited in the excavations which have been formed. The fat of the bones is generally richer in olein, and hence more liquid than that of other organs of the animal body. The proportion of the mineral constituents of bone substance is nearly as follows: 57 parts of phosphate of lime, 8 of carbonate of lime, 1 of fluoride of calcium, and 1 of phosphate of magnesia.

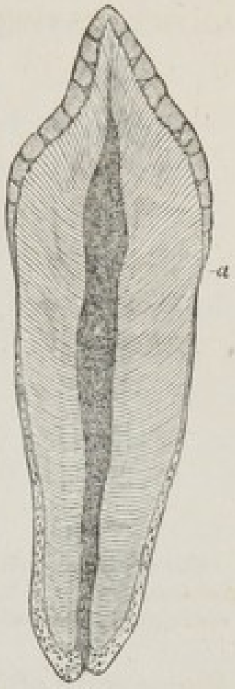
The variations from these proportions of the mineral substances of bone are not often very great, especially in the bones of the same individual. With regard to the composition of the different bones of *the same individual*, the following holds good: the bones of the extremities are richer in earths than those of the trunk; the femur and humerus, than the other cylindrical bones; those of the skull resemble the latter in this respect; the metacarpal and metatarsal bones, as also those of the pelvis, resemble those of the trunk; the ribs and clavicles contain more mineral substance than the vertebræ. In the thick bones (even when the spongy substance has been removed, as far as possible), more fat is constantly found than in the cylindrical. The flat bones contain rather more water than the cylindrical. In the composition of the bones of the two sexes, no material difference is found. The bones of *children* are poorer, and those of *old persons* richer, in mineral constituents, than those of adults. The period of life is without influence on the proportion of fat. With reference to the bones of *mammalia*, the following has been established: those of the herbivora are somewhat richer in carbonate of lime than those of the carnivora; those of the pachydermata and cetacea are particularly rich in it. Fat animals also usually contain more fat in their bones. The bones of *birds* contain more earths than those of the mammalia, especially those of the *Rasores* (76 per cent. or even 84 per cent.); the proportion of carbonate of lime, relatively to the phosphate, is slightly increased. The bones of the graminivorous birds always contain a little silica. Fat is found in the bones of birds more largely than in those of mammals: they also appear to contain, on the average, more water than those of the latter. The bones of the *amphibia* are poorer in earths (55 to 63 per cent.) than those of mammals; their ash always contains sulphate of soda. The bones of *fishes* are still poorer (12 to 57 per cent.); they also contain sulphate of soda, and are richer both in fat and water, than those of any other animals.

In nearly all *pathological* processes occurring in bones, the mineral substances are abstracted sooner and in larger quantities than the organic matters; when partial wasting, or rarefaction of the osseous tissue takes place, the cavities formed are usually filled with fluid fat. When masses of bone are again deposited in these cavities, the organic matters still retain the preponderance; hence, even in sclerosed bones, far more organic matter is found than in normal. As regards the proportions of the mineral constituents of diseased bones to each other, the carbonate of lime seems to increase and diminish in proportions corresponding to the phosphate of lime; but in osteophytes and new formations of bones, a larger quantity of carbonate of lime is usually found, relatively to the quantity of this salt, in normal bones. In determining the chemical composition of *fossil* bones, reference must always be had to the stratum from which they were derived; for the mass in which they have been imbedded not only affects them by infiltrating readily into the bone-canals, as, *e. g.*, carbonate and sulphate of lime, but also affects them chemically, by transforming or decomposing the organic matters, and the phosphate of lime. It is, hence, easily seen why the proportion of *organic matters*, in fossil bones, is so various; there are some which scarcely contain a trace of organic substance, while others are almost as rich in it as recent bones. The phosphate of lime is occasionally found arranged in small crystals of apatite. Carbonate of lime is, generally, contained abundantly in these bones, partly infiltrated from without, partly arising from the decomposition of the phosphate of lime by the carbonates of the stratification. Magnesia is found, on the average, in larger quantities, in the bones of fossil vertebrata, than in recent bones. It should be noticed that most fossil bones are much richer than the modern in *fluoride of calcium*. *Alumina*, *peroxide of iron*, and *silicic acid*, which are often found in fossil bones, are always infiltrated.

DENTAL TISSUE.

Every tooth consists of three morphotic parts, distinct from each other, viz: of dentine, enamel, and cementum. The *dentine*, *substantia tubulosa*, is a fusiform or wedge-shaped body provided with a club-shaped cavity destined for the reception of nerves and nutritious vessels. Fine canaliculi pass through it, diverging from the cavity of the tooth toward the outer coat, near which they subdivide minutely; here and there are found (instead of the bone corpuscles) in this substance, rounded cavities, the *interglobular spaces*. The latter are lined with a peculiar membrane, insoluble in acetic acid, and in boiling water; they are seen distinctly when the dentine is freed from salts by dilute muriatic acid, and the cartilage is dissolved by boiling in water. This cartilage yields gelatin. The mineral constituents of dentine, like its cartilage, are the same as those of bone; they amount to 72 per cent. on the average. The *enamel, substantia vitrea seu adamantina*, is a very hard and somewhat brittle compact mass, traversed neither by canaliculi nor cavities, which consists of fibrils diverging from the crown of the tooth, and resembling four- or six-sided prisms. When the salts are abstracted from the enamel by muriatic acid, a sort of skeleton of these prisms remains behind which does not dissolve by boiling, but bursts and behaves like epithelial substance towards reagents. Only 2 to 5 per cent. of organic matter is found in the enamel. Much fluoride of calcium relatively is found in it, with 88 per cent. of phosphate, and 7 to 8 per cent. of carbonate of lime. The *cement* covering the neck and fangs of the tooth resembles ordinary bone substance so far that bone-corpuscles exist in it with their prolongations, but no Haversian canals are to be found. Its chemical constitution agrees nearly with that of the bones. The molars contain on the average more mineral substances than the incisors. The tusks of the elephant and wild-boar are relatively rich in organic matter. The teeth of the pachydermata contain more phosphate of magnesia than those of other animals.

Fig. 22.

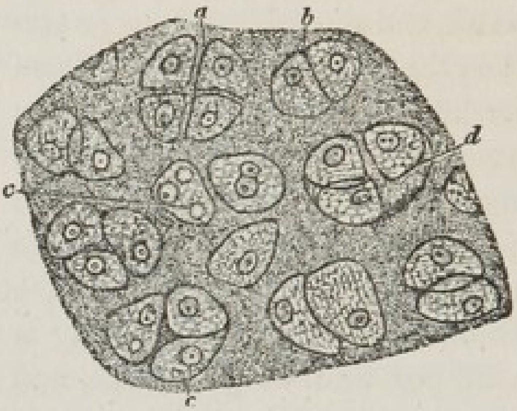


VERTICAL SECTION OF HUMAN INCISOR, SHOWING THE GENERAL ARRANGEMENT OF ITS CONSTITUENT PARTS.—The dentine and pulp-cavity, the enamel on the crown, and the bone on the fang, are seen. *a*. Neck of the tooth. Magnified 3 diams.

CARTILAGINOUS TISSUE.

Histologically, two species of cartilage are to be distinguished: true cartilage and fibro-cartilage. *True cartilages* consist of a basis-substance, at first sight homogeneous with numerous cavities, in which one or several cells with simple or compound nuclei are imbedded. This basis-substance is, however, by no means perfectly homogeneous; as a rule, it appears finely granular, often slightly fibrous. By microchemical treatment with concentrated sulphuric acid, and subsequent addition of water, it is ascertained that the granules or fibrils of the intercellular substance are dissolved more slowly than the cartilaginous substance found between them. By 12 to 18 hours' boiling with water in the air, or one hour's treatment with water in Papin's Digester, the whole basis-substance of the cartilage together with the granules is dissolved, leaving only the cell-formations. The intercellular sub-

Fig. 23.



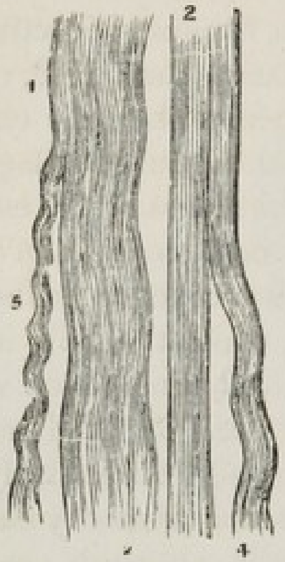
SECTION OF THE BRANCHIAL CARTILAGE OF TADPOLE.—*a*. Group of four cells, separating from each other. *b*. Pair of cells in apposition. *c*, *c*. Nuclei of cartilage cells. *d*. Cavity containing three cells.

stance only of cartilage affords chondrin; the chemical composition of the cartilage cells is hence materially different from that of the intercellular substance. The former is by no means thoroughly ascertained; it is only known that the nuclei of the cells resist the action of concentrated sulphuric acid, or potash ley, longer than the cell-membranes; the principal cell-membrane of the mother-cells disappears after the prolonged action of acetic acid. *Fibro-cartilages* contain, besides the ordinary cartilage-cells, an entirely fibrous basis-substance; the fibres either run parallel to each other, or cross each other in different directions, have usually dark sharp contours, and show no traces of nuclear formations. No difference has been found between the composition of the cells of this cartilage and those of true cartilage. On the other hand, microchemical, as well as macrochemical researches, show that the gelatin resulting from the fibrous intercellular substance is not identical with the chondrin of true cartilage; its solution gives only a slight precipitate with tannic acid, but with alum, as chondrin does, a dense precipitate, which, however, does not redissolve in an excess of the alum-solution; so also, bichloride of platinum causes a precipitate insoluble in an excess of the precipitant. When potash ley, sulphuric acid, or concentrated acetic acid, are caused to act upon preparations of this cartilage under the microscope, the fibrillation of the basis-substance disappears to the eye; the fibres do not, however, dissolve, but swell up gelatinously, and thus become invisible. In concentrated sulphuric acid, a few fibrillæ, resembling nuclear fibres usually, still remain visible. There are also fibro-cartilages (*e. g.*, the interarticular cartilage of the knee-joint), the basis-substance of which consists of actual, but very dense, fibrous connective tissue, interspersed with a few nuclear fibres; hence they yield, on being boiled with water, glutin, but no chondrin. The cells embraced in the basis-substance behave like those of true cartilage. In a third species of fibro-cartilage (epiglottis, cartilages of the ear, &c.), the fibrous mould inclosing the isolated cells consists of a dense tissue of fine elastic fibres. These fibres are changed neither by concentrated potash ley nor sulphuric acid, while the cells inclosed in them are destroyed after six or seven hours' action of these re-agents and the subsequent addition of water. Cartilaginous tissue has not hitherto been thoroughly investigated quantitatively. The 2 to 5 per cent. of *fat*, which may be extracted from dry cartilage, are chiefly deposited in the cartilage-cells, although occasional globules may be recognized in the intercellular substance. The proportion of *water* varies in recent cartilages between 54 and 70 per cent. Of *mineral substances* in the cartilages of the ribs, 3 to 6 per cent. have been found; they consist of phosphates of lime and magnesia, carbonates of the alkalies, and a large portion of chloride of sodium and sulphates.

CONNECTIVE TISSUE.

This tissue is formed of a network sometimes with close, and at other times with loose, meshes of long fine fibres, generally united into bundles. In the serous membranes the fibres are grouped more closely, forming thick bundles, often interlacing with each other, with tolerably wide meshes between them. When the bundles of fibres lie closer together, and follow one direction, they form ligaments and tendons. Independently of vessels, nerves, and fat-cells, *so-called nuclear fibres*, or *elastic fibres*, occur constantly. When connective tissue is placed in boiling water, it becomes shrivelled at first, but soon swells up gelatinously, and dissolves by continued boiling. It is contracted, and loses its liability to putrefaction by the action of bichloride of mercury, alum, protosulphate of iron, and tannic acid. It is transformed into *glutin* much more rapidly by boiling with diluted acids or alkalies than with pure water. In concentrated acetic acid it swells up, and takes the form of jelly, so as to become invisible under the microscope, but is not dissolved by it; for, if the preparation be washed with water, or the acid neutralized by ammonia, the fibres present themselves again in their original form. As these fibres become invisible by acetic acid, while the elastic fibres of the connective tissue remain unaltered, the latter become much more visible under the microscope by means of this reagent. In *alkalies*, likewise, the fibres of connective tissue swell up, but are then actually dissolved by the subsequent addition of water. The *connective tissue of the embryo* consists of fusiform cells and a peculiar inter-substance, which affords on digestion with water, besides albumen, a gelatinoid mucous substance; it yields, however, on boiling, neither glutin nor chondrin. It has been proposed to call this *mucous tissue* (*e. g.*, gelatinous tissue of Wharton).

Fig. 24.



SECTION OF TENDON (magnified 320 diameters). 2. Straight appearance when stretched. 1, 3, 4. Wavy appearance when relaxed.

ELASTIC TISSUE.

The elastic fibres are distinguished, under the microscope, either as flat, tolerably broad, slightly brittle, much-branched bands, or as narrower fibres; they have a tendency to become spiral, and are provided with nuclei (nuclear fibres). They are generally found interspersed through other tissues as the nuclear fibres in connective tissue. When they occur in larger groups, they sometimes form wide-meshed or arabesque reticulations, with hook-like curvatures; sometimes they are collected in a tissue, leaving tolerably equal interspaces, and resembling an anastomosing rete of capillaries. They are found in greatest abundance, but always mixed with the fibres of other elementary tissues, in the yellow ligaments of the spinal column, and in the ligamentum nuchæ. These fibres do not lose their elasticity either by alcohol or by boiling with water; even when the latter is maintained for sixty hours, they are not

Fig. 25.

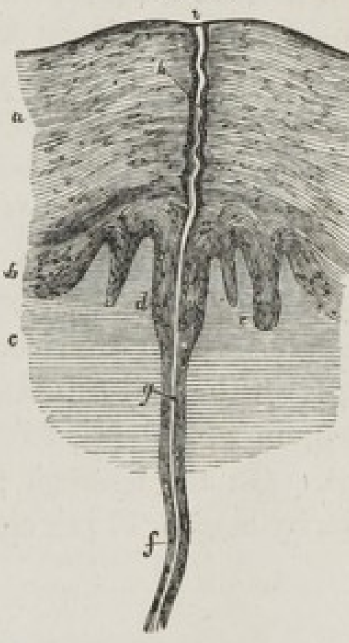
Section of yellow elastic tissue.

dissolved. On the other hand, after thirty hours' boiling at 320° F., they are changed into a brownish fluid, smelling like glue, but not gelatinizing, which is precipitated by tannic acid, picric acid, and corrosive sublimate, but not by other reagents, which throw down chondrin. In cold, concentrated acetic acid, the elastic fibre is insoluble; in tolerably dilute muriatic acid it dissolves with a brown color; the product of transformation thus arising is soluble in water and alcohol. Digested with tolerably concentrated sulphuric acid, it yields only leucin, but no glycin. In moderately concentrated potash ley it is changed into a gelatinous mass only after being heated for several days.

HORNY TISSUE.

The structure of the tissues belonging to this class, the epidermis, the nails (claws and hoofs), horns, and whalebone, can only be made clear by the application of certain reagents, by means of which all these tissues are resolved into nucleated cells; they are hence to be regarded as nothing more than different forms of one and the same basis-substance, *keratin*, or *sulphamide of protein*. Even by treatment with cold or lukewarm water, most of them are softened and resolved into cells in which a nucleus is more or less distinctly visible. The epidermis and epidermic excrescences are resolved most readily into flatly pressed oval cells, especially those lying near to the rete Malpighii; water affects the nails more slowly, horns and hoofs but slightly, whalebone and tortoise-shell not at all. Caustic alkalies, especially caustic soda, display, when the solutions are very concentrated, the cellular structure of all these tissues in the clearest manner. Even diluted alkaline leys act so powerfully on the epidermis that the epidermic scales are transformed into clear oval or spherical vesicles, from which the previously visible nucleus gradually dis-

Fig. 26.



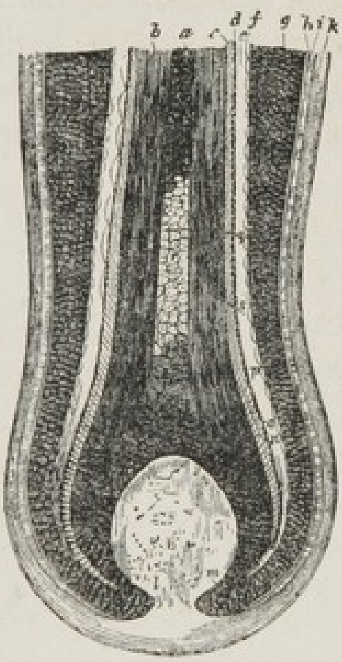
Vertical Section of the Skin of the Thumb, treated with acetic acid.—*a*. Horny layer. *b*. Mucous layer. *c*. Cutis vera. *d*, *e*. Papillæ. *f*, *g*, *h*, *i*. Duct of a sweat-gland.

appears. Phenomena perfectly similar, but more slowly developed, are caused by the action of caustic alkalies on nail and horn-substances, especially when the preparations, after being treated with concentrated ley, are acted on by water. The laminæ of whalebone, when similarly treated, exhibit themselves as composed of flatly-compressed cells; the substance of the nucleus is always more easily dissolved than the investing membranes of the cells. Tortoise-shell is resolved into polygonal and oval cells only after prolonged action of these reagents. *Acetic acid* affects the horny tissues but little, or not at all. *Sulphuric acid*, especially with gentle warming, renders the cellular structure visible in all these tissues. *Nitric acid* stains most of them yellow, but brings out the cells imperfectly, or not at all. From these reactions, it may be concluded that all these tissues have resulted from cells or nucleated vesicles, which, without further developing morphotically, as the cells of other organs, have in a measure dried up, and are agglutinated by an intercellular substance generally difficult of detection. Besides this problematical intercellular substance, there are in each tissue three substances morphotically and chemically different, viz: the substance of the cell-membranes almost insoluble in alkalies, the cell-contents with the nucleus more readily soluble in alkalies, and the granular matters wholly insoluble in alkali, and by no means merely consisting of fat, which remain behind after the entire solution of some of these tissues. The proportion of *mineral substances* in these tissues does not vary materially from 1 per cent.; their proportion of unoxidized sulphur is, however, somewhat variable. In the epidermis, there have been found only 0.74 per cent.; in tortoise-shell, 2.22 per cent.; in the nail-substance, 2.80 per cent.; in cows' horn, 3.42 per cent.; in whalebone, 3.60 per cent.; and in horses' hoofs, 4.23 per cent. On the average they contain 51 per cent. carbon, 6.8 per cent. hydrogen, 17 per cent. nitrogen, and 20 to 22 per cent. oxygen.

HAIR TISSUE.

As regards the chemical composition of this tissue, only the shaft of the hair has undergone a close investigation; this consists, according to histological observations, of three important parts, viz: the cuticle, the cortical substance, and the medulla. The *cuticle* of the hair (Fig. 27, *c*, *d*, *q*, *n*) consists of tile-shaped plates overlapping each other; these, when isolated, appear extremely transparent and quadrangular, without nucleus or other contents, and are remarkable for their entire insolubility in caustic alkalies and concentrated sulphuric acid. The *cortical* or fibrous substance, *b, s*, which forms the most considerable part of the hair, is disintegrated by concentrated sulphuric acid, especially with moderate warming, first into long, flat fibres, which again split into long slender plates, with an elongated dark nucleus. After prolonged digestion with diluted potash ley, the cortical substance is dissolved, leaving behind long, fusiform nuclei. There are also in the fibrous substance a number of cavities filled with air, and, besides these, greater or less accumulations of pigment granules, according to the color of the hair. The *medullary substance* of the hair, *a, r*, which can only be recognized distinctly when the cortical substance is rendered more transparent by treatment with alkalies, consists of cells lying close to each other in rows, quadrangular, occasionally rounded, and containing, after treatment with alkalies, dark granules, with a clear, rounded-oval spot (rudimental nucleus); the granules are, in great measure, nothing more than very minute air-vesicles. In hair deprived of fat, there have been found, after subtracting the ashes, 50.65 per cent. carbon, 6.36 per cent. hydrogen, 17.14 per cent. nitrogen, 20.85 per cent. oxygen, and 5 per cent. sulphur. We have not succeeded in detecting a peculiar *coloring matter* in hair.

Fig. 27.



HUMAN HAIR BULB, with its papilla, *l, m*; internal and external root-sheath, *e, f, g*; and basement-membrane, *h*, of the cutis vera, *i, k*.

The white color of hair depends upon a larger content of air; the proportion of *iron* is without influence upon its color. The fat of the hair consists of margarin, margaric acid, and olein, to which are adherent the volatile acids of the sweat. The proportion of *mineral constituents* in the hair is very variable (from 0.54 to 1.85 per cent.), without producing any influence upon the color, or any other property of the hair. The quantity of sesquioxide of iron varies between 0.058 and 0.390 per cent.; hair always contains a little silicic acid, that of animals, on the average, more than that of man. *Wool* and *bristles* have a composition nearly identical with that of hair; *feathers*, on the other hand, contain much less oxygen, and are distinguished by their larger proportion of silica.

CONTRACTILE FIBRE-CELLS.

These cells present themselves grouped in bundles and membranes, in the so-called *smooth muscles;* they are also found interspersed in many other tissues, which owe to them a contractility under nervous influence. They occur usually as long, fusiform, slender fibres, with delicately tapering extremities; they also often form quadrangular, or club-shaped plates, drawn out longitudinally, frequently with fringed margins; in most of them, especially on the addition of acetic acid, there may be recognized a cylindrical or wand-shaped, perfectly homogeneous nucleus, without nucleoli. The substance of the cells is rendered more pellucid, and the nucleus more visible, by very dilute hydrochloric acid (one part acid to 3,000 parts water), as well as by dilute acetic acid. Prolonged action of the diluted acid, or of more concentrated acetic acid, dissolves

Fig. 28.

CONTRACTILE FIBRE-CELLS.—*a*. Treated with acetic acid. *c*. In their natural state. *b*. Detached nuclei, or corpuscles of different shapes.

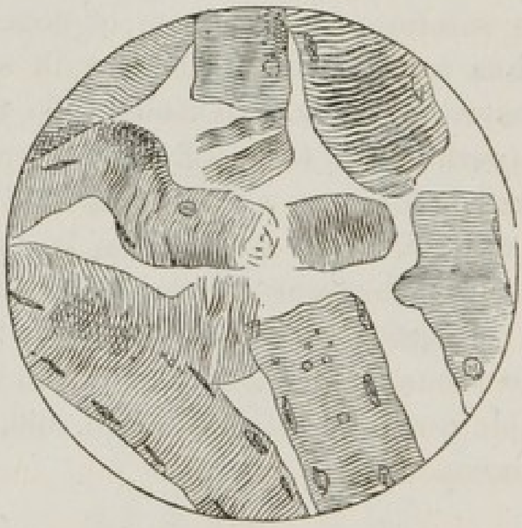
the cell-substance, leaving behind cucumber-shaped nuclei, and minute fat granules. In *concentrated muriatic acid*, the fibre-cells shrivel up, and the nuclei are not visible; upon the addition of water they again expand. By means of moderately dilute *nitric acid*, the fibre-cells become very sharply defined, and somewhat contracted, so as often to be rendered easily visible where they had been recognized with difficulty; by concentrated nitric acid they are transformed into yellowish-colored fibrillæ. By concentrated sulphuric acid, chromic acid, or caustic alkalies, the fibre-cells are destroyed, or, at least, so much altered that their constitution cannot be again manifested.

In moderately concentrated solutions of carbonate of potassa, or of soda, the fibre-cells undergo no perceptible change; even prolonged digestion, with a very dilute solution of *nitre*, leaves them wholly unaltered. A *sarcolemma* is not to be detected, chemically, in the organic muscles. The chemical nature of the substance of the nuclei of the fibre-cells, is still unknown. The cell-substance is dissolved, as above mentioned, in very dilute muriatic acid: on neutralization of the solution, a jelly, hardly visible at first, is separated, which finally collects in flocculi at the bottom of the liquid; the solution in lime-water coagulates on boiling; the flocculi deposited by neutralization are readily soluble in alkalies and dilute acids, but not in solutions of carbonate of potassa, or saltpetre. This substance thus corresponds perfectly with syntonin, *i. e.*, the fibrin of the transversely striated muscles. To the tissue of the organic muscles (perhaps to the contractile tissue of the animal organism in general) belongs, as a whole, the fluid which saturates it, and surrounds the individual cells. This is distinguished from the liquor sanguinis, and the transudations of the serous membranes, as also that of the connective tissue, principally by its acid reaction; it contains, besides albumen, more or less casein in solution, some creatin, considerable quantities of lactic acid, and, relatively, more potash than soda compounds.

TRANSVERSELY-STRIATED MUSCULAR FIBRES.

The longitudinal striation, which is noticed on the finer bundles still recognizable with the naked eye, of voluntary muscles, is seen by microscopical examination, to depend upon still finer bundles of fibres, which present rounded, irregularly compressed, and often hexagonal cylinders, with a marked transverse striation. These very minute transversely-striated bundles consist of fibres lying close to each other (almost like a string of pearls), which are surrounded by a structureless, smooth membrane (sarcolemma). Blood capillaries, and nerve fibres, run between the sarcolemmas of the different primitive bundles, which are held together by fibres of connective tissue. In the sarcolemma, a rounded nucleus is to be observed here and there; in the muscular cylinder, inclosed in the sarcolemma, there may be distinguished a longitudinal and a transverse striation; some, hence, think that this cylinder is composed of long, transversely-striated fibrillæ; others, of discs lying upon each other. Between these fibrils of the primitive bundles an intersubstance may also be found; probably the peculiar acid fluid of the muscles surrounds the individual fibrils. *Dilute acetic acid*, and *very dilute mineral acids*, cause the primitive bundles to swell up and become pale; the transverse striation is plainly, while the longitudinal is but seldom visible; the nuclei, parallel to the long axis, are stretched; the sarcolemma remains unaltered. By the action of concentrated *muriatic* or slightly diluted *sulphuric acid*,

Fig. 29.



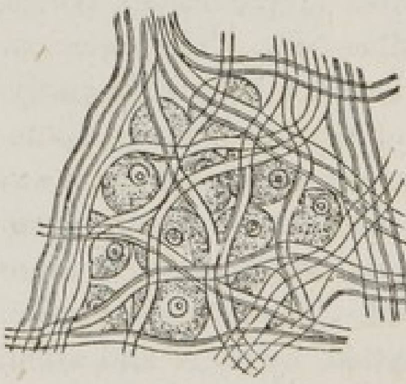
Striated muscular fibres, treated with acetic acid.

the primitive bundles are resolved into rather short parallelopipedons, with marked transverse striation; the nuclei and sarcolemma are not visible. Concentrated *nitric acid* produces a similar reaction, except that the parallelopipedons are colored yellow. *Chromic acid* also splits the primitive cylinder into intensely yellow parallelopipedic fragments, but, in these, the longitudinal striation is often as marked as the transverse. When prepared muscular bundles are digested for some time at 95°, in a solution of nitre (one part to 17 parts water), a longitudinal striation becomes remarkably visible in the primitive bundles; the portion of the muscular cylinder projecting beyond the sarcolemma is split into a tuft of single fibrils. By a mixture of *protonitrate* and *protonitrite of mercury*, the primitive bundles are split into pale, bluish-red parallelopipedons, in which the sharpest and most delicate transverse striation is visible. The sarcolemma remains uncolored. In moderately diluted solutions of *carbonate of potash*, the muscles become hard and rigid; under the microscope, the primitive bundles appear somewhat swollen, without longitudinal striation, and with fine and sharp transverse striation. An extremely dilute *soda-ley* (one part in 8,500 parts water), transforms the muscular cylinder into a mucoid mass, so that there remains visible only the sarcolemma contracted in its diameter. If a dilute potash or soda solution is added to a recent preparation under the microscope, the transverse striation disappears, and a very transparent jelly, partly fibrillating, partly granular, emerges from the sarcolemma. A solution of *iodine* stains the muscular primitive bundle intensely yellow, and renders the longitudinal striæ remarkably distinct, while the transverse striæ become less so. By repeated washing with distilled water, the primitive bundles lose the transverse striation; while the longitudinal striation becomes very distinct; by means of salts, especially chloride of calcium, or carbonate of potassa, the former becomes again visible. The basis-substance of the muscles, *i. e.*, the peculiar *substance of the fibrillæ*, which is dissolved both by very dilute alkalies and dilute acids (1 per mille), corresponds entirely with the syntonin of the fibre-cells. The chemical nature of the substance of the nuclei has not been sufficiently investigated; it is not dissimilar to that of the fibrillæ; by dilute alkalies it is more slowly dissolved; in concentrated alkalies, it swells up and dissolves upon the subsequent addition of water; even in acetic acid, and very dilute mineral acids, which render it more perceptible at first, it is gradually dissolved. The *granules* visible in the sarcolemmas which have been emptied by acids and alkalies, consist, in great measure, of fat. The microchemical reactions of the *sarcolemma*, and its incapability of being transformed into gelatin by boiling, prove conclusively that it does not belong to connective tissue; its elasticity, which is unaffected by acids and alkalies, indicates at least that it does not stand far from the elastic tissue. The *fluid* which permeates the muscles is, when recently expressed, usually cloudy or opalescent from fat, and has a decidedly acid reaction. It contains albumen, casein, creatin, creatinin, inosic acid, lactic acid, and several volatile fat acids, especially acetic and formic acids, but no trace of urea. It is worthy of remark, that the carbohydrogen, *inosit*, occurs only in the juice of the heart-muscle. It is not yet decided, whether the muscles possess a peculiar coloring matter. With reference to the *inorganic constituents* of the muscular fluid, the remark made above holds good; the potash salts and phosphates preponderate far over the soda salts and chlorides of the metals; in like manner, the phosphate of magnesia preponderates over the phosphate of lime. Sulphates are found merely in traces. The proportion of water in recent muscles has been found to be, in the ox, 77 per cent.; in man, 80 per cent.; from 2 to 6 per cent. of gelatin-yielding substance may be extracted from it; the proportion of fat is also variable, and the quantity of soluble constituents of flesh; the former amounts to between 2 and 4 per cent. in well-prepared muscles, the latter from 6 to 8 per cent.

NERVE-TISSUE.

There are two species of nerve-fibres or nerve-tubules, which, however, exhibit very gradual transitions into each other. The coarser nerve-fibres (*animal, cerebro-spinal*), form cylindrical fibres

Fig. 30.



Small portion of the otic ganglion of the sheep, showing the nerve-tubules interlacing among the ganglionic vesicles.

of 0.004 to 0.010 of a line diameter; when examined fresh (especially when moistened with solution of albumen), they appear under the microscope perfectly homogeneous, transparent, and sharply defined. When, however, they are moistened with water, they have double contours, and resemble broad dark bands, in the centre of which runs a bright stripe. The limiting membrane of the nerve-tubules can only be recognized by the application of certain reagents; it is a perfectly structureless, slightly elastic membrane, as clear as glass. The content of the tubules, the nerve-medulla, which appears perfectly homogeneous in recent preparations, divides afterwards—especially on the addition of water—into a cortical substance, and a cylindrical axis-fibre. The external layer of the contents of the nerve-tubules, the *cortical* or *medullary substance*, becomes, in the case mentioned, darker, somewhat crumbly, or granular, while in the long axis of the nerve-tubule a clear fibre, with tolerably sharp contours, the *axis-fibre*, or *cylinder-axis*, becomes visible. By the medulla becoming crumbly, the nerve-tubule is irregularly expanded and contracted so as to assume the so-called varicose shape. The *finer* or *sympathetic* nerve-fibres, of 0.00212 to 0.00300 of a line in diameter, resemble rather solid cylinders; they appear to consist only of an axis-cylinder and an investing membrane. The bundles, composed of several nerve-fibres, are surrounded by a fibrous, glistening, white, dense membrane, the so-called *neurilemma*, consisting of connective tissue, with numerous elastic fibres. The *nerve-cells* or *ganglionic vesicles*, which exist in the nerve-centres, are of very various form and size; the diameter of the largest reaches 0.05 to 0.06 of a line, while that of the smallest is often only 0.002 to 0.003 of a line; some are large, almost spherical or oval; these are found principally in the gray substance of the brain and spinal marrow; in the same positions there occur also fusiform, trapezoidal, irregularly triangular cells with numerous prolongations, which frequently branch again. Cells with one or two very pale prolongations are found in the ganglia of the sympathetic. The investing membrane is very thin, structureless, scarcely visible in the nerve-cells of the brain, and spinal marrow; on the contrary, in the cells of the ganglia it is thick, readily distinguishable, and elastic. The nuclei, 0.0015 to 0.008 of a line in diameter, are generally spherical or oval, clearly defined, with transparent contents resembling fat, and one or two rounded or elongated, oval nucleoli of 0.0005 to 0.003 of a line in diameter. Besides these, the nerve-cells contain a colorless semifluid mass, in which are suspended finer or coarser granules; the granular matter is often accumulated in groups. In nerve-fibres which have been boiled in *alcohol*, the sheath is more sharply defined, and the contents more translucent, and of a dull granular appearance; the axis-cylinder projects from the ends of some. Nerve-cells similarly treated only appear more faintly granular than in the recent state. By means of the prolonged action of *ether* upon cerebro-spinal nerves, their double outline vanishes, the investing sheath becomes more visible, the granular content paler, and the axis-cylinder here and there visible. Ether acts but little upon the nerve-cells. When nerve-fibres are warmed with concentrated *acetic acid*, the investing membrane presents itself more perceptibly here and there; between the inner outlines there remains a pale-reddish spiral interrupted streak, with hernial protrusions; at the ends of the torn fibres the axis-cylinder protrudes as a very pale fibre. If acetic acid be added to a microscopical preparation, the nerve-tubules become shorter, and from the cut ends the axis-cylinder projects together with granular medullary substance. In the sympathetic fibres, the contents become contorted, and occasionally the axis-cylinder visible, by the application of acetic acid. The nerve-cells become more sharply defined in dilute acetic acid, the cell-contents become more granular, and the nucleus more perceptible. In concentrated acetic acid, the nerve-cells are gradually disintegrated. In concentrated *muriatic acid*, the nerve-fibres are shortened in length, but remarkably augmented in diameter; the medullary substance becomes coarsely granular and dark; at the cut ends coarsely granular masses emerge, and the axis-cylinder becomes clearly visible. Concentrated *nitric* and *sulphuric acids* act similarly, except that by the former the axes cylinders are stained yellow, and by the latter the entire nerve-fibre and fluid surrounding it become violet. *Chromic acid* contracts the nerve-fibres in their diameter, so that the investing membrane splits in some places, and coarsely granular medulla exudes through the rents; the fibres are also colored intensely yellow by it—some are so disintegrated by it, that only the axis-cylinder with the disintegrated medullary mass is perceptible. The nerve-cells are slightly contracted by chromic acid, but not otherwise visibly changed.

In *iodine-solution* the nerve-fibres become pale yellow, tolerably sharply defined (the animal-fibres lose their double outline), the sheaths more recognizable, the nerve-medulla darker and finely granular; here and there a pale yellow axis-cylinder protrudes from the nerve-tubule. Solutions of *bichloride of mercury*, as also the mixture of *proto-nitrate and proto-nitrite of mercury*, render the nerve-fibres hard and brittle; on tearing apart nerve-fibres thus treated, the axis-cylinder becomes remarkably distinct. In concentrated solutions of *carbonate of potassa*, the nerve-tubules swell up slightly, but appear with intestine-like convolutions, protrusions and lumps; the medullary substance becomes more transparent, but the axis-cylinder and the sheath are not visible. In *dilute soda-ley*, the sheath of the nerve-fibres contracts, the double contour vanishes, and the nerve-medulla exudes from the cut extremities in granules and dark globules; sometimes the axis-cylinder is seen to swell up gelatinously, and then disappear. Nerve-fibres previously treated with alcohol or ether, become considerably contracted, and perfectly pale in dilute soda-ley, so as to resemble nerve-sheaths deprived of their contents. The nerve-cells swell up slightly in soda-ley, and the investing membrane becomes more distinct; the nucleus, however, usually disappears. In concentrated potash-ley the nerve-fibres and nerve-cells are gradually destroyed, so that only a granular matter remains visible. In order to bring into view the sheaths of the individual nerve-fibres, the nerve preparation is brought into contact, after being boiled with nitric acid, with dilute potash-ley; the previously granular content then exudes from the sheath in pale globules. When also the nerve-fibres previously treated with alcohol and ether are subjected to the action of concentrated acetic acid, perfectly emptied nerve-sheaths are obtained. With regard to the chemical constitution of the investing membrane of the nerve-fibres, the following may be concluded from its microchemical reactions: As it does not swell up gelatinously in acetic acid, and does not dissolve on boiling, or treatment with dilute alkalies, it cannot consist of the element of connective tissue. In concentrated acetic and sulphuric acids, as also in stronger soda or potash-ley, it dissolves after prolonged digestion, especially with the aid of heat; accordingly, it cannot belong to the elastic tissues, but as it is comparatively difficult of solution in the menstrua named, and is not perceptibly colored yellow by concentrated nitric acid, it cannot be a protein-substance, although it approaches the latter more closely than the elastic tissue. The *axis-cylinder* consists of a protein-substance which closely approximates syntonin, as is evident from its reaction with acetic acid, concentrated mineral acids, and alkalies; from fibrin it is distinguished by its insolubility in carbonate of potassa, and difficult solubility in acetic acid, and from syntonin by its insolubility in dilute muriatic acid; it stands still further from the substrata of other tissues. We are yet wholly in the dark as to the chemical constitution of the nerve-medulla; the most probable opinion at present is that it contains a soluble protein-substance, and fats dissolved by easily decomposed soaps; the perceptibility (so-called coagulation) of the medulla which follows the addition of water, is less the consequence of a coagulation of the protein-substance than of the separation of the fat derived from the decomposing soaps from the protein-body. Still less can be decided from the above reactions as to the chemical constitution of the morphotic elements of the *nerve-cells.* The *investing membrane* is difficult of solution in acetic acid and insoluble in carbonate of potassa, thus resembling syntonin. The *nuclei* of the nerve-cells react similarly to those of most animal cells: we know nothing further of their structure. The granular *contents* of the nerve-cells consist, according to the above reactions, of a protein-substance partly dissolved, partly only swollen up, and contain far less fat than the medulla of the nerve-fibres.

The brain and nerve substance has not yet been investigated according to the basis furnished by the microchemical investigation of the nerves. The coarser investigations of larger portions of nerve-substance, and of the brain especially, have resulted as follows: According to most of the analyzers, a coagulated protein substance is found in the nerve mass; but the above microchemical experiments prove that the albuminoid substance contained in the nerve medulla must be wholly in the soluble state. As regards the axis-cylinder, which also has a protein-like basis, it is by no means decided whether or not it is formed by the coagulation of a substance resembling syntonin, in consequence of chemical treatment; the perfect homogeneousness of the medulla of recent nerves must at least render doubtful the assumption of a pre-formed axis-cylinder. We are also, unfortunately, still by no means enlightened as to the fats of nerve-substance, notwithstanding the numerous experiments devoted to their investigation. Whatever was dissolved in hot ether and boiling alcohol has usually been considered as cerebral fats; but in this there is a series of substances not clearly characterized, part of which belong certainly to the fats, and part exhibit very different properties from them. It is ascertained that *olein*, *oleic acid*, and *margaric acid*, may be separated from the ethereal extract of the brain substance; so, also, *cholesterin* is found constantly, and with this two other substances, which demand further chemical investigation, viz: *cerebrin* and *lecithin*. *Cerebrin* is a white powder, soluble only in hot alcohol and ether, melts above 212°, and decomposes; it contains phosphorus, and consists of 66.8 per cent. carbon, 10.7 per cent. hydrogen, 2.9 per cent. nitrogen, 19.6 per cent. oxygen, and 0.4 per cent. phosphorus. *Lecithin* is still less known; it forms a viscid mass, which, by means of either acids or alkalies, decomposes into oleic, margaric, and glycero-phosphoric acids. The *mineral substances* of the brain consist of phosphoric acid, phosphate of potassa, phosphate of soda (one-half less), and a little chloride of sodium. The ash of the gray substance of the brain reacts strongly alkaline, that of the white strongly acid. The *quantitative determinations*, which have been instituted with reference to the chemical constitution of the brain, have reference principally to the proportion of water and the amount of matters extracted by ether. The *white substance* of the brain contains much less water, and is richer in fat (ethereal extract) than the gray substance. With reference to the individual portions of the brain, the amount of water stands generally in inverse ratio to that of the fats. The cortical substance of the cerebral hemispheres contains 84 to 88 per cent. of water, and 4.8 to 6.5 per cent. of fat, and very little cerebric acid; the white substance of the corpus callosum, on the contrary, 63 to 70 per cent. of water, and 15 to 21 per cent. of fat. The largest amount of fat, and least of water, is found in the *medulla oblongata*. The brain of new-born infants contains more water than that of adults; and, in that of aged persons, the proportion of water is again increased. In the ethereal extract, from 1.68 to 2.53 per cent. of phosphorus is found; in animals, the amount of phosphorus ranges between 1.53 and 3.40 per cent. In the white substance there are found from 14 to 16 per cent. of substances, insoluble in ether (protein substances and investing membranes); in the gray, from 9 to 11 per cent.; in young subjects, less on an average than in older.

EXUDATIONS.

The exudations resemble the transudations in many respects, and hence have been, until very lately, classed with them, as there exist numerous transitions from the one group of secretions to the other. But, scientifically considered, the exudations must be separated and distinguished from the transudations. They differ materially from the latter in their origin, the manner of their separation from the blood, their physical properties, and in certain constituents. We have seen that the formation of the transudations is dependent upon simply physical laws; without an actual stasis of the column of blood in the capillaries, the constituents of the liquor sanguinis only passed through the walls of these vessels, partly on account of their increased penetrability, partly on account of increased transudability of the liquor sanguinis; the exudations take place only in consequence of actual inflammation, *i. e.*, a perfect stasis of the blood in the capillaries, alteration of its physical properties, and partial rupture of the vessels. Hence the properties and constituents of the exudations must differ from those of the transudations. In the exudations we always find very considerable quantities of fibrin, and far more albumen, than in the transudations; among the salts, the phosphates and potassium-compounds are more prominent; we almost always, in fresh exudations constantly, find more or less altered blood-corpuscles, which are wholly wanting in true transudations. But they are especially distinguished from the latter by their capability of metamorphosis, or inclination to change; while the transudations remain for a long time in the cavities into which they have been poured out, without undergoing even in their composition any material alterations, all the exudations, without exception, are distinguished by the fact that morphotic formations are developed in them, a certain plasticity is never wanting, and that they almost continually undergo alterations both in morphotic and chemical respects. Even if the exudations when formed do not pass into actual tissue or into cells, there are always found in them, a short time after their secretion, together with coagulated fibrin, morphotic elements, which show this tendency to a further organization. The greater or less plasticity of the exudations, as opposed to the entire want of organization of the transudations, indicates that the source of plasticity is to be sought in the substances occurring only in the exudations. These substances, according to our present knowledge, can only be the following: fibrin, the phosphates, and the hæmatocrystallin of the blood-corpuscles, which have passed into the exudation. It is usually assumed that the organizability of the exudations depends mainly upon the fibrin it contains; but, as we know of transudations, *e. g.*, in so-called acute dropsy, in which, while no small quantities of fibrin are present, no organization takes place, the plasticity cannot be referred, at least wholly, to the fibrin contained.

It is, hence, more than probable that the constituents of the blood-corpuscles disintegrated in the capillaries by the inflammatory process, or externally to them in the exudation, give rise to the organizability of the secretion. The organic contents of the blood-corpuscles, the so-readily changeable hæmató-crystallin, would next occur to mind; but, as this is entirely wanting in the plastic fluid of recent incised wounds which contains no blood-corpuscles, this hypothesis is at least very doubtful. The power of rendering an exudation plastic has been hence ascribed particularly to the phosphates; in favor of this is the fact that wherever cells and fibres are being formed even in lower animals, the organisms of which are deficient in these salts, phosphates accumulate in appreciable quantities; and, on the other hand, the fact that the blood which flows from organs of great vital activity, *e. g.*, the muscles, in which the renewal is most active, contains a much smaller quantity of the phosphates than the venous blood, which comes from the capillaries of organs of less vital activity. Finally, numerous careful analyses have shown that, even in the plastic secretions of wounds which are free from blood-corpuscles, more phosphates exist than in the liquor sanguinis of the same organism. It is, hence, no longer doubtful that the phosphates are necessary to the formation of cells and tissues (in which we also constantly find them); but, that the plasticity of an exudation is actually occasioned by them, is by no means decided. The chemical transformations, by which the various visible morphotic changes of the exudations are accompanied, we have not hitherto been able to follow precisely; investigations are even wholly wanting by means of which the actual chemical condition of the exudation, in its different stages of development, may be ascertained; numerous investigations, indeed, though not particularly exact, and very unproductive, have been made of the modification of exudation, which has been called suppuration. We must, hence, regard in a chemical aspect all other forms of exudations as a wholly unknown region. The following embraces all that is actually established with reference to the constitution of pus: The purulent exudation is generally a yellowish, thick fluid, which is distinguished from other exudations by containing a considerable proportion of corpuscles tolerably evenly distributed through it. Pus, thus, is divided, like the blood, into corpuscles and intercellular fluid, or serum. These corpuscles, generally 0.004 to 0.005 of a line in diameter, consist frequently of a granular or crenated investing membrane, a viscid, hyaline content, and a nuclear substance clinging to the investing membrane, and, of course, eccentric. As perfectly similarly constituted elements occur in the lymph, the blood, and the mucus of the mucous membranes, it has been proposed to include the so-called lymph-corpuscles, colorless blood-corpuscles, mucous and pus-corpuscles, under the common designation of *cytoid corpuscles*, *i. e.*, cell-resembling molecules. The examination of these corpuscles separately from the intercellular fluid is less successful than that of the red corpuscles in the blood; we know, as yet, of no mechanical means of separating them from the pus-serum, for, even on the addition of salts, they do not become capable of separation by filtration; like the blood-corpuscles, they possess a tendency to sink, but this is so slight that the pus has generally undergone some decomposition before even a limited sinking has taken place, and clear serum collected on the surface. Pus, when exposed to the air, very soon undergoes several transformations; it may pass into the acid fermentation, or the alkaline, or putrefaction. The *acid fermentation* of pus occurs at a moderate temperature in well-corked vessels; it soon loses its normal alkaline reaction, and finally becomes acid; volatile and fixed fat-acids are formed; butyric acid is detected chemically; the margaric acid, formed from the previously neutral fat, is easily recognized by the microscope.

The action of these acids upon the corpuscles, is the cause of the appearance, in the latter, of the previously invisible or indistinct nuclei. Impure pus, *i. e.*, mixed with mucus or blood, or so-called unhealthy pus discharged from abscesses, passes rapidly into the alkaline fermentation, without having undergone the acid; it begins to smell of ammonia and sulphuret of ammonium, the pus-corpuscles are distorted or dissolved into a gelatinous mass; nuclei are neither to be found isolated nor in the corpuscles; finally, only molecular granules and vibriones are to be recognized. Like the blood corpuscles, the cytoid corpuscles are remarkably susceptible to endosmotic currents; their diametric size hence depends, in great part, upon the specific gravity of the intercellular fluid; thus, they are larger in saliva than in pus, and smaller, on the other hand, in the blood. As the intercellular fluid of pus has, without doubt, some relation to the intercellular fluid of the blood, the variations in size of the corpuscles of the pus secreted is thus explained in diseases in which the blood is altered. For, when pus is diluted with distilled *water*, the corpuscles are seen to swell up strongly, the granular or folded condition of the investing membrane vanishes, and the nuclear formation becomes more perceptible; some of the corpuscles absorb so much water that they burst. *Extremely dilute mineral acids*, or moderately dilute solutions of *organic acids*, produce the same effect as water; they occasion a current from the intercellular fluid into the corpuscle. These means are hence used to render the nuclear matter more perceptible; the original, simple, lens-shaped nucleus often splits in consequence of the application of acids, into two, three, or more vesicles, in which often one or two granules (nucleoli ?) are to be recognized. Solutions of *neutral salts of the alkalies* cause the pus-corpuscles to shrink together, by depriving them of water; they then lose their sharp outline, and become small, granular, jagged masses. *Caustic alkalies* rapidly disintegrate the corpuscles; in the fluid, there are to be recognized only lighter and darker points. But little can be deduced from the further microchemical reactions which different chemical substances exhibit with the constituents of the pus-corpuscles, as to their chemical constitution; the cell membrane, nuclear substance, and viscid contents, afford, with nitric and nitrous acids, and protonitrate of mercury, reactions, which denote protein substance as far as they can be recognized, on account of the albumen secreted at the same time in the pus-serum. The lighter and darker granules, which are still visible after the treatment of pus with caustic alkalies, consist of fat. There are frequently found in pus, as accidental morphotic constituents, fat-globules, blood corpuscles, epithelial cells, so-called exudation globules, fragments of connective tissue, &c. The *serum of pus* is perfectly clear, colorless, or slightly yellowish, of a feeble alkaline reaction, and coagulates on being heated to a dense white mass. The principal constituent of pus serum is *albumen*, which usually exists in it to the amount of 1.2 to 3.7 per cent. *Mucosin*, *casein*, *pyin*, are only abnormal constituents of pus. Several constituents of pus belong, probably, as much to the serum as to the corpuscles; at least, it is impossible to decide as to them. Among these is to be classed the *fat*, of which, certainly, a large part belongs to the corpuscles: that which is extracted from the residue of pus consists not only of olein and margarin, but contains, also, oleic and margaric acids, and cholesterin, the latter often amounting to 1 per cent. of the fluid pus. In general, the amount of fat ranges from 2 to 6 per cent. Normal pus contains from 14 to 16 per cent. of *solid constituents.* The solid residue contains only 5 to 6 per cent. of mineral substances; among which the insoluble salts are to the soluble in the ratio of from 1 : 7 to 1 : 9. In so-called unhealthy pus, the number of the corpuscles usually decreases; hence such pus contains fewer solid constituents: among these, however, more salts, relatively, especially the soluble. In the insoluble part of the *mineral substances,* together with phosphates of lime and magnesia, a little sulphate of lime and peroxide of iron may be detected.

As pus is generally richer in *soluble salts* than the blood-serum, the proportion of *chloride of sodium* in pus is much greater than in the blood-serum: on an average, pus contains thrice as much chloride of sodium as the corresponding blood-serum. The quantity of *soluble phosphates* contained in the ash ranges between 3 and 10 per cent. Bile-pigment, resinous bile-acids, urea, and sugar, may occur abnormally in pus.

ZOOCHEMICAL PROCESSES.

FORCES AND LAWS OF THE ORGANIC MOVEMENTS.

We understand, usually, by a *process*, a certain sum of phenomena belonging together, which occur in a regular sequence, and finally lead to a sort of stasis which we regard as the result or object of the previous movement. We do not take cognizance of the movements as such with our senses, but only observe, at different periods of time, the stages of the alterations which are visible in the substances. Hence, to comprehend a process, a physical or chemical movement, we must bring the succession of the phenomena into an ideal connection; we must seek to ascertain the causal dependence of one phenomenon upon another; we therefore *explain* a process when we indicate the causal connection of the individual phenomena of the movement, and refer its result to a general moving cause. This moving cause is usually a more general point of observation, from which we can review various series of movements whose variety is occasioned only by the difference of the masses in which we recognize the movement, or by the difference of its point of attack on them. It is these general causes which are usually called *forces*, and for which short expressions have been found in definite laws. It was not doubted, previously, that in the animal organism, besides the known laws of physics and chemistry, an organic law, or, rather, a force not subject to any law, a *vital force*, was active in the movements of life. The molecules, in which the life-processes took their course, were regarded as materially different from other chemical bodies, and placed, in great measure, beyond the law of affinity, while their origin and maintenance were to be ascribed solely to a peculiar organic force. It has, however, been proved, by the most careful chemical investigations, that organic bodies are constituted according to the same laws, and, in their transformations, follow the same laws that prevail in inorganic chemistry. All the differences which have been presented between organic and inorganic bodies, are accidental, relative, and non-essential. The constitution of organic bodies corresponds merely with the functions to which they are destined in the living organism. The quality of the molecules, which serve as points of action in the living body to the forces there active, corresponds always to the functions required for the attainment of the object of life. The most evident proofs of this proposition are afforded by zoochemistry, and the science of the animal fluids and tissues (compare p. 123 and p. 201). It is, moreover, self-evident that the result of the operation of physical forces upon the very inconstant molecules, formed differently from those of inorganic bodies, but developed upon the same principles, must be very different from that which follows the action of the same forces upon the simpler mineral substances. We must, hence, necessarily meet with a number of phenomena in the animal organism which do not exist out of it, as the substrata of the animal body afford entirely different points of action to the physical forces. By a closer investigation of life-phenomena from this point of observation, we find that many of them stand in the simplest relation of dependence upon otherwise well-known physical laws, and that it is mostly only the different arrangement of the individual elements of the movement, and the complication of numerous conditions, which impress upon the phenomena of life a character often so specific. We are too often still unable, certainly, to comprehend some of the life-processes with relation to their physical causality; but this is no reason for taking refuge at once in a specific vital force; for, although physics and chemistry have already progressed so far, the molecular forces, and their manifold connections, have not been so far investigated in the various circumstances and relations of masses, that all the phenomena depending upon them, even in the inanimate world, can be explained, *i. e.*, recognized in their causal connection. It is one of the leading maxims of natural philosophy, that we should not lay down a new force, a general specific cause, until we have eliminated all other possibly operative forces from the group of phenomena in question. A proof of the existence of a purely vital force, is hence only to be obtained by an exclusion of everything physical. This cannot be adduced, because all the physical is not yet seen through by us.

We are so much the less at liberty, on the other hand, to assume a vital force for the explanation of vital processes, as the idea of such a force is based upon nothing less than upon reason. A force is only the abbreviated expression for a law from which the *causal* connection of certain phenomena may be deduced; vital force, however, as it is usually understood, corresponds with no law. On the contrary, it is usually represented as transcending all laws; it is conceived of as a spirit acting for purposes, not as a necessary cause of numerous consequent phenomena. Vital force thus lies wholly without the sphere of natural philosophy, for this is concerned only with the causal connection of phenomena, while the ascertaining of conformity to the end in view belongs to a purely speculative science, metaphysics.

It is usually sought to represent the assumption of a vital force as an unavoidable necessity. The certainly wonderful conformity to the end in view of most of the vital processes is adduced first for this purpose; but independently of a force operating only for ends being, as we have seen above, a physical nonentity, it should have been remembered that, in so-called inanimate nature, the phenomena which result only from physical laws display likewise a great conformity to the end in view, and that, on the other hand, vital force operates often enough without this conformity. Thus, *e. g.*, it is a wise provision of nature that the ice in winter does not sink down into the streams and seas, as otherwise they would soon congeal wholly into ice, and deprivation of water would ensue; this is not, however, the operation of a wise vital force of the earth, but only the consequence of the less specific gravity of the ice, and its bad conduction of heat. That also the pretended vital force often operates unconformably with the end in view may be observed in almost every case of disease.—A second proof of the necessary existence of a vital force has been thought to be found in the morphotic development of animal and vegetable tissues and organs. It has been held impossible that the organic forms inaccessible to mathematical treatment should be the results of physical laws; but is not, *e. g.*, heat the *primum movens* which disposes animality to development? In the animal ovum, the conditions are given under which the physical force of heat, which operates so diversely on different substances, calls forth those chemical transformations from which the morphotic proceed. Who, then, would have sought, *e. g.*, in the bichromate of ammonia, the conditions in consequence of which heat, operating only on a portion of it, confers so great a volume, and such remarkable tea-leaf-shaped forms upon the sesquioxide of chrome which is developed? And are the forms thus arising accessible to mathematical calculation?—The prolonged duration of organic movements has been regarded as an especial proof of the operation of a vital force, as the processes depending upon purely chemical forces were thought to be accompanied by an immeasurably short period; but we are now acquainted in chemistry with sufficiently simple processes which require a prolonged period for their accomplishment. We need scarcely recall to mind the decomposition of the compound ethers, the paired compounds, &c.

But these few hints may suffice to show that it is as impracticable as it is unscientific in physiological chemistry to make use of a so-called vital force for the explanation of the animal-chemical processes, and to refer the causal sequence of the phenomena to a force thus overleaping all bounds of conformity to law. In physiological chemistry, *explanation* can mean nothing further than a reference to established physical laws; as soon as physiological chemistry allows a vital force, it resigns all effort to be numbered among the exact sciences. If the phenomena of nature are of a complicated description anywhere, they are so in the living body; the recognition of natural laws is hence more difficult here than in any other portion of natural philosophy. The only sure anchorage which remains for us is often that here also the laws of molecular movements continue as steadfast as those of gravitation among the heavenly bodies. Even he who, from subjective feeling, makes for himself any form of a vital force, must be conscious that in the animal organism the laws of nature have still the same efficacy as out of the organism, and that an investigation, an explanation of animal phenomena is impossible without the application of physical laws. We have already, in considering the individual factors of the metamorphosis of animal tissues, constantly referred to the influence which they exercise over this or that animal-chemical process; but we have thus collected only the foundations for attaining a general view of the processes themselves, and the causal chain of the phenomena. Such a general view can only be combined immediately with zoochemistry, and with the science of the chemical substrata of the animal body, by considering the actual *agents of the metamorphosis of animal tissues*, and pursuing the transformations which they undergo during their function in the living body. We must, then, here embrace all those processes in which the individual chemical factors actively participate, and whereby they themselves undergo various changes, and hasten to their dissolution or excretion into the outer world. For the explanation of these processes, there are necessary principally two moments—viz: an exact knowledge of the chemical constitution and quality of the substrata, and a reliable acquaintance with all the laws of the movements of molecular matter. Unfortunately, we can congratulate ourselves neither upon the one nor the other. How insufficient, how imperfect our chemical knowledge of the substrata is, we have already sufficiently learned in considering precisely the most important of them, the protein-bodies; and still extremely deficient knowledge of the laws of the molecular movements of matter deprives us at once of the means of explanation; a connection with established physical propositions is hence often impossible. In the second degree, we can connect together series of processes, which afford a view of certain general processes of animal life; this portion of our physiological observations will find its support more in the science of the animal fluids. Thus, we must, in the first place, follow in their individual stages, and indicate causatively all the processes which have reference to the *digestion* and *resorption* of the food ingested; the reciprocal actions between the agents and the objects of digestion, as well as the physical conditions which control the passage of the digested matter into the general mass of the fluids, must be here taken into consideration. After the process of digestion has afforded to the organism the material needed for the performance of the various life-processes, there is a process without which the results of digestion, *i. e.*, the chyle and the blood, could not be further utilized, and which participates so deeply in the whole of animal life that a short cessation of this process brings it to destruction; this is the *process of respiration*. Without the proper investigation of this, the processes of *nutrition*, of the formation of tissues, and of secretion and excretion, are incomprehensible. We thus embrace together all the processes in conclusion, which, together with digestion and respiration, are necessary to the maintenance of life.[1]

[1] For remarks upon this chapter, by Dr. Jackson, see p. 41; and also, in the appendix, under "Life Phenomena."

TISSUE-METAMORPHOSIS IN GENERAL.

When we recur to the constitution of those substances of which nature makes use for the attainment of the most various operations, and the fulfilment of the most different purposes in the living organism, we are struck here, as everywhere in nature, by the wonderful simplicity of means and forces by means of which the world of phenomena is governed in change often so inconceivable. There are, properly, only four groups of substances in which all the phenomena of life take their course; the protein-bodies and their derivatives, the fats, the so-called carbo-hydrates, and the inorganic salts.—What resemblances, what coincidence in the most various particulars are presented by the members of each individual group! But it is not only the great analogy of the individual members of each group, and the ready transition of one into another which render this arrangement of the organic molecules so wonderful and so applicable to the uses of life, but also the peculiar relations in which the individuals of different groups stand to each other. Several facts indicate that the protein-bodies may be resolved in the animal organism into sugar, as also into fat, together with other products: and again others, that fats may be produced from carbo-hydrates. Possibly these three groups of the actual animal substrata may stand to each other in a typical relation similar to that of the organic acids, the haloid bases, and the ammonia-bases. Although we are by no means acquainted with all the *molecular forces* which come into application in the transformations of these bodies for the object of the life-phenomena, we are able, from the constitution, from the homology of these bodies, and from the near relations in which even the different groups stand to each other, to draw the conclusion that the expenditure of force which these movements demand must always be but small. How differently the otherwise almost apparently identical protein-bodies participate in the movements of the organism! How many different purposes the most homologous substances of the animal body, the fats, are applied to in the organism! The carbo-hydrates, which appear on superficial observation, only to be hastening to their destruction in the animal body, undergo the most manifold transformations and divisions in order to participate in this or that direction in the apparent tumult of the life phenomena. Potash and soda, finally, substances which the chemist has difficulty in separating, and which elsewhere often appear to perform vicarious functions for each other, are used in life to form the most striking contrast; while the most volatile and feeble of the acids, carbonic acid, must perform under some circumstances the same services in the organism as the powerful and stable phosphoric acid. Phosphate of soda occurs at one moment as a powerful base, while in another, by the aid of carbonic acid, it supplies the place of an acid. We must wonder at the insignificance of the expenditure of force which nature requires to utilize the few substrata for the purposes of life.

The most superficial glance at the mode of occurrence (Vorkommen) of *albumen* teaches us that this must be one of the most important substances of the animal body: we have found it in greatest quantity in the blood and in all the animal fluids which are intended immediately for the nutrition of the organs; a close investigation of many animal tissues has shown that albumen needs only slight modifications for its consolidation under various forms, sometimes constituting the fluid of the crystalline lens under the form of globulin, sometimes developing, under that of syntonin, the solid contractile parts, by which alone voluntary and involuntary movements are performed in the animal body; we have found it again in the soluble and insoluble form in the most delicate organic compound, in the contents of the nerve-tubules, in which, in a measure, the highest potentiality of all organic life is deposited. Unfortunately, in our present entire ignorance of the chemical constitution of this body, we can hardly imagine upon what the transformations of albumen into globulin, syntonin, &c., depend, and what, properly speaking, adapts these substances to their life-functions, as different as important. The animal germ is found imbedded in a fluid abounding in albumen and casein, from which it draws the materials necessary for its development; to the suckling also, a fluid is afforded to it, for its development, in milk, which, together with sugar and fat, contains only a protein-body rich in salts, casein. Thus, at the time when the organism needs for the development of the gelatinous, non-albuminous tissues the greatest afflux from without, protein-substance only is afforded to it, together with these non-nitrogenised bodies; hence gelatin-yielding tissue, elastic tissue, in short all the non-albuminous nitrogenised tissues must be formed in the animal organism from it. So also the herbivorous animals find in their food no substances yielding gelatin, but only protein-bodies with these non-nitrogenised substances. There can hence be no doubt that from casein and albumen result all the solid substances of the tissues; but as the latter are on the average much richer in oxygen than the protein-bodies, it is more than probable that the oxygen introduced into the blood through the lungs occasions this transformation of the protein-substances into the different materials of tissue. We are still far too little acquainted with the process of this development of tissue, the individual stages of this transformation of the protein-bodies into tissue-materials, the individual steps, to venture to represent these processes in chemical equations. Even if we had reason to suppose that albumen is transformed into fibrin before subserving the formation of gelatin-yielding tissue, and that a tissue is always chondrin-yielding or mucus-yielding (connective tissue of the fœtus) before it becomes gelatin-yielding, the actual matter-of-fact condition of the process in question is by no means thereby ascertained. For if, chemically speaking, the rational composition of all these substances were precisely known, it could not be decided with certainty, in our ignorance of the individual conditions of the process, to which of the many possible combinations and modes of representation capable of being expressed in formulas, the preference should be given. We must not think that the simplest formula or mode of representation must always be the right one in the explanation of these processes. As no cell, no fibre appears to be formed without the concurrence of fats and certain salts, these should probably be taken in generally as integral factors of such processes in the chemical equation; indeed it may be maintained almost with certainty of some substances, *e. g.*, the nitrogenised acids of the bile, that they are not simple products of transformation of the protein-bodies, but that the non-nitrogenised carriers (Träger), of the animal tissue-metamorphosis contribute to their composition. In all attempts to explain the formation and transformation of these nitrogenised bodies, we only move in a circle of probabilities or possibilities without having obtained any fixed basis for this or that view. This much only results with some degree of certainty, from the simple comparison of the empirical composition of these substances, and from corresponding statistical investigations of the metamorphosis of tissue in the animal body, that the different phases under which the organic molecule appears in the animal body, are materially influenced by the oxygen respired, and that this influence, under various circumstances, affords the principal cause for the numerous modifications which the albumen molecule undergoes, even to the final excretion of its last effete particles in the form of urea and similar substances.

Mention has previously been made of the physiologico-chemical processes respecting the *fats* (p. 69). These bodies are introduced into the animal organism from without in great quantity; we have seen that they are absorbed in the alimentary canal principally by the aid of the bile. Reasons were also given, which render probable the opinion that a small quantity of fat is necessary for the transformations of the articles of food, particularly the nitrogenised, which take place in the stomach and intestines. After its arrival in the blood, the fat must undergo various transformations according to the purposes to which it is applied in the organism. In reality, these transformations amount to a separation of the fat base, and a gradual oxidation of the fat acids thus formed. Whether the alkali of the blood gives rise to the decomposition of the fat, or any other substance resembling a ferment effects it, has not been yet decided; we also do not know in what gradations the fat-acids of higher atomic weight, *i. e.*, those richer in carbohydrogen, are decomposed into those that are poorer in carbohydrogen, and of less atomic weight. The final result of all the transformations of fats in the animal body is either that they are perfectly consumed into carbonic acid and water, or that they are excreted with the sweat in the form of formic, acetic, and butyric acids. The fats must hence contribute with their small content of oxygen more than any other bodies to the maintenance of animal temperature by means of this more or less rapid oxidation; they have hence been called *agents of respiration*, as opposed to the nitrogenised articles of food; we shall recur more fully under "Respiration" to their thermogenetic equivalent. The fats undergo, however, by no means so rapid an oxidation in the animal body as might have been expected from the last-named function, and as we see other non-nitrogenised substances consumed in the blood, *e. g.*, lactic, citric, and malic acids, &c. They seem to be the most difficult and last of the easily combustible substances to undergo oxidation; for if furnished to the organism in sufficient quantities, they are deposited in peculiar cells, as fat-cells in different places in the connective tissue. According to exact investigations, occasion is given by their abundant introduction into the body for the formation of new cells; that such fat may be stored away, protein-bodies must be applied for the formation of the places of deposit. It is even believed that by excessive introduction of fat, and deficiency of disposable protein-substance, even the muscular fibre is emptied of the latter, that fat may be deposited in these protein-membranes.—As here the protein is appropriated, in order to develope these fat-cells, so fat appears to participate in the formation of cells and tissues; in fact, a theory of *cell-formation* has been presented, according to which the first foundation of every cell is formed by a fat-globule, surrounded by a thin protein-layer. It is a fact that in all cellular organs or in all tissues in the act of development, considerable quantities of fat are found; we thus see pus and many cancers rich in fat; the hair-bulbs, in which an active cell-formation takes place, imbedded, as it were, in the sebaceous glands; in the chyle, where the cell-like corpuscles are to be observed in different stages of their development, much fat is always contained; the germinal vesicle is surrounded by the fat-abounding yolk-fluid; in the muscular fibrils of the fœtus we recognize still numerous fat-globules, &c. The opinion is thus not without grounds, that fat is an important factor in cell-formation. We are, however, so much the less able to give a scientific demonstration of the chemical changes accompanying this process, as we are destitute of any investigations which afford conclusions as to the composition of the fat found in such cells, and even of the morphotic constituents forming the cells.—The deposition of a peculiarly modified fat in the nerve-tubules, indicates very significantly that fat is not to be regarded only as a simple material for combustion, and also gives room for the suggestion that it plays a part even in the *function of the nerves*, and undergoes, during the latter, certain modifications, to which we find it exceedingly inclined by close chemical investigation. The peculiarity of the nerve-fats, their different melting and congealing points, prove that we have here different stages of fat-transformation. Finally, the fact that when the fat has disappeared from almost all other organs, it remains in unaltered proportion in the nerves, indicates very significantly that these fats are indispensable for nerve-action. As yet we know neither the individual nerve-fats, nor their constitution, precisely; we are hence wholly unable to indicate, even in a degree, the chemical process which accompanies nerve-action with reference to the fats.—Attention has already been called in zoochemistry (p. 79), to the grounds which render it probable that a portion of the fat in the animal body, especially the oleic acid, co-operates in the formation of the resinoid bile-acids. The process cannot be any further pursued in this place.—A very important question in the consideration of animal tissue-metamorphosis is, whether *fat can be developed in the animal body itself, i. e., from protein-bodies or carbohydrates.* That the animal organism must possess this power has been previously (p. 70) stated, from statistical researches; the general opinion now is that the fat newly originating in the animal body, has its sources in the *carbohydrates* of the food. Certain phenomena indicate, however, that *protein-bodies* are also able, in their decomposition in the organism, to yield fat, together with nitrogenised products. We have not been able chemically to produce ordinary fat from protein-bodies, but chemical facts do not at least contradict such an opinion; for under favorable conditions casein, fibrin, &c., are disintegrated into ammonia-salts and volatile fat-acids. As far as observations on the formation of *adipocire* extend, it assumes the appearance of the muscular substance being transformed simply into an ammonia-soap. It is also well known that, in paralyzed muscles, the substance of the fibrils gradually vanishes, and quantities of fat are deposited in its place. In pathologically affected tissues, especially after inflammatory processes, we very often see fat-granules occur, which fill up, and surround the remnants of wasted cells (fatty degeneration). Animal substances free from fat, such as the crystalline lens, white of egg, &c., have also been introduced into the peritoneal cavity of living animals; in the course of from four to eight weeks the residual mass has not indeed vanished, but is found poor in protein-substance, and very rich in fat. These experiments give a high degree of probability to the opinion that here fat arises from protein-substances; but it is readily conceivable that in these cases the fat has been infiltrated and deposited from the mass of the fluids into the vacuities resulting from the absorption of the protein—as we see, that, in diseases which are accompanied with rarefaction of the osseous tissue, an oily fat enters into the enlarged bone-cavities. Further investigations have shown, on the one hand, that protein-bodies inclosed in collodion, gutta-percha, or corked vials, do not undergo such fat-metamorphosis in the organism, and on the other, that non-albuminous substances, *e. g.*, pieces of bone, wood, and alder-pith, take up quantities of fat in their pores when long resident in the peritoneal cavity of an animal, and become covered with a yellowish, fatty layer of exudation. A definitive decision of the pending question is not, however, afforded by the last experiments, which contradict in a measure the hypothesis, as it is not only conceivable, but very probable, that the access of the organic fluids to the protein may be necessary to induce in it the fat-metamorphosis, and as the exudation which incloses the dead material may undergo the same process. Certain experiments which have been instituted upon the eggs of the *Linnæus stagnalis* during their development, seem to indicate an increase of fat during the development of the embryo caused by decomposition of albuminous material, and thus, at least in this case, to exhibit an origination of fat from albumen. The whole question is therefore to be regarded as still open.

The physiological importance of the third group of substances which participate actively in the metamorphosis of animal tissue is but little esteemed in general, as these bodies have been long since withdrawn from dokymastic analysis. Only four of the carbohydrates occur in the animal body—dextrin, grape-sugar, lactin, and inosit. With the exception of the cellulose deposited in the mantles of the *Tunicata*, none of these carbohydrates forms the basis of animal tissue; we find them, on the other hand, in nearly all the animal fluids, which either are destined for nutrition or in which an active metamorphosis of material takes place. We have found sugar in the blood, the lymph, the chyle, the white and yolk of egg, and in milk; proof enough that this carbohydrate is to participate actively in different animal processes. Nature herself, however, affords us the best proof of the importance of sugar in the metamorphosis of animal tissue in providing, by means of an organ, the liver, that even when no sugar is introduced from without, the organism shall still not be deficient in it (compare p. 98). Like the fats, sugar is numbered among the *materials for respiration* and must contribute importantly to the maintenance of animal temperature, as it does not pass into the excretions, but is very quickly oxidized in the blood into water and carbonic acid. But this substance subserves exclusively this purpose as little as the fats do; the sugar would scarcely in that case be first formed in the liver from nitrogenised bodies.—Sugar undergoes before its oxidation various transformations, by which it participates in this or that process conducive to life. Thus, it is at least partly transformed into acids; even in the primæ viæ, some free acid results from the sugar derived from the starch which, in consequence of its diffusibility, contributes to the absorption of the intestinal contents. We find, as already stated, alkali and free acid very differently distributed in the animal organism; we shall again recur to the importance of this distribution. If the carbohydrates were merely burned off in the organism without forming acids, in that of the herbivora, at least, an acid reaction, or, what is the same thing, an acid phosphate, could never be formed. As the ashes of plants (except those of some seeds) constantly react alkaline, the food of herbivorous animals could develop only alkaline-reacting fluids in their organism, and the opposition between acid and alkaline fluids so necessary to the life of the animal could not occur.—Sugar is a very good solvent of carbonate and phosphate of lime. In the development of the fœtus in the bird's egg, in which we find so remarkable an increase of lime, this may be derived from the egg-shell through the agency of the sugar.—Statistical experiments on mast-fed animals, as also upon bees fed only with sugar or refined honey, have shown that fat must be developed in the animal body from the carbohydrates; but where this formation of fat takes place, and with what process it is combined, it has not yet been possible to ascertain. In the colon we often see butyric acid occurring after the ingestion of amylaceous food; but this knowledge does not entitle us to the supposition that the formation of fat takes place here. The focus of fat-formation has also been sought in the liver: but is it possible that, on the one hand, sugar should be formed from protein-bodies, and on the other, be at the same time transformed into fat, while we yet see it leave the liver in such great quantities?—It is certain that sugar participates in several other processes besides those here indicated; but unfortunately all points of support for their consideration are wanting.

The contrast in the reaction of the proper nutritive fluids of the body, and most of the parenchymatous fluids, has already been often noticed. Besides the muscles, the liver, spleen, thymus gland and supra-renal bodies contain free acids. There exists some ground for the opinion that the occurrence of these *free acids* is less directly associated with the functions of these organs than with the presence of smooth muscles, which are present in all of them; at least those organs are found to be richest in free acids which contain most muscular fibrillæ. Numerous observations indicate that free acid appears in the muscles only when these are or have recently been in action. The free acid would thus seem to have its origin in the waste, *i. e.*, the disintegration of the muscular substance. Its presence in the parenchymatous fluid must, however, necessarily be followed by certain physical and chemical relations. Whether, in the first place, a certain *manifestation of polarity* connected with the function of the organs is occasioned by this contrast, is not yet ascertained. That, further, certain *diffusive currents* in different directions are thereby excited, may rather be inferred than specially demonstrated, as we are still by no means sufficiently informed as to the laws of diffusion to be able to deduce from them the molecular movements concerned, and thus explain the mechanical tissue-metamorphosis in question.—A chemical consequence of the occurrence of lactic acid in the organs which contain muscles and fibre-cells is the *formation of acid phosphates.* We have found, in all these parts, the phosphates increased at the same time as opposed to the alkaline fluids. This abundance of acid phosphates may partly depend upon the withdrawal, by the free acid, of the phosphates from the undecomposed protein-bodies, and partly by the former becoming separated, and thus in a measure free from the latter in the decomposition of the muscular fibre. If, however, some peculiar, and to us at present incomprehensible, conditions of diffusion were not here operative, their accumulation in these fluids, as opposed to the blood-serum, would still remain inexplicable. It is also worthy of remark that potash salts accompany this free lactic acid and the acid phosphates, while we find soda compounds preponderating in the blood-serum. Had not recent experiments shown that even very strong chemical combinations are decomposed by diffusion, and further, that the equivalents of diffusion of potash and soda salts are somewhat different, we would scarcely have ventured to seek the cause of this striking separation of the potash and soda compounds in physical relations. Although we are not yet able to follow precisely the currents of diffusion as conducted according to definite laws, we still know that these laws exist, upon which this peculiar separation of the mineral substances depends. But, if we are deficient in methods of explanation, *i. e.*, in thoroughly investigated and established laws, we are so much the more admonished to remember the facts concerned, so that hereafter we may have a firmer basis for the application of the laws in question. As we have already seen, contrasts similar to that between the muscular and blood fluid are also found between the yolk and the white of the egg, and between the contents of the blood-cells and the intercellular fluid. A free acid, indeed, is not demonstrable either in the yolk or in the contents of the blood-cells, but each of them, on careful incineration, yields an ash reacting strongly acid, on account of acid phosphates. Numerous investigations render it probable that we have here paired compounds of phosphoric acid to deal with; glycero-phosphoric acid is as yet the only certainly-known compound of this sort, but other similar compounds may frequently exist in the animal body, especially wherever the ash contains acid phosphates or metaphosphates. To this class belong, *e. g.*, most of the substrata of animal tissues which yield an ash, in which only 1 equiv. of base occurs to 1 equiv. of phosphoric acid; a fresh argument for the opinion previously expressed (p. 225), that the phosphates may participate in the formation of cells and tissues.—That, moreover, it is not only the conditions of diffusion which produce the accumulation of the phosphates and potash salts in the muscles, but that chemical relations also detain the phosphoric acid in those organs, may be concluded from the fact that, in the organs alluded to of the herbivora, there are found no less phosphates and potash than in those of carnivora; while in the liquor sanguinis of the former scarcely traces, and in that of the latter very variable quantities of phosphates are found, depending upon the amount of animal food ingested.—While we can only present conjectures as to the function of the free acid, or the paired compounds of phosphoric acid in these organs, certain consequences of the presence of free or loosely combined alkali in the liquor sanguinis may be foreseen of necessity. We can predict, with certainty, that the alkali must exercise an oxidizing operation upon many organic materials, under the conditions which obtain in the blood while circulating; for, it is a well-known chemical experience, that many organic substances are oxidized in the air, *i. e.*, on the access of oxygen only by the agency of an alkali, or at least much more rapidly than without it. While we see organic acids out of the body (for instance gallic and pyro-gallic acids), when combined with an alkali, rapidly absorb oxygen, and become decomposed, we find that lactates, tartrates, acetates, &c., of the alkalies directly injected into the blood, or absorbed from the intestine, are very soon consumed to carbonates of the alkalies by the presence of the oxygen dissolved in the blood. Can we wonder further at the rapid consumption of the sugar in the blood, when we remember that this sugar, in the presence of an alkali, is able to take away even combined oxygen, and withdraw it from the oxide of copper and many other oxides? As, however, in chemical researches, the sugar is not perfectly oxidized into water and carbonic acid, but a highly oxygenated acid is formed, so also in the blood the sugar is probably not oxidized at one blow; at least an acid, without doubt originating from the sugar, is discovered in it. It cannot be denied, further, that the alkali in the blood, even when combined with carbonic acid, must effect a saponification of the fats; whether it also, with the help of the oxygen of the blood, exerts an oxidizing influence upon the fat-acids formed, cannot be asserted with equal certainty; yet the gradual consumption of the fats in the animal body is scarcely otherwise to be explained. The part which the alkali takes in the transformation of albumen into fibrin, and chondrin- and glutin-yielding tissues, cannot as yet be accurately pointed out; but numerous pathological facts indicate that this part is not an unimportant one. That, moreover, purely chemical relations, combined with number and mass, are the conditions of these phenomena, may be most readily seen from the fact that this oxidizing power of the blood is very intense, but not very extensive; for, as soon as the introduction of sugar or acids into the blood exceeds a certain, and by no means far-removed bound, these substances pass unchanged into the excretions. Hence salicin, *e. g.*, is oxidized in the body according to the individual conditions and the amount of it taken sometimes only into salicylous and sometimes into salicylic acid.

Chloride of sodium, also, a body apparently so indifferent and difficult of decomposition, is an active factor in several animal processes. Facts indicate that in most of the animal fluids, and especially in the blood, the proportion of common salt remains nearly constant, whether much or little of it be introduced; direct experiments, also, on animals, a part of which received common salt in their food, and part did not, have proved that the abundant use of chloride of sodium is without influence upon the formation of flesh and fat, but that the animals thus fed exhibited a better appearance (especially with reference to the hair-growth) and greater activity than those fed without chloride of sodium. The proportion of chloride of sodium is, moreover, so consulted by nature that, *e. g.*, in abstinence, or the use of food absolutely free from common salt, the blood maintains its previous proportion of chloride of sodium, so that none then passes into the excretions. But few of the properties of chloride of sodium will serve for the explanation of the processes in which it actively participates; several protein-bodies, *e. g.*, albumen and casein, when poor in alkali and salts, are dissolved by the solution of this salt, while others, as glutin and syntonin, are precipitated by it from acid solutions. The presence of chloride of sodium in the blood, in exudations, &c., may hence serve in one case for the solution, in the other for the precipitation of certain protein-bodies; but such an influence is not yet specially demonstrable. Chloride of sodium enters into definite compounds with *urea*, and with grape sugar; hence, both of these constantly occur in the organism accompanied by it. It is possible that the chloride of sodium participates in the transformation of the sugar, and in the excretion of the urea. Chloride of sodium must also be decomposed in the animal organism. Whether the *free muriatic acid* of the gastric juice arises from it, and not from the more easily decomposed chloride of calcium, is at least doubtful; in the blood of the herbivora, however, the chloride of sodium must be decomposed by the carbonate of lime arising from the food, for we find in it, in four parts of carbonated alkali, three parts carbonate of soda, and only one part carbonate of potassa, while in the fluid of the muscles only chloride of potassium exists. The bile also of herbivorous animals contains soda salts almost solely; it appears thus as if these were more necessary for the formation of bile than the potash salts. These phenomena cannot be merely accidental, although we do not at present know how to explain them. Chloride of sodium is of manifest importance to the *mechanical tissue-metamorphosis;* the constant proportion of it in the blood is an influential factor of the process of absorption. The intestines contain a fluid of but little concentration; from the blood diluted by this, the water which has been absorbed is immediately withdrawn again by the kidneys, so that the common-salt solution of the blood retains almost constantly the same concentration. As we finally find large quantities of chloride of sodium in organs abounding in cells, as, for instance, in cartilage and hair, in secretions and exudations, which are especially disposed to the formation of cells, such as mucus, pus, and cancer, and see it disappear wholly from the urine upon the secernment of these exudations (as in pneumonia), it is probable that chloride of sodium has an influence over the formation of cells, or rather that it hinders their further transformation into tissues; as to the manner of this operation, we have unfortunately no idea.

DIGESTION.

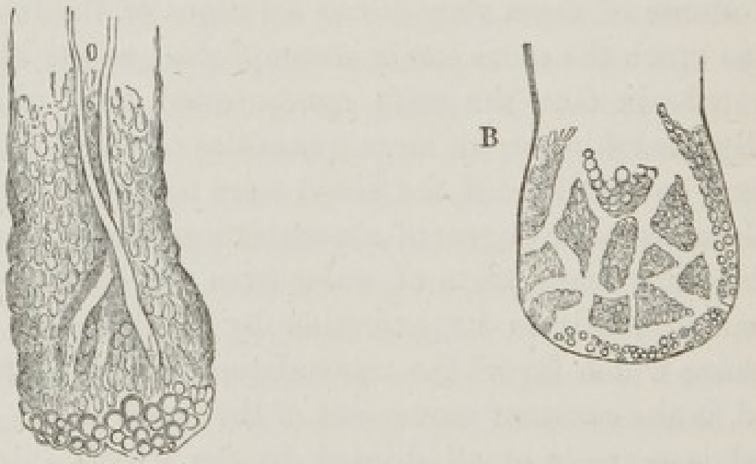
By digestion, we understand the series of processes, chemical and physical, by means of which the introduction of food into the vascular system, for the replacement of the effete portions of the organs, and for the maintenance of the functions of life, is accomplished.

In order to become capable of being received into the fluids of the animal body, the articles of food must be transformed into a soluble condition. The capability of absorption is not an accidental, unconditional property belonging to them; this property must stand in as close relation to all their other physical and chemical qualities as these do to each other (compare p. 55). On this account, the substances which, under similar circumstances, will undergo absorption, exhibit otherwise very decided analogies; in analogous substances, the absorbability will coincide with certain other qualities; these qualities are again properties, closely connected together; the solubility, the degree of condensation in the solution, and the equivalent of diffusion or endosmose. These are the proximate conditions which are to be considered in the explanation of the absorption of substances in the intestines; *absorption is nothing more than a function of the mechanical conditions just mentioned.* As, however, we have not reduced any of the different varieties of attraction between water and solid bodies to a mathematical formula, and the relations between them are not ascertained, we are still unable to give an actual explanation of the process of absorption; for, how is an explanation, *i.e.*, a deduction of the phenomena from laws, conceivable, when these laws are still unknown? We must, therefore, at present, content ourselves with a general indication of the phenomena of absorption according to physical analogies, being confident, however, that physical conditions alone give rise to absorption. As, then, the capability of absorption is occasioned by the relative combination of several qualities connected with the original relations of each individual substance, so is also their whole behavior to the agents by which digestion is effected, *i.e.*, the digestive fluids. Chemical and physical properties are by no means such dissonant ideas as they are generally regarded; many recent observations have clearly shown the transition of physical into chemical qualities; and it is well known how much physical properties influence the chemical, and the latter the former; it is not, therefore, paradoxical to believe the absorbability of a substance to be as much dependent upon its essential qualities as its behavior to the digestive fluids, and hence, to conclude that *definite relations* must exist *between the capability of absorption of a substance*, and *its reaction with the digestive fluids.* Since, then, the properties of substances most important for their digestion depend upon certain of their essential qualities, we must, in a scientific treatment of this subject, in order to take a safe course for a scientific knowledge of the whole process, divide the *objects of digestion*, not according to their physiological purposes, nor according to their useful or injurious qualities, but group them together only according to the analogy of their essential qualities.

As we consider the process of digestion (in the narrower sense) as inseparable from the process of absorption, we must, before following the objects of digestion themselves, and their fate in the alimentary canal, notice, first, several *mechanical conditions of absorption.* The current of diffusion from the intestinal cavity in the direction of the mass of the fluids, is very much favored by the following conditions: the solution of substances in the intestines is very dilute, partly because the materials to be digested, as starch and protein substances, are very gradually transformed into the soluble state, and partly because the fluids flowing into the intestines are very watery, and contain but few solid constituents. The endosmose of these very dilute solutions of the intestinal contents, is so much the more easily accomplished, as the blood is very concentrated—in fact, the most concentrated fluid of the animal body. By the taking up of large quantities of water, this condition would soon be disturbed if the blood were not, by certain mechanisms, maintained at its degree of concentration; these consist, partly, in the abundant evaporation of water from the blood by the lungs and skin, and partly in its excretion by the kidneys. A second circumstance which favors the transudation from the intestines into the blood, is the constant movement of the blood in the capillaries; the blood is scarcely at all diluted by the watery intestinal fluid before it is driven into the larger veins, and concentrated blood again takes its place. Another circumstance which promotes the passage of the intestinal fluids into the blood, is the normal acid reaction, in a great part, of the intestinal contents, while the fluids destined for the absorption of the intestinal solution, have a strongly alkaline reaction. We know, however, that free acid promotes while free alkali hinders, exosmose. Notwithstanding these arrangements, so extremely favorable to endosmose, there are numerous substances, which, although dissolved in the water of the intestinal contents, would still pass with great difficulty, and some not at all, into the blood of the intestinal capillaries. These substances are either incapable of endosmose, and hence must first be modified by the digestive fluids, and rendered capable of it, or they are introduced into the mass of the fluids by means of peculiar mechanical agencies. For the digestive fluids are of service not only in rendering the objects of digestion soluble, but by so changing their qualities as to incline them to those molecular movements which we include under the term of diffusion. The blood is moreover separated from the intestinal contents, not by a single membrane, but by several membranes and series of cells, by which the transition must be in some degree delayed, especially in substances which are not easily diffusible, *e.g.*, gum and albumen. We find, therefore, peculiar mechanical provisions, also, for the acceleration into the blood of substances which are not easily diffusible; these consist of the *chyle-vessels*. We do not, indeed, as yet, possess a clear idea of the mechanism of absorption by the latter. All the experiments for the explanation of absorption by the lymphatics,

Fig. 31.

A B



Extremity of Intestinal Villus.—A. Seen during absorption, and turgid with fat-globules. B. Seen during the interval, and showing the supposed peripheral network of lacteals.

have reference only to the onward movement of the fluid which has already entered the lacteals; the contractility of the intestinal villi, dependent on the smooth muscular fibres which enter into their structure, must naturally, from time to time, cause the fluid contained in them to be driven forward, while the valves in the vessels themselves prevent its return. But, how the minutest ramifications of the lymphatics are filled, and how it happens that a number of substances, while close to the blood-capillaries, pass by into the extremities of the lacteals, we are entirely unable to explain. For, although we may imagine a specific permeability of membranes (as caoutchouc, *e. g.*, is not permeable by water, while it is by alcohol), yet we have no proof that the bloodvessels and lacteal-membranes are specific partitions, which afford a passage to one substance, and not to another. The next question for consideration is, which substances pass immediately from the alimentary canal into the blood, and which arrive there through the agency of the lacteals? And also, what essential qualities are peculiar to these groups of different absorbability? There are two methods especially which have been devised in order to ascertain what substances follow the one or the other mode of absorption. The first method which was pursued was to place the substance in question in the intestine, or in a portion included between ligatures, the ductus thoracicus, or the branch of the lacteal leading from the knuckle having been previously tied. For these experiments, either such substances were chosen as could readily be detected chemically in the blood, or such as produced very soon striking toxical phenomena, in order thereby to discover their passage into the general mass of the fluids, or exclusion from it. The second method consisted in searching in the blood, especially of the portal vein, and in the chyle for the substances placed in the alimentary canal of an animal a short time after their ingestion; from the speedy appearance of such substances in the blood and urine, or the exhalations from the lungs, an immediate absorption through the intestinal capillaries was inferred.

What substances, then, according to these experiments, are taken up immediately by the blood-capillaries of the stomach and intestines without undergoing any material chemical alterations? We meet among these, in the first place, many neutral salts of the alkalies, the acids of which are not disposed to enter into combinations with other matters of the intestinal contents; here also belong, secondly, the acids, organic as well as mineral; thirdly, the volatile haloid bases and their hydrates (ethers and alcohols); fourthly, the volatile oils in general; fifthly, many alkaloids, volatile as well as fixed; and lastly, a number of pigments whose chemical constitution is not yet sufficiently explored. It is difficult, and indeed at present impossible, to discover in these various substances, any common essential relations upon which their ready absorbability by the bloodvessels may be thought to depend. That the mere solubility does not occasion their absorbability, is evident from the fact that some very soluble substances, *e. g.*, gums, turmeric, &c., are not generally absorbed. The diffusive capacity of these substances is unfortunately so imperfectly ascertained, as yet, that we can form no opinion as to the relations in question. In the mean while it may be stated that those substances which have hitherto been regarded as very diffusible, are absorbed by the blood-capillaries, while those whose powers of diffusion are proved to be slight, usually enter by the lymphatics in preference.

From the deficiency of fixed physical principles, we shall regard the objects of digestion according to their chemical categories, and begin with the so-called *carbohydrates.* Among the carbohydrates here concerned, *grape sugar* is the most prominent, partly because it is found pre-formed in many articles of food, and partly because other carbohydrates must generally be converted into it before they are absorbed, or undergo further transformations. When sugar is introduced into the digestive canal by the mouth, it is distributed, as is proved by direct experiments, very soon (within one hour) over large tracts, generally as far as the cœcum; there is then found (about an hour after the reception of the sugar) in the small intestine a thin, often quite limpid sugar-solution, which vanishes from the intestine sooner or later, according to the degree of concentration of the solution. Generally speaking, the absorption of sugar takes place very gradually; we hence but seldom find demonstrable quantities of absorbed sugar in the chyle and in the blood of the portal vein. At the same time, the amount of its absorption does not stand in direct relation to the amount of sugar consumed by the blood; for after abundant ingestion of sugar, its quantity in the blood may rise to 0.6 per cent., when the excess is excreted by the kidneys with the urine. From the increase of the sugar content of the blood after its ingestion, it results that the greater part of the grape sugar is absorbed unaltered; while a small portion of the sugar received is always transformed into acids. After the ingestion of sugar, the contents of the duodenum and jejunum have a strongly acid reaction, those of the ileum less so: the acid reaction depends upon the lactic acid which is formed; the cœcal contents then again react strongly acid, but here much butyric with only a little lactic acid is found. In the small intestine, the lactic acid fermentation must be caused by the bile or pancreatic fluid, and not by the intestinal fluid or intestinal mucus; for sugar-solutions placed in emptied and cleansed knuckles of intestine, are thence absorbed without the occurrence of acid reaction being observed. That grape sugar is principally and in great part absorbed by the intestinal capillaries, is to be inferred from its rapid increase in the blood (in $1\frac{1}{2}$ to 2 hours after the reception of the sugar); but access by the lacteals is not closed to it; at least, after its ingestion in large quantities, a small proportion is always found in the chyle. According to what *laws*, then, does the *absorption of sugar* in the intestine ensue? To answer this question, it must be remembered that the diffusive tendency of sugar is about one-half less than that of chloride of sodium, so that when 58.7 parts of chloride of sodium are diffused, under similar conditions, only 26.6 parts of sugar undergo diffusion. In the endosmometer, in the place of one part by weight of sugar, seven parts by weight of water enter; according to comparative investigations with chloride of sodium and hydrated sulphuric acid, it results that the endosmotic equivalent of sugar is twice as great as that of chloride of sodium, and twenty times greater than that of hydrated sulphuric acid. If absorption follows the laws of diffusion, according to this, sugar will be absorbed twice as slowly as chloride of sodium, and twenty times more slowly than hydrated sulphuric acid.

Carefully conducted experiments upon animals have led to the following results as to the absorption of sugar: When sugar-solutions are included in ligated knuckles of intestine of living animals, the *quantities of sugar absorbed in given periods* appear to be wholly *independent of the length of the loop*, or the *square content of the absorbing surface;* this rule allows of exceptions only when the ligated intestinal loop containing the concentrated sugar solution is so short that it cannot contain a quantity of water corresponding to the endosmotic equivalent of the sugar.

The absorption of the sugar-solution stands in DIRECT *ratio to its concentration; i. e.*, the more concentrated the solution, the greater the quantity of sugar absorbed in equal time. Hence, in the first periods, when the sugar solution is the most concentrated, the greatest quantities of sugar will be absorbed. It is actually thus found, that of equal quantities of injected sugar-solution of the same concentration, in the first portions of time the most sugar disappears from the loops, and in the latter always less. The intestinal loop containing a concentrated sugar-solution, is seen to swell up by the absorption of water in a manner corresponding closely with the phenomena of endosmose; a quantity of sugar corresponding with this increase of water enters into the blood, until the whole of the sugar has vanished from the loop. It is evident from the law of endosmose why the size of the intestinal loop (when this is not shortened below a certain limit) seems to be without influence upon the absorption of sugar. If the loop is large enough to allow of the entrance of the equivalent quantity of water, the corresponding quantity of sugar only can pass out, whatever may be the size of the loop. As the quantity of the water entering is dependent upon the proportion of sugar in the injected solution, when the solution is of the same concentration, the absorption must remain perfectly equal, even in loops of the most different size. The above-mentioned facts, according to which the sugar is but slowly absorbed from the intestine in which it is generally contained in very dilute solution, its rapid distribution over the whole of the small intestines, &c., find their physical explanation in the detailed results of these experiments. From these laws, it is easy to comprehend why a question of the highest importance for the physiology of quantitative tissue-metamorphosis cannot readily be answered with precision. If we would learn, for instance, how much sugar an animal is capable of absorbing from the intestine in a given time, the result of the experiments relating thereto will always depend upon the concentration of the sugar-solution in the intestine. If an extremely dilute sugar-solution is placed in the intestine, the absorption will occur more slowly than under normal conditions; if a very concentrated one is introduced, a very great amount of water is withdrawn from the blood, the intestine is distended with watery fluid, so that the abdomen is swelled out, and great difficulty of respiration and often death ensue. Cane sugar is in great measure changed into grape sugar before its absorption; after abundant ingestion of cane-sugar, it is found unaltered, as far as the middle of the jejunum. As neither the saliva nor the gastric juice is capable of producing this transformation (in scientific experiments), it is probably occasioned by the pancreatic fluid, or other constituents of the intestinal contents participating in its conversion.

Lactin, like grape-sugar, pervades rapidly the whole of the small intestine; it may be pursued even to the cœcum in one hour after its ingestion, and leaves behind, like grape and cane-sugar, an intensely acid reaction in the jejunum and ileum, which disappears again from the intestine during the third or fourth hour after the sugar has been eaten. *Starch* is not absorbed as such, as it is insoluble; it is impregnated in the mouth with more or less saliva, according to the intensity of the movement of chewing, its dryness, and other conditions; although normal saliva acts so powerfully in the conversion of boiled starch into sugar (compare p. 166), its influence upon raw starch can be but slight, on account of the short duration of the delay of each morsel in the mouth. In the prolonged delay of the articles of food in the paunch of ruminating animals, by means of the continued action of constantly freshly increased quantities of saliva, on the contrary, a great part of the starch contained in the food is metamorphosed; the same probably occurs in the crop of birds. In all other animals the greatest part of the starch reaches the stomach unaltered, where the further action of the saliva upon the amylum is in some degree impaired by the gastric fluid. After a delay of various duration in the stomach, this substance reaches the duodenum, where it is brought into contact with the powerfully operative pancreatic juice, and the commencement of its transformation takes place. Towards the ileum the pancreatic fluid disappears, and its place is occupied by the somewhat less powerful intestinal fluid.—The conversion of starch into sugar takes place gradually; the starch-granules are softened from the surface inwards, and resolved into dextrin and sugar: some of the lamellæ of the granules become torn, and may be recognized often as shreds under the microscope. The further the starch proceeds from the jejunum into the ileum, the smaller the granules appear, in consequence of this solution and removal of their surfaces. The excessively developed cœcum of herbivora, provided (especially in the appendix vermiformis) with peculiar follicles, gives rise to the hypothesis that another ferment may here exercise a transforming power over starch; but this is not yet demonstrated with certainty. *Dextrin*, the proximate product of the transformation of starch, is found only in small quantities in the intestine, and is probably soon changed into sugar. *Inulin* appears to behave precisely as starch does in the process of digestion. *Gum* is not changed at all, or in very small quantities, in the most various processes of fermentation, and as little by the digestive fluids in artificial experiments. It must hence be absorbed unaltered. The diffusive power of gum is, according to direct experiments, half as great as that of sugar. It penetrates animal membranes with much more difficulty than many other substances, and especially sugar. It is hence not to be wondered that all direct experiments instituted upon animals have afforded the result, that the greater part of the gum taken in by the mouth passes off, unaltered, by the rectum, and a very small portion only is absorbed. *Gluten* comports itself in the digestive process exactly in the same manner as gum. *Cellulose* is a substance insoluble in all the ordinary chemical solvents, and in all known digestive fluids; it is hence held to be unfit for digestion; but it must not be overlooked, that certain chemical and anatomical facts render it apparently not impossible that cellulose is transformed into sugar in certain animals, *e. g.*, in the beaver, the caterpillar, &c. Dilute alkalies corrode the cellulose corpuscles, a ferment of putrefying potatoes destroys them. The beaver, whose stomach and intestines seem to be filled with fragments of wood, possesses greatly developed salivary glands, a large gastric gland, and an enormous pancreas; caterpillars have largely developed salivary organs.

The method of reaching the blood which is adopted by the *fats*, may be in great measure traced by the microscope. In the mouth and the stomach they undergo no perceptible alteration; so also in artificial experiments, the saliva and gastric juice are seen to be without influence upon these bodies. Fatty tissue is dissolved in the stomach, leaving large fat-globules, as the connective tissue, and the cell-membranes of the fat-cells are digested. In the duodenum we usually find the fat no longer in large drops or semi-fluid masses; and the further we descend in the alimentary canal, the more finely we find the fat divided. That the fat takes its course through the intestinal villi principally to the lacteals is shown by microscopical examination. In the cylinder epithelium covering the villi, we recognize the absorbed fat, while the sponge-like parenchyma of the villi soon becomes filled partly with clear, highly refractive vesicles, and partly with granular matter (finely divided fat-globules). The lacteals become shining and milkwhite, and the chyle is very much clouded with minutely divided fat. The lacteals are, however, not the only way by which fat reaches the blood; after its abundant ingestion, the fat-granules may be recognized by the microscope in the blood-capillaries of the villi, between the blood-corpuscles; the blood of the portal vein is also then found much richer in fat than usual. There are certainly no specific membranous partitions for fat, and yet it remained doubtful until very recently, according to what physical laws the passage of the fat, which is insoluble in water, through membranes moistened by this fluid is effected. We have already seen (p. 173) that it is not the pancreatic fluid, but the bile which renders it possible for the fat to penetrate through these moist membranes. According to recent investigations, animal membranes become capable, by means of a solution of soap or of bile, of allowing fat to penetrate through them without the application of external pressure. As, then, in animals whose bile is brought to the surface by means of a fistula, very little fat is absorbed, there can scarcely remain any doubt that it is the bile which causes the absorption of fat, although the laws of adhesion concerned are not yet fully ascertained.

The bodies belonging to the *protein groups* and their proximate derivatives, *e. g.*, glutin and chondrin, as also several substances similar to these, such as emulsin, the poison of vipers, curarin, and those poisons which result from infectious diseases, such as hydrophobia, acute glanders, typhus, phthisis, mortification of the spleen, are, even when dissolved in water, but slightly susceptible of endosmose; thus, *e. g.*, the capacity of diffusion of soluble albumen is 8½ times less than that of sugar, and 19 times less than that of chloride of sodium; it is asserted of soluble albumen, as also of several others of the above-mentioned substances, *e. g.*, emulsin and curarin, that they are incapable of endosmose. Even if this incapability is not absolute, the few exact experiments which are at hand, prove that these physical observations accord with physiological perceptions, according to which, these substances must undergo certain transformations before being absorbed. By the gastric fluid, both soluble and insoluble protein-bodies are changed into materials which, although equivalent to the parent substances in elementary composition, are distinguished materially from them, by their great solubility in water, their want of coagulability, and by other physical and chemical properties. We have called these products of transformation of the protein-bodies and of gelatin, *peptones*. Emulsin is, likewise, wholly metamorphosed in the primæ viæ; for when absorbed into the blood, it no longer effects the decomposition of amygdalin; the curarin, as well as the other poisons just mentioned, are altered by the digestive fluids; as otherwise they would prove as poisonous in the intestine, as when introduced directly into the blood. We know only of the protein-bodies and gelatin-yielding substances, that it is especially the gastric fluid which produces the transformations in question; how far it acts upon the other substances named, is as yet wholly unknown. The quantity of the gastric fluid secreted is, however, usually insufficient to dissolve and modify, in the manner mentioned, the protein material necessary for the nutrition of the body; hence, we find a quantity of undigested albuminous substances passing from the stomach into the small intestines, which first undergo further transformation by the fluid of the intestines (see pp. 169 and 176). In the large intestine, according to the observations hitherto made, no action seems to take place upon the protein-bodies which have reached it.—As we always find in the chyle albuminoid coagulable materials, the regeneration of the albumen, from the corresponding peptones, seems to occur in the commencements of the lacteals, or, perhaps, in the mesenteric glands; for in the chyle of the ductus thoracicus, they (the peptones) can no longer be detected with certainty.—As the fats do not enter the blood solely by the lacteals, so also the protein-bodies probably do not choose only this avenue to the blood, but are, in part at least, taken up directly by the capillaries of the villi; for even although soluble albumen is, according to the above physical observations, only slightly capable of transudation, animal membranes, and especially those of the intestinal capillaries, are by no means impermeable to unaltered albumen; for if water be injected into a carefully ligated intestinal loop, after some hours, all appearances of inflammation being avoided, solution of albumen is found in the contents of the loop. We, hence, must not conceive of absolute separating walls, in this respect also, in the villi.

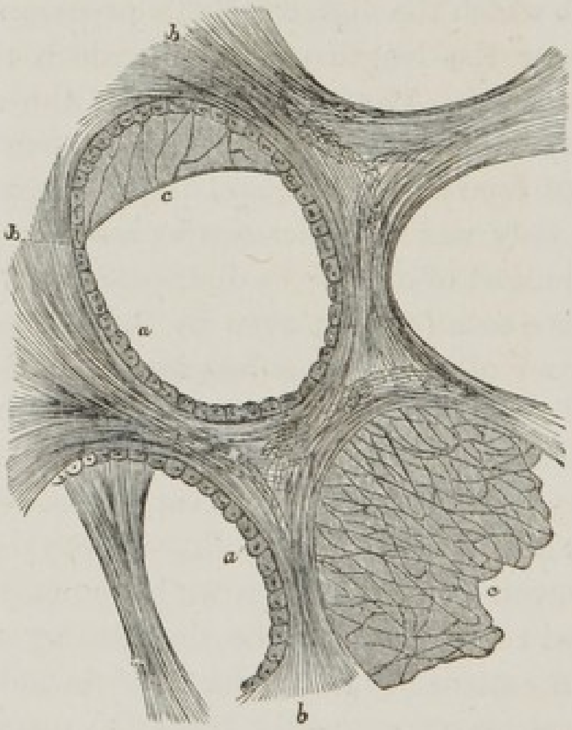
It is of importance, in the further consideration of the quantitative relations of animal tissue metamorphosis, as well as for a view of the extent of the process of digestion, to ascertain in what quantities the individual digestive fluids are usually secreted. The experiments with reference to this have been, of course, instituted upon animals, especially upon dogs and cats. If we may be allowed, from such experiments, to infer the amount of the agents of digestion secreted in man, we obtain astonishingly large quantities. According to this, a man of about 140 pounds would secrete, in twenty-four hours, 24,695 grains of saliva, containing 231.5 grains of solid matter, 24,695 grains of bile, with 1234.7 grains of solid substances, 98,778 grains of gastric fluid, with 2963.3 grains of solid substances, 3,087 grains of pancreatic fluid, with 308.7 grains of solid substances, and 3,087 grains of intestinal fluid, with about 46 grains of solid substances. The amount of fluid which enters into the intestines in twenty-four hours is, hence, far greater than the quantity of blood which, according to recent observations, is contained in the body of an adult. This mass of fluid, which contains altogether only 4,784 grains of solid constituents, is, hence, especially designed to effect the lixiviation (Auslaugung) of the food ingested.—The researches which have been instituted, as to the quantities of articles of food which an organism is able to take up from the intestine, in a given time, are far less numerous, and, on this account, far less reliable. According to them, a man is able, in one hour, to absorb 6,635 grains of sugar, 695 grains of fat, and 1,540 grains of protein substance.

The term *digestibility* is usually understood in a medico-vulgar sense, as by easily digested food is understood such as would cause no remarkable difficulty even to enfeebled digestive organs; this idea is scientifically embraced more closely when by it is understood the facility with which the digestive fluids prepare an article of food for absorption, or the length of time in which the substance in question is absorbed. The experiments for the ascertainment of this circumstance are generally unproductive, partly because composite articles of food were used, and partly because the digestion in the stomach only was had reference to, and the digestibility of a substance was judged of only by its disappearance from the stomach, while, as we have seen (p. 253), even in the normal state tolerably large quantities of albuminous substances leave the stomach undigested. Strictly scientific investigations, conforming to the theory of digestion, as above laid down, we do not yet possess; we must, therefore, content ourselves with observations made upon dogs with artificial gastric fistulas. The digestibility of even the simpler articles of food is, however, so relative that we have not yet been able to establish general rules; for, *e. g.*, the time during which articles of food remain in the stomach, independently of the individual intensity of digestion, depends very greatly upon the quantity of the substance introduced at once into the stomach (large quantities even of easily digestible substances remain much longer in the stomach than smaller), upon the degree of comminution or fine subdivision, upon the aggregate form (cellular tissue is much more quickly dissolved than tendinous membranes, boiled protein-bodies with more difficulty than those not boiled, boiled vegetable substances more easily than not boiled, casein coagulated in masses with more difficulty than that coagulated in flocculi, &c.). We therefore pass over all closer results, as they differ too much from each other to allow of the establishment with certainty of any general propositions.

RESPIRATION.

The process of respiration consists mainly in an exchange of certain gaseous substances, which takes place in peculiar organs, lungs, gills, or tracheæ, between the blood and the atmospheric air; in considering this exchange, the knowledge of the amount of the gases to be exchanged in the blood and in the air must first be ascertained. The composition of the atmosphere is well known; but we are not so thoroughly acquainted with the amount of gases in the blood at all times (compare p. 134). We are thus the more

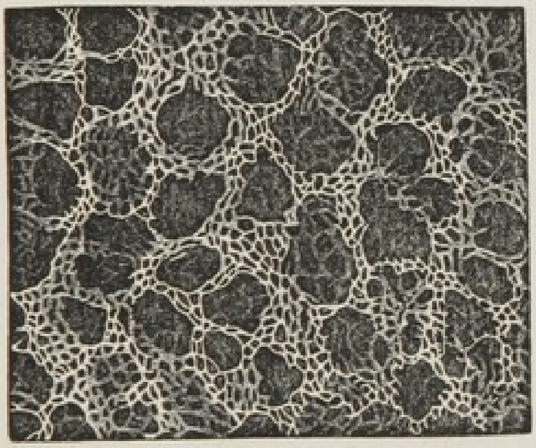
Fig. 32.



SECTION OF HUMAN LUNG, SHOWING THE AIR-CELLS.—*a.* Epithelial lining. *b.* Fibrous intervening structure. *c.* Thin membranous wall of the air-cells.

stimulated to investigate the changes which the atmospheric air undergoes by means of respiration; these changes stand, again, in definite relations to the mechanical conditions of respiration. There occurs, to wit, upon the surfaces in which the blood comes into closest contact with the atmosphere a continuous change of air, occasioned by certain physical agents of motion. Part of this movement is effected by means of muscular action and elastic tissue, by an expansion and contraction of the spaces existing in the lungs or tracheæ; another and a greater part takes place by simple diffusion. Modifications of these external conditions are followed by modifications in the consequences of the respiratory process. One of the first objects of investigation in this process must be to ascertain their influence; the composition of the blood, *i. e.*, its content of gases, will also materially affect the quantitative relations of this exchange of gases. As, however, we cannot ascertain the proportion of gases in the blood at every moment, we must go back for a full comprehension of the respiratory process to its remoter conditions, to the so-called physiological states of the organism, which

Fig. 33.



Distribution of capillaries on the membranous parietes of the air-cells.

operate to produce modifications of the mechanical conditions in consequence simultaneously of the nervous influence and the muscular action occasioned by it. Before, however, we enter upon the causal connection of the modifications of the exchange of gases with the individual conditions, we must point out briefly the methods by which it has been sought to obtain the material for investigation. The simplest method is to conduct the air exhaled from the mouth immediately into a cavity filled with a liquid, so that the latter gives place readily to the entering gas; a second method consists in bringing the man or the animal into a closed place, to which fresh air is constantly introduced, while that which escapes is collected for analysis. For certain researches, animals were caused to breathe a certain time in a perfectly-closed space, the air of which was then examined; finally, an apparatus has been applied, in which the carbonic acid exhaled by breathing animals is constantly absorbed, while a quantity of oxygen, corresponding to that which has disappeared, is introduced into it. The most general results to which the experiments instituted according to the differently modified methods have led are the following: The blood gives up to the inhaled air *carbonic acid* and *watery vapor*, and takes *oxygen* from it; a very small portion of nitrogen also usually passes from the blood into the air respired; but under peculiar circumstances the reverse takes place. The relation between the *oxygen inspired* and the *carbonic acid exhaled* is not always constant; very considerable variations occur within certain bounds. Under normal conditions, far more oxygen is absorbed than is contained in the carbonic acid expired; on the average, for one volume of oxygen absorbed 0.85 of a volume of carbonic acid is exhaled. The volume of the air expired is always greater than that inspired, partly because the expired air is heated to 97° or 99°, and partly because it is usually saturated with watery vapor. The relative weight of the nitrogen and carbonic acid exhaled is usually = 1 : 100. In the air exhaled, there have usually been found small quantities of hydrogen and carbohydrogen; many volatile substances, also, as phosphorus, camphor, alcohol, and ethereal oils, after their reception by the mouth, pass into the air of expiration. The air exhaled by a healthy man at rest contains, on the average, about 4.334 per cent. by volume of carbonic acid. In twenty-four hours, there are exhaled by an adult powerful man 13,381 grains, or (at a temperature of 32°, barom. at 29.48 inches) 443,409 cubic centimetres (a centimetre is equal to 0.39371 of an English inch) of carbonic acid, 123 grains of nitrogen, and 5,016 grains of water in the form of vapor; in the same time, 11,514 grains, or 520,601 cubic centimetres of oxygen, are taken up. If we deduct from the latter the amount of oxygen contained in the carbonic acid and watery vapor exhaled, there remain 1,790 grains of oxygen in the blood.

The *proportion of carbonic acid in the exhaled air depends very much upon the frequency of the respiratory movements.* When the respirations are doubled (without diminution of the normal depth), the relative quantity of carbonic acid exhaled is about 0.907 per cent. less than in normal, quiet respiration; when the respirations are trebled, 1.125 per cent.; when quadrupled, 1.292 per cent.; when multiplied eight times, finally, 1.600 per cent. From these and similar observations, it results that the numbers of the expirations are functions of the corresponding numbers expressing the percentage of carbonic acid; according to this, each expiration, of whatever length it be, attains an expirative value of 2.5 per cent., to which a second quantity of carbonic acid, exactly proportionate to the duration of the respiration, is added, as may readily be perceived from the following table:—

Respirations.	Per cent. of carbonic acid.	Constant.	Increment of the per cent. of carbonic acid according to the length of the respiration.
6	5.7	2.5	3.2
12	4.1	2.5	1.6
24	3.3	2.5	0.8
48	2.9	2.5	0.4
96	2.7	2.5	0.2

From this may be deduced one of the following formulæ, which may be of service in calculating the relative quantities of carbonic acid occurring in respirations of different frequency. If the quantity of carbonic acid existing in 100 volumes of exhaled air, formed by an expiration of the duration of $\frac{60}{3} . 2—$ seconds, $= a$, then the value of the carbonic acid for the period of $\frac{60}{3} . 2—^{n}$ seconds $= a = 3.2 + \frac{6.4}{2^{n}}$; or, let a represent the carbonic acid constant in every respiration, T the duration of the shortest respiratory movement, then the value of the carbonic acid *I.* for the period $T . 2^{n}$ of each respiratory movement corresponds to $a + \frac{2^{n}—1}{10}$. As $T . 2^{n}$ represents an expiration of any duration t whatever, $2^{n} = \frac{t}{T}$. This expression gives, when introduced into *I.*, for the value *II.* of carbonic acid for an expiration of any duration t, $a + \frac{t—T}{10\ T}$. That the rhythm of the respirations is the actual regulator of the excretion of carbonic acid results from the following tabular view of the quantities of carbonic acid exhaled in definite periods, calculated according to the above formulæ:—

No. of expirations in one minute.	Carbonic acid in 100 cubic centimetres of exhaled air.	Air exhaled in one minute, in cubic centimetres.	Carbonic acid exhaled in one minute, in cubic centimetres.	Carbonic acid exhaled at one expiration.
6	5.7	3,000	171	28.5
12	4.1	6,000	216	20.5
24	3.3	12,000	396	16.5
48	2.9	24,000	696	14.5
96	2.7	48,000	1296	13.5

A similar influence upon the excretion of carbonic acid is exerted by the *amount* or *depth* of the respiration, as is most evident from the following view: If the air of normal respirations contains 4.60 per cent. of carbonic acid, that of

Twice as deep will contain	. . 4.00	per cent.
Thrice " " "	. . 3.70	"
Four times " "	. . 3.38	"
Eight " " "	. . 2.78	"
Half as deep " "	. . 5.38	"

The proportion of carbonic acid of the air increases in the *finer bronchia*, and is most considerable about and within the *air-vesicles:* it is hence evident on the one hand, that the latter half of the expiration is always somewhat richer than the first half (*e. g.*, in this 3.72 per cent., in the other 5.44 per cent.), and on the other hand, that the air of a very strong expiration is more abundant in carbonic acid than that of a normal one (the former contains, *e. g.*, 5.18 per cent.; the latter, about 4.63 per cent.). Hence it is calculated that 5.83 per cent. are contained in the air of the air-vesicles, that is, 1.2 per cent. more than in a normal expiration. After holding the breath for a long time, there is found in the exhaled gaseous mixture a considerable decrease of the absolute, and an important increase of the relative, quantity of carbonic acid.—The earlier experiments, which were instituted as to the inhalation of pure oxygen or of highly oxygenated atmospheres, led to singular but not to corresponding results; more recent experiments made upon animals, show in this respect no difference from breathing in pure atmospheric air.

Pure carbonic acid cannot be inhaled on account of spasmodic closure of the glottis; even an atmosphere containing only 40 per cent. of this gas is not respirable. From an atmosphere which is rich in carbonic acid, but still respirable, less oxygen is absorbed; at the same time less carbonic acid and somewhat more nitrogen are exhaled than when normal air is breathed. In nitrogenised air, according to some experiments, nitrogen appears to be absorbed; more oxygen also is absorbed, and less carbonic acid exhaled. Breathing in nitrous oxide gas causes violent excitement, accelerated circulation and respiration, and finally asphyxia; on the whole, more carbonic acid is produced in this gas than in atmospheric air. In an artificial atmosphere which contains *hydrogen* instead of nitrogen, with as much oxygen as ordinary air, respiration takes place perfectly normally, except that a little more oxygen appears to be absorbed.

Certain *influences of the external world* exert a decided effect upon the respiratory process; this is generally not a direct one, but results indirectly from the great alterations of the frequency or depth of the respirations, occasioned by a series of causes. As the organism enters into the most intimate relations with the atmosphere through the lungs, atmospheric influences must produce visible effects. By means of numerous experiments variously modified, the fact has been placed beyond doubt that at a higher temperature less, and in a lower more, carbonic acid is exhaled, and that the quantity of carbonic acid exhaled (within the degrees of temperature at which the organism maintains its welfare) stands nearly in inverse proportion to the temperature of the inhaled air. This phenomenon becomes explicable by the decrease in the number and depth of the respirations with the increase of temperature. It is remarkable that, at a higher temperature, less watery vapor also is exhaled. An exception to this rule is found only in animals which fall into a torpid state at a lower temperature, *e. g.*, in frogs; these exhale in this state far less carbonic acid than at temperatures just above those at which they become active. The *degree of humidity* of the air appears especially to influence the depth of the respirations, and indeed their frequency also; on this account we find that in a damp atmosphere more carbonic acid is exhaled than in a less damp or a dry one. The *atmospheric pressure* is of less influence on the whole; as it ascends it increases the pulse and the respirations, so that more air passes in a given time through the lungs than at a lower pressure, but as the relative proportion of carbonic acid in the air expired is diminished, the absolute quantity of carbonic acid exhaled is nearly the same as at a lower atmospheric pressure. But sudden variations modify the respiratory function materially, as then with more frequent respirations far more carbonic acid is exhaled, whether a higher pressure becomes lower, or a lower higher. Even in excessive increase or diminution of the atmospheric pressure, when they take place gradually, the quantity of carbonic acid exhaled in a given time remains constant.—The influence of the period of the day upon respiration was formerly held to be very important; but the variations actually observed in the respiratory function are reduced mostly to the time of reception of food, to sleep, bodily exercise, &c. In regard to the influence of the seasons of the year it is only established that during the winter, on the average, one-fifth more carbonic acid is excreted than in the summer.

The *internal states* of the organism are of the most important influence upon respiration, as they affect one of the most important factors of the process, the proportion of gases, and especially of carbonic acid, in the blood; they are, besides, not without influence upon the circulatory and respiratory movements. Among these internal states the influence of food stands first.

In *entire abstinence from food*, in so-called inanition-experiments, the absorption of oxygen diminishes nearly constantly until death, being a little more sudden at the beginning and at the end. In the commencement of inanition, about eighty per cent. of the oxygen absorbed is applied to the formation of carbonic acid; towards the end, only about seventy-three per cent. The quantity of carbonic acid excreted decreases in the first third of the period of inanition tolerably evenly and rapidly; in the second third slowly; in the last, again, more rapidly.—In experiments in which drink was not withheld from the animals, together with solid food, for 100 parts of carbonic acid seventy-five parts of watery vapor were exhaled; in fasting animals, especially in birds, an absorption of nitrogen is also observed.—Even the passing over of a single meal alters materially the conditions of the exchange of the gases, as the absorption of oxygen and excretion of carbonic acid are thereby considerably lessened; on the other hand, during *digestion*, and indeed for one or two hours after the ingestion of food, an important increase in the oxygen absorbed, as also in the carbonic acid excreted, may be observed. The chemical *nature of the food* is of material influence upon the products of respiration. After the use of amylacea, far more oxygen is applied to the formation of carbonic acid than after feeding upon flesh; while after the latter, of 100 parts of oxygen taken up only 74 parts are found again in the carbonic acid; after vegetable diet, of 100 parts of oxygen absorbed more than 91 parts are usually applied to the formation of carbonic acid. Nitrogen is exhaled after vegetable food, but in far less quantities than after animal; it is then a question whether this *difference which we find in the relations of the oxygen absorbed to that contained in the carbonic acid exhaled after different kinds of food* can be referred to definite chemical relations. If we reflect, in the first place, that the non-nitrogenised substances are perfectly burned in the organism to carbonic acid and water, it is evident from their composition that they will need very different quantities of oxygen for this perfect combustion, according to the quantities which they already contain. The carbohydrates, *e. g.*, will only take up as much oxygen as is necessary for the oxidation of their content of carbon; the fats, on the other hand, will need also oxygen for the oxidation of a great part of their hydrogen. On the contrary, so much oxygen is contained in the organic acids as to be sufficient for the oxidation of part of their carbon; and they hence will take but little free oxygen for their combustion. In the nitrogenised articles of food, we must assume that part of their carbon, hydrogen, and oxygen, with the accompanying quantity of nitrogen, is separated under the form of urea; and we can hence only regard these substances as contributing to respiration after the subtraction of the elements of urea. If we assume oxygen as unity, and calculate how much of each individual article of food is necessary in order to form carbonic acid and water, with the unit of oxygen, we obtain in a measure *respiratory equivalents*, which stand in inverse ratio to the value which each individual substance may have for the oxidizing process in the animal body, or the development of animal heat. We find principally in this consideration the answer to the above-named question; for if we conceive that the exchange of gases in the lungs for a time is only the result of the combustion of an individual article of food, of 100 parts of oxygen applied to the perfect oxidation of a body, very different quantities go to the oxidation of the carbon. Hence, very different quantities of oxygen will be found in the carbonic acid formed, *i. e.*, here excreted. The following table will give the best conclusions as to the relations here spoken of:—

Substances.		Carbon.	Hydrogen.	Oxygen.	Still necessary, together with the previous oxygen, for the formation of CO_2 and HO.	Respiratory equivalent: 100 parts of oxygen oxidized.	Of 100 parts of oxygen absorbed, there are contained in the CO_2.
100 parts fat	contain	78.13	11.74	10.13	292.14	34.23	71.32
" starch	"	44.45	6.17	49.38	118.52	84.37	100.00
" sugar	"	40.00	6.66	53.34	106.67	93.75	100.00
" malic acid	"	41.38	3.45	55.17	82.78	120.80	110.53
" albumen	"	47.48	4.98	13.14	153.31	65.23	82.60
" collagen	"	42.52	4.47	13.59	135.56	73.77	83.64
" flesh	"	46.10	4.72	13.66	147.04	68.01	83.60

It need scarcely be remarked that even on an exclusive diet of starch, or sugar, or fat, the relation between the oxygen absorbed and that exhaled in the carbonic acid will never present itself as in the figures of the last column; for it must be borne in mind, that besides the oxidation of the non-nitrogenised articles of food, a portion of the nitrogenised tissue-elements becomes useless at the same time, and likewise undergoes oxidation, and thus this proportion is naturally altered. These figures, however, are very useful in the *determination of the quantitative relations of the metamorphosis of animal tissue.* We here adduce only two instances, by way of example, which find their solution in a simple equation based upon these figures. We might first ask the question, what relation will the oxygen absorbed bear to that contained in the carbonic acid exhaled when an animal receives for a certain time a given quantity of starch as food? If the typical amount of the daily loss of nitrogenised tissue, which must naturally occur $= c$, the numerical proportion of the relative amount of oxygen for the consumption of these parts (as results from the experiments on inanition, as also experiments with animal diet) $= 83.6$; the quantity of starch absorbed and oxidized $= a$, the numerical proportion of the carbonic acid excretion is obtained from the equation, $\frac{c \,.\, 83.6 + a \,.\, 100}{c + a} = x$. Or if we wish to ascertain how much fat in experiments on inanition undergoes oxidation, together with nitrogenised material, we may calculate the typical waste of the albuminates from the quantity of urea formed. Let this $= c$; the numerical proportion for the use of pure fat $=$ 71.32; the proportion of oxygen absorbed and exhaled in carbonic acid in the state of inanition, *e. g.* $= 75$; we thus obtain the simplified formula, $\frac{(83.60-75.00) \,.\, c}{75.00-71.32} = x$, *i. e.*, the quantity of fat which has, together with albuminates, c, undergone combustion.

After what has been said, it need hardly be remarked that the *quantity of food partaken of* has considerable influence upon the amount of the exchange of gases taking place in the lungs; there is, however, of course a certain limit beyond which the absorption of oxygen and excretion of carbonic acid does not pass; but we also see that the absorption of the different articles of food cannot exceed a certain measure. Under "Nutrition" we shall recur to the so-called superfluous consumption (Luxusconsumtion). After the moderate use of *spirituous liquors*, the carbonic acid excretion is absolutely and relatively diminished; the same takes place after the ingestion of thein, ethereal oils, &c.—*Sleep* occasions a very considerable diminution of the excretion of carbonic acid; in man it was found that the proportion of carbonic acid excreted during waking to that during sleep = 40.74 : 31.39.

The relations of respiration during the *hibernation* of animals are very remarkable; the marmot has been observed very carefully in this respect. While 1,000 grains in these animals when awake absorb 1.2 grains of oxygen, during the winter-sleep they take up only 0.045 of a grain; while also of the oxygen absorbed by waking animals, 73 per cent. appears again in the carbonic acid excreted, in the hibernating state only 56.7 per cent. passes into carbonic acid.

Immediately upon *waking* from the night's sleep, a very considerable excretion of carbonic acid is observed in man. By means of *bodily exercise*, the absorption of oxygen and excretion of carbonic acid are relatively and absolutely augmented. With regard to the influence of the *period of life* upon respiration, experiments have shown that the quantity of carbonic acid daily excreted increases on an average up to the 40th or the 46th year of age, principally, however, with the development of the muscular system. If, however, the carbonic acid excreted by children or young animals is calculated for an equal bodily weight, it results that children produce nearly twice as much carbonic acid as adults. Men excrete more carbonic acid than women; sex shows the same influence in animals. The following table, calculated from direct experiments, may afford a general view of the relations just alluded to, the results of which agree closely with most other experiments made in this direction:—

Subject.	Age.	Weight.	Carbonic acid excreted in one hour.	Carbonic acid excreted in one hour for 1000 grains weight.
		Pounds.	Grains.	Of a grain.
Man	35	145.	517.50	0.5119
Youth	16	127.	529.08	0 5887
Soldier . . .	28	181.	565.24	0.4466
Maiden . . .	17	123.	391.13	0.4546
Boy	9¾	48.5	313.89	0.9245
Girl	10	51.	295.75	0.8831

With reference to the relative respiration of different classes of animals, the following may be considered as established: In *mammalia*, the ratio between the oxygen absorbed and the carbonic acid excreted, depends materially upon the food; we find here the proportions above established, confirmed. On the average, the carnivora also appear to absorb rather more oxygen, and to produce more carbonic acid than the herbivora; more nitrogen is also exhaled by the former than by the latter.—In *birds*, the amount of respiratory products depends principally upon their degree of activity; as smaller birds are generally more active than larger, the former exhale, for equal bodily weights, a far greater amount of carbonic acid, and absorb more oxygen correspondingly. The *eggs of birds*, also, exhale carbonic acid during incubation, and absorb more oxygen than is contained in the carbonic acid exhaled; the further the development of the fœtus advances, the more considerable are the absolute quantities of gases exchanged.—It is also seen in the *amphibia* that the more agile animals perform a more active exchange of gases in the lungs than the more sluggish. Upon the whole, however, this is much less than in mammalia and birds.—*Insects*, which breathe through tracheæ, exhibit, in the quantitative relations of the exchange of gases, no marked difference from those of animals breathing by lungs. The same holds good of animals breathing by gills, the *fishes;* in these, also, the amount of the excretion of carbonic acid depends greatly upon the activity of the animals. Those animals, also, which breathe only by means of the skin, *e. g.*, the earth-worms, have presented no material differences in the relations of respiration. In order to facilitate a general view of the relations indicated, we introduce the following table:—

Species of animal.	Food.	Of 100 parts of O absorbed, there pass into the CO_2 excreted—	OF 1000 GRAINS WEIGHT OF ANIMAL IN 1 HOUR.		
			Oxygen consumed.	Carbonic acid exhaled.	Nitrogen exhaled.
		Per cent.	Grains.	Grains.	Of a grain.
Dog	Flesh	74.5	1.183	1.211	0.0078
Rabbit	Carrots	91.9	0.883	1.116	0.0036
Fowl	Oats	80.7	1.053	1.320	0.0079
Small birds	Oats	75.3	11.473	11.879	0.1296
Frog	...	76.0	0.084	0.088	0.0005
Salamander	...	82.4	0.085	0.096	
Lizard	...	75.2	0.192	0.198	0.0025
Cockchafer	...	80.8	1.0195	1.1372	
Caterpillar of the silk-worm	...	78.2	0.899	0.960	
Tench	...	72.3	0.0143	0.0138	
Gold-fish	...	72.3	0.0409	0.0419	
Earth-worm	...	77.5	0.1013	0.0982	

In all these experiments, the products of perspiration are reckoned with those of respiration by the lungs, as they were determined by the one or the other method in which both were collected together. According to recent investigations, however, the perspiratory products are extremely small, as compared with the respiratory. Thus, *e. g.*, the ratio of the carbonic acid exhaled by the skin, to that exhaled by the lungs, in mammalia and birds, is found to be as from 4 to 17 : 1,000. In some animals, *e. g.*, in the amphibia, the ratio is found to be very different; for frogs, whose lungs have been extirpated, not only live a long while, but also yield almost the same quantities of perspiratory products as those with uninjured lungs.

But little has been ascertained as to the *relations of the interchange of gases in diseases*. The experiments as to this circumstance hitherto instituted have led to no further results than that in every pathological affection, whether it be called acute or chronic, the excretion of carbonic acid is diminished, or at most approaches the normal amount, but never exceeds it. An excessive oxidation or a too large excretion of carbonic acid has not been observed as yet in any disease.

The *theories* as to the process of respiration have changed much since the discovery of oxygen. Besides the facts above laid down, we must take into consideration the following physical conditions, in order to obtain a general view of the respiratory process.

The purely *mechanical conditions* of respiration are known from general physiology; we know that the cavities formed by the air-passages from the trachea to the air-vesicles are lessened and expanded in breathing, and that by this act only a small portion of the air contained in these cavities is expelled, and replaced by fresh air. The fresh air forced into this cavity is not agitated with that which has remained behind; but it can enter into an exchange of constituents with that contained in the remoter parts of the air-passages, in the system of tubes constantly becoming finer and more numerous, only according to the law of *diffusion of gases;* hence we found by direct experiment that the lower parts of the air-passages contained more, and the air-vesicles most, carbonic acid. The numbers found correspond exactly with the law of diffusion.—It is more difficult to explain the interchange of gases which occurs between the air of the air-vesicles and that contained in the blood, through the animal membranes. We have already seen that we cannot subject the air of the blood to such exact and repeated investigations as the air of expiration; thus the knowledge of the actual composition of the air contained in the blood is wanting—the second most important factor for the establishment of a firm basis of a theory of the respiratory process. It is, therefore, necessary that we should first go back to the *sources of the gases in the blood*, and especially of the carbonic acid, before we can obtain an intuitive idea of the process which takes place in the lungs. The *carbonic acid* is formed in great measure during the activity of the organs and by the chemical processes which occur in them; this results not only from the fact that we find demonstrable quantities of carbonic acid in all the tissue-fluids, in all the organs, and that on the other hand during greater activity of the organs, larger quantities of carbonic acid are formed and excreted, but also, principally, from direct experiments with the isolated organs in which the most considerable activity is usually developed, namely, the muscles. It is established by the most unequivocal experiments, that well-prepared muscles (of frogs) absorb oxygen, and exhale carbonic acid as long as their irritability or contractility lasts; that the latter is lost in irrespirable gases, and that, finally, a perfectly bloodless muscle maintains this interchange of gases as long as it is capable of contracting. The exchange of gases and formation of carbonic acid takes place immediately from the organ, from which otherwise, the carbonic acid reaches the atmosphere by many roundabout ways (and indeed necessarily through the blood and lungs). That the carbonic acid is formed in the parenchyma of the organs is, moreover, taught by comparative physiology; for we see, *e. g.*, that in insects the atmospheric air is conducted by the tracheæ even into the innermost parts of the organs, and that there this interchange of gases between oxygen and carbonic acid is performed immediately. In the higher animals we must then, before considering the exchange of gases in the lungs, distinguish a second *exchange of gases, between the oxygen contained in the blood of the capillaries and the carbonic acid of the parenchymatous fluids.* No doubt can be entertained that the capillaries give out oxygen and take up carbonic acid; this is taught by the difference between arterial and venous blood, with respect to their content of gases (compare p. 134). From these facts it is by no means to be concluded that all the carbonic acid is formed in the parenchymata of the organs, and all the oxygen taken up in the lungs is conveyed to the organs in mechanical combination. More than one fact indicates that *a part of the oxygen absorbed enters into chemical combinations in arterial blood.* We need only refer to the fact that the oxygen is taken up in far larger quantities by the blood than it is able to take up in accordance with mechanical laws; that, further, the absorption of oxygen on the part of the blood is not dependent upon the external pressure, which it necessarily would be if it were simply mechanical (see p. 134); it also should not be forgotten, that the blood undergoes, in its passage through the lung-capillaries, *i. e.*, in its surrender of carbonic acid, and reception of oxygen, such chemical alterations as can be deduced only from the chemical action of the oxygen (compare p. 146); and, finally, the phenomenon should be remembered that the content of the blood-corpuscles, the substance which yields hæmato-crystallin, is more accessible to the chemical action of oxygen than several other protein-bodies (compare p. 132). Hence if the oxygen in arterial blood be ever so loosely combined, it is nevertheless as much chemically combined at the second atom of carbonic acid in bicarbonate of potassa. It does not follow, however, from the at least partial chemical combination of the oxygen in arterial blood, that in it also carbonic acid and water are formed.

The blood-corpuscles, the principal carriers of oxygen, undergo in the capillaries of the greater circulation such material modifications, that we should transfer here the formation of carbonic acid, if the above-mentioned facts did not demonstrate that at least a very great part of the carbonic acid has its origin in the functions of the organs, and the chemical processes there occurring; in the mean while, a part, although a very small one, of the *carbonic acid* is certainly *formed in the arterial blood.* We find in the latter always so much carbonic acid that it is not easily credible that it depends upon the venous blood, and has not been excreted in the lungs (as is well known, absolutely more carbonic acid has been found than in venous—compare p. 134); but especially is a partial formation of carbonic acid in the blood proved by the fact that organic salts of the alkalies and sugar disappear so quickly in the blood, being changed into carbonic acid and water, that it cannot be conceived that these substances penetrate first into the parenchymata of the organs, in order there to undergo combustion.

After we have convinced ourselves that this exchange of oxygen and carbonic acid, which we improperly call respiration, is not confined to any single spot of the organism, that on the one hand an exchange of air is effected in the air-passages in a twofold manner, by mechanical transport and by diffusion, and that on the other an active exchange of gases takes place in the parenchymata of all the organs, and in the blood-capillaries, there still remains to be answered the question, *according to what laws the exchange between the elastic gases of the air adduced and the condensed gases of the blood of the lung-capillaries is executed upon the moist mucous membrane of the air-vesicles?* There are two physical laws which, in our present state of knowledge, may assist in answering this question; viz: one, according to which *the quantity or volume of an absorbed gas is dependent mainly upon the pressure under which the gas over the fluid stands after the absorption is completed*, and the other, according to which *in mixed gases the pressure of each individual gas*, which, as is known, is entirely independent of that of the gases mingled with it, *in great measure determines the proportion in which it is absorbed by a fluid.* Hence, if more carbonic acid is contained in the blood than the pressure under which the carbonic acid atmosphere in the air-vesicles stands is able to hold condensed in the blood, a corresponding quantity of carbonic acid will escape from the blood, but only so much that the quantity in the blood is reduced to the figure which blood free from carbonic acid would absorb under a tension corresponding to the carbonic acid pressure of the air-vesicles. The quantity of carbonic acid passing into the lungs would, according to this, depend as well upon the quantity of it condensed in the blood as upon the tension of the gaseous carbonic acid already contained in the air of the air-vesicles. To the *oxygen*, according to these laws, under the conditions given in the animal body, precisely the opposite direction of movement is occasioned. The blood found in the lungs is not saturated with oxygen; it is in a condition under the pressure which it sustains in the lungs, to take up a larger quantity of oxygen. The tension of the oxygen contained in the air-vesicles is so considerable that thereby a part of oxygen is driven into the blood, *i. e.*, is condensed by it. *Both gases are then perfectly independent of each other;* their exchange takes place not by an opposite displacement, but is for each one occasioned by *the content in the blood of a condensed gas, and by the tension of the corresponding elastic fluid gas contained in the air of the air-vesicles.* But although the law of absorption must remain, in the manner described, the basis of every theory of respiration, it must not be forgotten that the oxygen is not only mechanically absorbed by the blood, but is also chemically combined, a circumstance, however, of little importance in the first entrance of the oxygen into the blood. More regard is probably to be had to the circumstance that the gases must penetrate through moist membranes, as a further factor of this gas-movement; but it is yet entirely unknown what influence their permeability exercises upon the exchange of gases. Of the *effects of respiration* upon tissue-metamorphosis in general in the animal organism, we shall treat in the following chapter. The theory of animal temperature is usually associated with that of respiration, as this is held to be a principal effect of respiration; the animal temperature, however, is not the immediate consequence of respiration, and is not developed properly in the lungs, but is, at least in greater part, the result of the oxidizing processes which take place in the various parts of the organism. Direct investigations for the purpose of comparing the amount of animal temperature with the amount of food taken, or rather with their calorific value, have indeed shown that at least one-twentieth of the amount of heat developed by one organism cannot be referred to the oxidation or combustion of the food taken in (*i. e.*, that the oxidation of the food can only develop nineteen-twentieths of the animal temperature); but it is by no means hence to be concluded that a peculiar organic force develops this twentieth of animal temperature, for it must be borne in mind, on the one hand, that the fundamental experiments which we now possess, according to which we usually calculate the amounts of heat from certain quantities of oxidized substances, are by no means so complete that they may serve as indisputable bases for calculation, and on the other it would be very singular if, when so many other chemical processes take their course in the animal organism, these

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were not to contribute to the development of the animal temperature. It is, therefore, by no means necessary, in order to explain the origin of this twentieth of the animal temperature, to take refuge in the still enigmatical nervous agency. When we above (compare pp. 246 and 250) took account of the fats and carbohydrates, as not merely means for the production of heat, but also ascribed to them other functions in the animal body, we proceeded on the view of regarding *animal heat not as the proper end*, the ultimate object of the movements of non-nitrogenised substances; animal heat stands no higher than any other phenomenon, any other consequence which is recognized by us in the animal organism. It presents itself at once as effect and cause, as in combustion, from processes which it again in turn promotes; it is nothing more than the unavoidable consequence of the chemical processes in the animal organism.

NUTRITION.

Under nutrition, which forms properly the sum of all the animal processes before considered, come into question, in the first place, the relations of those substances which, introduced from without, serve for the maintenance of the animal functions. As the albuminous substances, the fats, the carbohydrates, and certain salts constitute the agents of the metamorphosis of animal tissue, they must principally be contained in the material necessary for the maintenance of the life-functions, *i. e.*, in the articles of food. Even if a portion of the sugar, a portion of the fat is formed in the animal economy, the quantity thus formed is by no means sufficient to subserve the purposes of life. Experience has also taught that those articles of food are the best, and most powerful, in which are found representatives from all four classes of these important articles of diet; milk affords us the most striking instance. Numerous experiments have moreover shown that no living being can be nourished for a long time upon a diet into which one of these four groups of food does not enter. As these four categories of substances are continually being used, transformed, and rendered effete, in the animal organism during life, they must be absorbed again in corresponding proportions by the animal body, in order to replace that which is lost (whether fluid or tissue, ponderable or imponderable), and for the regular continuance of the life-phenomena. *The renewal must hence be regulated by the waste.* The idea of the *nutri-*

tiveness of an article of diet must always be a relative one, as this is dependent partly upon the proportions in which the four bases are mingled in it, and partly upon the individual necessities of the organism to be nourished. For a scientific determination of the nutritive power of a composite article of food, two points are therefore to be considered, viz: its content on one side of these four elements of nutrition, and on the other, the circumstances under which the organism exhibits a greater or less need of all, or one of these nutritive elements for the maintenance of its integrity as well as for the production of certain effects of forces. The answers to both of these questions result actually from quantitative investigations: hence statistico-chemical researches form principally the foundations for this portion of the physiology of nutrition. It is scarcely necessary to mention, after what has been said under "Digestion," that the digestibility of an article of food is one of the factors of its nutritive power, for it may contain all the nutritive elements in due proportion, and yet, perhaps, be placed in regard to its value for nutrition, after other articles of food, on account of its nutritive elements being less accessible to the digestive fluids.

In order to obtain approximative determinations of the nutritive value of different articles of food, attention has generally been turned to the amount of nitrogenised matter in the article, and a measure of its nutritive power was thought to have been found thus in the proportion of nitrogen; but independently of the fact that the nitrogenised substances are by no means sufficient for nutrition, the proportion of nitrogen can so much the less determine the nutritive power, as on the one hand, *e. g.*, gelatin-yielding substances have certainly far less nutritive value than the protein-bodies, and on the other, in these a great deal depends upon their digestibility. We must, therefore, take into consideration, together with these nitrogenised nutritive elements which serve for the regeneration of the tissues, and are hence called plastic, the non-nitrogenised digestible substances which finally serve especially for the maintenance of animal heat. Although we have so evidently arrived at the conviction from what we have already learned of animal tissue-metamorphosis in general, and from what is shown by direct experiments upon animals, that the salts must be present in the articles of food, and that they materially affect their nutritive value; yet the more exact experiments hitherto instituted for the establishment of the nutritive value of different articles of food have extended only to the relative proportions between plastic nutritive elements, and non-nitrogenised substances, viz: fats, and digestible carbohydrates; in the projection of corresponding series, on account of the deficiency of accurate determinations, the proportion of fat must be thrown out or reduced to carbohydrate according to its power of developing heat, as in the following table, where 10 parts of fat are counted as equivalent in this respect to 24 parts of starch. The relative weights of the plastic and non-nitrogenised nutritive elements are, according to this, in the following articles of food, as follows:—

	Plastic.		Non-nitrogenised.	
In cows' milk	= 10	:	30	= { 8.8 fat. 10.4 lactin.
" human milk	= 10	:	40	
" lentils	= 10	:	21	
" horse-beans	= 10	:	22	
" peas	= 10	:	23	
" flesh of sheep (fattened)	= 10	:	27	= 11.25 fat.
" do swine (do)	= 10	:	30	= 12.5 "
" do ox	= 10	:	17	= 7.08 "
" do hare	= 10	:	2	= 0.83 "
" do calf	= 10	:	1	= 0.41 "
" wheat flour	= 10	:	46	
" oatmeal	= 10	:	50	
" rye flour	= 10	:	57	
" barley	= 10	:	57	
" white potatoes	= 10	:	86	
" blue do	= 10	:	115	
" rice	= 10	:	123	
" buckwheat meal	= 10	:	130	

A more modern physiology of nutrition cannot be satisfied with these data; although we may thus obtain an approximate view of the value of an article of food as a plastic substance, and as a material for respiration, yet we know that the fats and carbohydrates have, besides, specific functions to perform; in fact, direct experiments show that the carbohydrates cannot be substituted entirely for the fats in an article of food. We, therefore, are at present unable to give *the proportion of these four nutritive elements, which is most favorable for the purposes of life*, in an article of food; numerous and circumstantial experiments are still wanting for this. We can only, therefore, in order to form a tolerable idea of the mixture of these four groups of bodies which agrees best with the prosperity of the human organism as to its growth, recur to the composition of the food afforded by nature herself to the child, woman's milk; according to this, the most favorable proportion between the four nutritive elements would be the following: to 10 parts of plastic substance belong 10 parts of fat, 20 parts of sugar, and 0.6 of a part of salts. We are in possession of some, though not very numerous facts, from which it appears that, in the food of an animal, no one of these four factors of nourishment can be wanting, and yet the animal be maintained alive; thus, *e. g.*, turtledoves, when fed with protein-substances and sugar, perished with the same phenomena as if they had received no solid food. Even when all the factors of nutrition are presented to an animal in its food, but one of them preponderates much over the others, nutrition takes place very imperfectly; thus, *e. g.*, potatoes and beets have been found alone very insufficient to nourish a cow. When, however, we seek to ascertain the *most favorable mixture of the nutritive elements*, we must *not* think that this will remain *one and the same for all conditions;* the proportions of the nutritive elements must, on the contrary, change, according to the state in which the organism to be nourished is; its necessities will as little demand always the same proportions of this mixture, as the necessity for food remains constant in regard to the absolute quantity. We have seen under "Milk," how the milk of the mother alters in certain portions with the growth of the child. The proportions of the constituents of this nutritive fluid which is presented to the new-born infant, are entirely different (although the same to it) from those which we find in the fluid flowing for the animal which has longer breathed the air. How different, further, is the proportion of these constituents in the milk of different animals! Although this depends partly upon the kind of food of the parent animal, yet here also the same proportion holds good for similar conditions of the suckling. There can, therefore, be no doubt that the proportions in which the four categories of nutritive elements are mingled, exercise a most decided influence upon the welfare of the organism, and that the mutual action of the different factors of nourishment is highly important for the metamorphosis of animal tissue. However great variations nature institutes in the proportions, an unconditional preponderance of any one of the factors operates injuriously upon the proper course of the process of nutrition; hence a diminution of any one of them cannot occur without the concurrence of all;

thus, *e. g.*, all the experiments instituted upon fattening, show that the carbohydrates alone will not suffice for the formation of fat in the animal body; in order that fat may be formed, protein bodies as well as salts must participate in the metamorphosis; a development of fat is only possible by the mutual action of these substances; in fact, a small quantity of fat, introduced from without, seems, according to the experiments, to be, if not necessary, at least of great assistance to this process.

We are better informed as to *the absolute quantities of food* required for the maintenance of life and for the energetic performance of all its functions, than as to the most favorable proportion in the mixture of the nutritive elements. We cannot assert, however, in regard to this question, that it has found a complete answer in all respects in the numerous investigations which have been made. In order to determine the quantities of food necessary to the animal organism, its secretions and excretions have been quantitatively ascertained and compared with the quantities of food taken. This was done from the view that *the need for food is regulated by the amount of waste;* but, however simple and just this idea appears at first sight, many difficulties present themselves to its carrying out. *The excretions*, namely, *depend far more upon the quantity of food taken, than the need for food upon the amount of the excretions;* for we have seen in the consideration both of the urinary excretion and of respiration, that far more nutritive elements may be taken up than are necessary for the maintenance of the animal functions, and that then the excreta are formed in a proportion nearly corresponding to the quantity of food received. Hence investigations upon inanition, so-called, were instituted, *i. e.*, animals were deprived of all food, and their excreta, in the state of hunger, quantitatively determined. In this manner, the *minimum quantities of nutritive elements* required by the organism for the continuance of life were ascertained; but experiments of this kind afford no test of the quantities of food which are necessary to maintain an animal in perfect health, and in the full use of its externally active powers. If an animal were furnished only with such quantities of food as would correspond to the quantities of excreta found in the experiments upon inanition, it would have a worse than miserable existence, and could never arrive at a full use of its powers. If, on the other hand, as much food were given to an animal as it would consume, the case just alluded to would occur; far more food would be ingested, digested and absorbed, than would be necessary for the most energetic performance of its functions. A so-called superfluous consumption (Luxus consumtion) would then take place, in consequence of which a very large part of the food absorbed would either be again excreted, or at least not be applied to the formation of cells, fibres, and tissues. In this way we might at furthest ascertain the *maximum quantities of nutritive elements* which can enter into the metamorphosis of animal tissue.

The ascertaining of the maximum quantities has, meanwhile, its value, as well as that of the minimum quantities. In these experiments, however, two circumstances must not be overlooked if they are to lead to practical results; viz: 1st, the animal subjected to them should not be taken during growth; and 2d, that condition should not occur which is usually denominated fattening. In both cases, through the detention of assimilated food in the body, this measure for the determination of the amount of the proper tissue-metamorphosis is lost. It is self-evident that during a greater energy of all the life-functions, during a considerable or continued exercise of the powers, a greater consumption takes place than in the state of rest or passive vegetation; the necessity of food then increases with the increase of the external activity. We might call this case that of *consumption of labor*. From all this, it is evident that the need for food is subject to excessive variations, and that it is, therefore, extremely difficult to fix definite numerical values, which shall indicate the quantities of food that are necessary. Such experiments, conducted in this manner, according to the statistical method, would have led to far more exact and conclusive results as to the nutrition of the animal organism if two other factors, of the greatest consequence for the knowledge of the nutritive process, could have been taken more closely into consideration; namely, firstly, the knowledge of *the quantities of the individual articles of food which can be absorbed in the intestines;* and, secondly, that of the alterations which the blood undergoes in consequence of the ingestion of certain quantities of differently mixed food. Experiments as laborious as careful have been instituted with reference to both of these questions; but they do not possess such a degree of accuracy and agreement as to render them satisfactorily available for the explanation of the process of nutrition. According to experiments conducted upon ducks, it may be calculated that in the intestines of an animal articles of food may be absorbed in *about* the following proportions:—

Protein-substance	100
Gelatin	336
Fat	65
Starch	401
Sugar	429

From other experiments (unfortunately instituted on different mammalia), it may be calculated that for every 1000 grs. weight of animal there may be taken up from the intestinal canal in one hour only the following quantities of nutritive elements:—

Protein-substance	0.710 of a grain.
Fat	0.465 " " "
Sugar	4.500 " " "

Still less have numerical values been obtained with reference to *the influence of food upon the chemical constitution of the blood*, as is shown by the following results of the investigations as to this point: After *animal food*, the "tendency to sink" of the blood-corpuscles increases, the color of the blood becomes somewhat darker, and its coagulation slightly hastened; the amount of fibrin is slightly augmented, as also its content of phosphates and salts generally.—*Fatty food* occasions, in the course of one hour, an increase of fat in the blood; this, however, soon diminishes again. By the prolonged use of fatty food, the average amount of fat in the blood is not increased.—*Vegetable diet* renders the blood somewhat brighter; the proportion of fibrin in it is not altered, while those of the fat and the salts, especially the phosphates, are somewhat lessened.—*After the last meal*, the quantity of the solid constituents of the blood increases up to the ninth hour; it then begins again to diminish.—We are, therefore, not in a condition to follow in this manner the transformations of the elements of food in their individual phases, and hence must recur to the following statistical investigations for the determination of the quantitative metamorphosis of animal tissue.

One of the first questions which it was sought to answer by means of quantitative researches into the recepta and final excreta of an organism was the following: *How are the products of disintegration, into which the nutritive elements fall during their service in the body, divided in the excretions?* A short and comprehensive answer to this question is not possible as yet, as the experiments concerning it have been made upon very different animals, with different quantities of various kinds of food, and under otherwise differing circumstances; hence, we dare not at present fix certain numerical values, *e. g.*, for man, for the reception of solid and fluid articles of food, and the division of the final products of transformation in the excreta. Although the cause of such differences is often easily explicable, yet they prevent almost all comparison. If, for instance, the elements of food are sought in the excretions, it appears that in carnivora far more of the food taken passes into the urine and the transpiration than in herbivora; this difference does not depend so much upon any actual difference in the tissue-metamorphosis of the animals of the two categories, but is to be referred to the fact that a large amount of indigestible material, or at least such as is inaccessible to the digestive fluids, is afforded to the herbivora in their food, which, therefore, reappears unaltered in the solid excrements.

But, disregarding this circumstance, there are presented, according to the researches thus far instituted, *several differences in quantitative tissue-metamorphosis between herbivora and carnivora.* In the former, far less *water* is absorbed from the intestine than in carnivora. The difference is very great; thus, in horses and cows only one-half of the water introduced into the intestine is absorbed, while in dogs and cats, on the other hand, seventeen-twentieths are absorbed. Further, in herbivora, only fifteen to twenty per cent. of the water which is absorbed and that developed from the elements pass off by the kidneys, while in carnivora about eighty per cent. passes off in the urine. That the *carbon* absorbed is excerned through the lungs in much greater quantities by the herbivora than by the carnivora (the ratio of the carbon in the urine to that in the air expired is in the former = 1 : 19, in the latter = 1 : 9.5) can arise only from the nitrogenised food of the carnivora, since the product of its transformation, urea, carries off a quantity of unoxidized carbon, while the carbohydrates are perfectly consumed, giving as their product carbonic acid and water, of which the former leaves the body almost solely by means of respiration; peculiar relations of organization can hardly be the cause of this phenomènon. We find a similar ratio with reference to the *hydrogen* in the animals of the different dietetic categories. The ratio of the hydrogen excreted by the urine to that excreted by the lungs is in herbivora = 1 : 23.0, in carnivora = 1 : 3.3; the reason of this difference is the same as that which occasions the difference in the quantities of carbon excreted.

In regard, also, to the ratios of the excretion of *nitrogen*, a striking difference is found with respect to the different categories of animals: herbivora excrete often of 100 parts of nitrogen absorbed in the protein-bodies nearly 40 per cent., by means of respiration and perspiration, carnivora, on the contrary, scarcely one per cent. The cause of this difference is not quite clear; it may be supposed that, in the organism of herbivora, the process of oxidation is so active, that a great part of the urea, which in carnivora is excreted as such in the urine, is further disintegrated; this view is supported, in some degree, by the total absence of uric acid in the urine of herbivorous mammalia. That the desquamation of the skin, or the growth and falling out of the hairs, which consume a great deal of nitrogen, is greater in the herbivora than in the carnivora, and thus causes this remarkable difference, we are not justified in supposing, at least according to other observations.—If it is thought to be a necessary consequence of the researches to be afterwards mentioned, that, in the carnivora, all the nitrogen taken up with the food is excreted in the urine in the shape of urea, yet other researches (compare p. 189) have shown that, especially upon a scanty diet of flesh, a great part of the nitrogen thus taken up does not appear in the urine as urea. Hence, we cannot directly infer the amount of the metamorphosis of tissue as regards the nitrogenised materials, from the quantity of urea contained in the urine.

In inanition, *i.e.*, when the tissue-metamorphosis takes its course in the organism without the supply of fresh material from without, the proportions of the elements of the urine to those of the perspiration are almost the same as in nutrition by means of fatty flesh; for the simple reason that the organism, when starving, lives, in a measure, upon its own flesh.—An interesting relation of the excretion of the elements presents itself when the bile is discharged externally (by means of a fistula of the gall-bladder), instead of being poured into the intestine. Whether the quantity of animal food taken be great or small, 10 to 12 per cent. of the carbon absorbed, and 11 to 13 per cent. of the hydrogen absorbed, are excreted by the bile; in the urine, carbon and hydrogen are excerned in the same proportions as when the bile is poured into the intestine, and there resorbed; the loss of carbon and hydrogen, arising from the abduction of the bile, is wanting in the products of respiration; thus proving that the secreted bile, after its reabsorption in the intestine, contributes to the process of respiration. Of the nitrogen taken up, only 3.0 to 3.2 per cent. pass into the bile, and this is found to be wanting, in the urine, when the bile is conducted off.

From experiments upon cats, it results that the *minimum of food for the carnivora* in the 24 hours is about $\frac{1}{23}$, and the oxygen necessary for its consumption about $\frac{1}{55}$ of the bodily weight. In starvation, on the other hand, the body of a carnivore loses (between the third and ninth day of inanition), in 24 hours, only about $\frac{1}{48}$ of its weight. Many carnivora (*e. g.* cats) are able to take so much animal food into their tissue-metamorphosis as to amount to $\frac{1}{9}$ of their bodily weight, the oxygen necessary being $\frac{1}{24}$th. These figures must, however, be regarded only as uncertain rules, as in other experiments ratios differing considerably from these have been presented.—On comparing the excretory products during scanty, with those during abundant, feeding upon meat, it appears, in the first place, that the quantities of the excretions stand nearly in direct proportion to the quantities of food taken; and, therefore, that the augmentation or diminution of animal food is without influence upon the proportions of the individual excretions, or upon their quality; in all cases, the ratio of the oxygen absorbed in respiration to that exhaled in the carbonic acid = 100 : 79.3. In excessive use of animal food, however, the proportion between the carbonic acid and the water which are expired is altered; under scanty meat diet, more water is expired, relatively to the carbonic acid, than under abundant meat diet: in the latter case, relatively more water passes off by the urine and feces; under scanty meat diet, and total abstinence from drink, the proportion between the carbonic acid and the water is so altered, that, in this case, relatively to the carbonic acid, far more passes off through the skin and lungs. The following tabular arrangement of the figures obtained from direct observations, will afford the best view of the relations here pointed out. I. has reference to the transformation of substances with the reception of the minimum of food, and water *ad libitum;* II. Greatest amount of food with unrestricted access to water; III. Normal animal diet while deprived of water.

Recepta and egesta.	I.	II.	III.
Meat (calculated as dry)	100.0	100.0	100 0
Oxygen absorbed	167.0	166.0	167.3
Solid residue of the urine . . .	31.3	30.4	30.6
Solid residue of the feces . . .	1.7	2.5	1.7
Carbonic acid expired	182.0	181.4	182.6
Watery vapor expired	137.6	76.4	152 6

Under these different conditions, therefore, the meat eaten is subjected in the organism to one and the same process of combustion, similar to an elementary analysis, *i. e.*, 1 part of dry flesh-substance is in one case exactly as in the others, decomposed with the aid of 1.67 parts of oxygen into 0.31 of a part of urine substances, 0.02 of a part of fecal matter, and 1.82 parts of carbonic acid.

As the lean flesh applied in such experiments contains 19.56 per cent. of albuminous and gelatin-yielding substances, 4.74 per cent. of fat, 1.00 per cent. of inorganic matters, and 74.70 per cent. of water, and as there are contained on the average in the solid urine-residue after the ingestion of such flesh, 85.5 per cent. of urea, and 14.5 per cent. of salts (including 2.3 per cent. of sulphuric acid), and in the dried solid excrements about 63 per cent. of bile residue, there results the following balance for 1,000 grains of a carnivore, supposing that it will consume in 24 hours 50 grains of lean flesh.

1000 grains of animal consume, during 24 hours—	Water.	Albumen and gelatin-yielding substances.	Fat.	Salts.
50.000 grains of flesh	37.350	9.780	2.370	0.510
21.125 " oxygen				
71.125 grains in all.				

1000 grains of animal excrete, during 24 hours—	Water.	Carbonic acid.	Urea.	Salts.	Intestinal excrements.	Bile.
39.468 grains of perspiration	16.445	23.023	...	...	...	...
30.761 " urine	26.839	...	3.53	0.569	...	...
0.806 " feces	0.681	...	...	0.041	0.039	0.135
71.125 grains in all	43.965	...	...	0.610	...	...

That the excess of water = 6.615 in the egesta denotes the water formed in respiration, scarcely need be mentioned; the increase to the amount of 0.100 of a grain is caused by the oxidation of the sulphur in the albuminates. According to these experiments, all the nitrogen of the food is excreted in the shape of urea, which is, however, incorrect, as we see from the previously mentioned experiments: as in them a deficit always presented itself. We do not know whither this nitrogen, which does not appear in the urine as urea, goes. We are therefore confined to the simple announcement of the facts relating to this deficit; it was relatively and absolutely greatest during insufficient meat-diet ($\frac{2}{3}$ of the nitrogen received); less ($\frac{1}{3}$ of that received) during exactly sufficient meat-diet; during very abundant meat-diet, it was relatively and absolutely diminished. When fat was devoured together with the flesh, this deficit was far less, so that then almost all the nitrogen actually appeared in the urine as urea. This deficit is also diminished, finally, by the free use of water (compare p. 189).

The metamorphosis of the *nitrogenised materials in the animal body* is also considerably modified by the simultaneous ingestion of *non-nitrogenised articles of food.* The ingestion of fat, *e. g.*, under all circumstances, restricts the transformation of the nitrogenised materials of the body; thus, for instance, during perfect starvation, more urea is excreted than when non-nitrogenised food only is eaten. Ordinarily, far less urea is excreted under a diet of fatty meat than corresponds to the quantity of protein-bodies received; but occasionally more urea is excreted than under a pure meat diet, as this deficit of nitrogen is lessened by the fat. Hence, especially, the quantities of urea excreted cannot be taken alone as the measure of the metamorphoses of the nitrogenised material ingested, since even in fully grown and old animals, sometimes more, sometimes less nitrogenised material is stored away as tissue, and thus remains in the body. For it must not be forgotten that in excess of fatty food, nitrogenised material is applied to the formation of fat-cells, and on the other hand, in excess of meat-food, the fat introduced into the body, or formed there, is applied to the growth or renewal of the nitrogenised tissues.—It is such considerations, which render so exceedingly difficult an exact determination of the amount of the tissue-metamorphosis, even with the most exact statistical researches of the kind described. Hence a number of highly important questions with regard to the metamorphosis of animal tissue must remain unanswered, and be left open for further investigations: thus, *e. g.*, the simple question, *whether all the protein-bodies taken in the food must first be transformed into tissue-elements, before they form urea, or whether they may be immediately disintegrated in the blood into urea, carbonic acid, and water*, cannot as yet be decided with certainty. The positive results of the researches hitherto made allow of so many interpretations, that we cannot, even with all the aid of our reasoning faculties, arrive at a degree of even relative truth.

The observations which have been made upon *animals deprived of all solid nutriment*, can serve only for the confirmation of several of the above stated propositions. The results of the best and most reliable of these experiments are as follows: The *total loss of weight*, which a starving animal undergoes previous to its death, varies according to the species; the animals perish when they have lost from 31 to 52 per cent. of their bodily weight. Carnivorous mammals (*e. g.* cats) lose, before death, 51.7 per cent. of their weight; as they can live about 18 days after the withdrawal of all food, the daily loss of weight would amount to 2.87 per cent. Other animals lose during starvation on an average 4.2 per cent. of their weight in 24 hours; thus, within this period, $\frac{1}{24}$ of the mass of the body is lost, which corresponds with the above-adduced results of experiments with exactly sufficient nutriment. From the first to the eighth day, the bodily weight diminishes (in cats) regularly, corresponding with the quantity of carbonic acid expired; afterwards the *excretion of carbonic acid* diminishes less than the bodily weight; and only during the last two days of life does the carbonic acid excretion sink more considerably as compared with the loss of bodily weight. The *kidney excretion* diminishes very considerably as compared with the loss of weight of the animal, and then remains almost exactly proportional to it until the 16th day; it sinks materially, like the carbonic acid excretion, during the last two days. The urine becomes richer in phosphoric and sulphuric acids, as also in extractive matters; the chlorine compounds disappear from the urine after the first few days. The proportion between the phosphoric and sulphuric acids remains constant during the whole period of inanition. As the carnivora (cats) subjected to inanition, perspire in every 24 hours, 2.16 per cent. of their bodily weight of carbonic acid, and 1.6 per cent. of watery vapor, and excrete 0.20 per cent. of urea, 0.008 per cent. of sulphuric acid, 0.011 per cent. of phosphoric acid, and also 0.080 per cent. of dry feces (including 0.020 per cent. of bile-residue), and 2.24 per cent. of liquid water by the kidneys and rectum; it may be calculated that on the average in the period named 0.611 per cent. of the bodily weight of muscular substance, and 0.422 per cent. of fat are subjected to disintegration during inanition. From the determinations of the *loss of weight which each individual organ undergoes during starvation*, it results that the total loss of the body is caused mainly by the destruction of the substance of the muscles, the blood and the fat. According to particular calculations of the diminution of the bodily weight, one-half comes upon the muscular tissue, one-fourth upon the fat, and one-fourth upon all the other organs. Thus it was found, *e. g.*, that in cats during an inanition period of 18 days, the blood had suffered the loss of 93.7 per cent. of its original weight, the fatty tissue, 80.7 per cent., and the muscles, 66.9 per cent.

The observations upon *animals which were deprived of all fluid nourishment* have thus far led to the following results: the animals always take less solid food, and hence the excretions are considerably diminished. During a 12 days' period of thirst, a dog discharged, on the first day, 926 grains of urine, on the seventh, 370 grains, and on the twelfth, only 108 grains; the skin peels off, and the hairs (in birds, the feathers) fall out; the excrements become brittle or hard. The quantity of the egesta exceeds far that of the ingesta; hence the considerable diminution of the bodily weight. Pigeons lost daily, during deprivation of water, 3.7 per cent. of their weight, and after 12 to 13 days' thirst, 4.6 per cent. The greatest part of the decrease of weight fell here also upon the muscles, the skin, and the fat; while the brain, eyes, and spleen presented no material change.

One of the most important questions in relation to the conditions of nutrition of the animal organism, has reference to the ascertaining of the relations of food to the metamorphosis of tissue, as with it is connected *the increase of the weight of the body*, and hence growth, and that kind of increase of bodily weight which is denominated the becoming fat. Unfortunately, we must yet wait for the answer to this inquiry. Several series of experiments have indeed been presented which are concerned with this condition; but they are not sufficient to direct us to any general conclusions, on account of the continual variations to which the bodily weight is subject, even under perfectly normal circumstances, as the consequence of the deposition and destruction of the tissues. Even the researches into the tissue-metamorphosis in the egg during incubation, are still too few or not accurate enough to authorize the attempt to draw general conclusions from them.—It needs only to mention here, that certain substances introduced into the body with the food, diminish the transformation of the nitrogenised matters, and hence possibly conduce to the more abundant deposition of nitrogenised tissue-material; while others, such as chloride of sodium, or abundant ingestion of water, appear to hasten their transformation, and interfere with this deposition.

As the science of the process of nutrition is the culminating point, or final object of all physiologico-chemical investigations, it is not surprising that this chapter has afforded relatively the least scientific profit; for all the chemico-physiological investigations hitherto made, have only tended to establish first a firm basis for the review and examination of this process at large and in general. We are still, however, so far behind in the theory of nutrition, that we must content ourselves with investigating the balances between the recepta and excreta, in order to form even the outlines of a representation of the tissue-metamorphosis in general. We must look to the future for an investigation of the internal exchange of elements in the process of nutrition, of its individual members and stages, of the so-called intermediate tissue-metamorphosis, in order to obtain an exact scientific comprehension of the chemical phenomena of life.

APPENDIX.

CIRCULATION.

By this term we understand the distribution of the blood throughout the organism during life, connected as this is with the various functions taking place in the system which have been already, in great measure, described in the previous part of this work—such as secretion, nutrition, digestion, respiration, and excretion. For the maintenance of the circulation, we find an apparatus provided which may safely be characterized as the most perfect hydraulic apparatus in existence. Nearly all the phenomena which pertain to the circulation may be readily explained on the ordinary principles of hydrostatics and hydrodynamics; our object, however, in this chapter, is not so much to illustrate the truth of this proposition as to call attention to the adaptation of the mechanisms here found to the execution of the life-functions. We shall therefore consider the subject under the following divisions—the Heart, and Arteries; the Veins, and the Capillaries. We might also divide it with reference to the so-called greater and lesser circulations, or the circulation through the system generally, and that through the lungs, but we hardly consider this as warranted by the difference in these two great branches of the circulatory system.

THE HEART AND ARTERIES.

From all parts of the system the blood is brought to the heart by means of the veins, and thence is driven onward through the arteries to supply again the various parts with that fluid which is necessary for their vital activity. In man, and in all the upper classes of animals, the heart is double, and two sorts of blood are brought to it, each of which is forwarded by that organ in its proper course. Oxygenated, and, in a great measure, depurated blood, is brought from the lung-capillaries through the pulmonary veins to the left side of the heart, to be sent thence through the general arterial system in order to subserve the general tissue metamorphosis, and to the kidneys and skin, there to lose other effete matters which are not discharged by the lungs; while, from the right side of the heart, the blood which has accumulated from the system at large, bringing with it the products of the tissues disintegrated in the life-processes, and also the results of digestion, is propelled through the pulmonary artery to the lungs, there to undergo such changes as shall fit it again for the general purposes of nutrition, and which have been fully treated of under "Respiration." As the blood enters the heart, it is dilated, from the base to the apex, gradually at first, then toward the last it is suddenly distended, and immediately contracts in the same direction, *i. e.*, from the base downwards. The dilatation of the heart is called the diastole, and is divided into two stages—the passive (during which the blood flows quietly through the auricle into the ventricle), and the active (in which there is apparently an active dilatation of the heart in order that it may be filled to its entire extent); this is then followed by the systole or contraction, which takes place first in the auricles (they thus emptying themselves into the ventricles), and next in the ventricles, the tricuspid and mitral valves being closed partly by the current of blood thrown against them and partly by the action of the columnæ carneæ attached by the chordæ tendineæ to their edges; the blood contained in them is thus forced into the aorta and pulmonary artery. Its return into the ventricles upon the relaxation which follows is prevented by means of the semilunar valves placed at the orifices of these arteries, which are closed by the pressure of the returning column of blood. This period of activity of the heart is then followed by one of comparative repose, nearly equal in length, when the same phenomena are again exhibited. They may be observed readily in the frog after the removal of the sternum, or in the sheep, the animal having previously been rendered insensible by means of a blow upon the cranium, and respiration being artificially maintained.

The rapidity with which the blood passes through the heart may be conceived of by recalling to mind the experiments performed by injecting ferrocyanide of potassium into one of the jugular veins of a horse, and noting the time which elapsed before its appearance in the other; in twenty seconds it had traversed the lung-capillaries, the heart, the carotid artery and its capillaries, and reappeared in the jugular vein of the opposite side. Allowing three fluidounces to be the quantity propelled by each contraction of the left ventricle, each particle of blood in the body would pass through the heart in a little more than one minute. Here we find an apparent discrepancy in the results of these two modes of investigation; we are not at present able to decide which of them is the most reliable.

The force with which the blood is sent from the heart through the system is more accurately determined; this is done by means of the so-called hæmadynamometer, which, in an improved form, consists of a glass tube, provided with a stopcock, and terminating in a U-shaped tube; the U is partly filled with mercury, and a small quantity of a strong solution of bicarbonate of soda is placed upon the mercury (to prevent the coagulation of the blood from interfering with the experiment), the straight portion of the tube being then attached to the artery, the stopcock is turned, and the depression ensuing in one leg of the U, and the corresponding elevation in the other, are noted; we thus have a measure of the pressure exerted by the heart upon the blood in the artery experimented upon. This has been found to be equal, in the aorta, to four pounds three ounces. Both the frequency and force of the current of the blood, as was to be expected, are found to diminish as we recede from the heart to the extremities.

When blood is forced into the aorta, the elasticity of its walls causes it to be lengthened and increased in diameter at the first impulse, and then to contract again, propelling the blood onward through its branches, in which the same process is repeated. A great advantage is attained by the elasticity of the arteries (which is due principally to their middle coat) in the equalization of the current of the blood. By this means the blood which is propelled in jets in the larger arteries is made to flow more regularly as it approaches the capillaries. A loss of power is, however, experienced, which is compensated in some measure by the introduction into the middle coat of the smaller arteries of contractile fibre-cells. These promote the current of the blood through the smaller arteries; they are, in great measure, under the influence of the sympathetic nervous system (as may be proved in the rabbit by section of the sympathetic, which produces a dilatation of the minute arteries on the side injured), and give rise, probably by their degree of contraction, to the tonicity of the pulse: thus, when they are stimulated to excessive action, we will find the pulse at the wrist corded and small; when, on the contrary, they are relaxed, the pulse will be full, soft, and compressible.

THE CAPILLARIES.

There is every reason to believe that in connection with these vessels, nearly all the phenomena which characterize life take place; the importance of their functions is hence readily perceptible. They receive from the arteries (in the systemic circulation), blood which is oxygenated and loaded with materials destined for the nutrition of the various tissues, or for the formation by the organs of their secretions and excretions; the changes accompanying these processes take place either within or around them; they receive from these tissues and organs their *debris*, the various products, such as carbonic acid, water, &c., which result from their vital activity, and consign them in their turn to the veins. The various phenomena here occurring can be but partially explained as yet, owing to the fact that only their results, generally speaking, are accessible to direct observation. We may refer for a view of some of these to p. 197, where, in treating of the formation of the urine, the mechanical arrangements for its excretion are fully explained. The same principles are applicable elsewhere; but one phenomenon remains open for discussion, *the movement of the blood through the capillaries.* The area of the capillary rete is enormously increased as compared with that of the arterial system: and the diminished force of the heart's action is in all probability wholly insufficient to drive the blood over this vastly increased extent of surface (some authors compute it as 400 times as great). We also frequently see in disease a great disproportion between the heart's action and the capillary circulation; and in inflammation, for instance, of one hand, the amount of blood passing in a given time through an inflamed part is greater than that passing through the corresponding healthy part, although the heart propelling the blood must obviously act equally on both. These facts suffice to show that the capillary circulation is maintained by some power besides the action of the heart, and that the metamorphosis of tissue must take place in connection with their function. Two factors of this movement may be recognized: 1st, the *chemical attraction of the tissues* beyond the capillaries, and in which they are imbedded *for their contents;* and 2d, *the capillary attraction of the capillary walls themselves.* The capability of chemical affinity to produce molecular motion need not be here discussed; it must be evident that the tissues and organs will attract to themselves the arterial blood so rich in the oxygen which they need for their transformations, while the venous blood, loaded with carbonic acid, water, and their other products of vital action, is forced on into the veins. The same takes place in the capillaries of the lungs; the blood which is rich in carbonic acid presses forward to exchange its excess for the oxygen which abounds in the air-cells; this done, it becomes indifferent, and is moved onward by the *vis à tergo* of other portions pressing forward to make the same exchange. Direct experiments prove the correctness of this reasoning; if access of air be limited, the blood is found to accumulate in the *arterial* system; the pressure in the arteries increases as long as the heart's action is maintained, as shown by the hæmadynamometer. Venous blood is also found to have accumulated in the arteries of the lungs, giving rise to their congestion. The importance of the second coefficient of this capillary movement is proved by the experiments performed with the view of determining the relative rapidity of passage of fluids of different densities through capillary tubes; *e. g.*, alcohol passes much more slowly than water, &c.

The distribution of the capillaries in the tissues and organs is well worthy of notice, each tissue having a mode of capillary arrangement peculiar to itself. The description of these modes, however, belongs rather to minute anatomy than to physiology; we therefore merely remark, in this place, that as the physiological function of a substance stands in close relation to its chemical nature, so also the mechanical arrangements, by means of which a part is supplied with nutritive matter, will be of the greatest moment in determining its mode of nutrition, *i. e.*, the substances which it will abstract from that complex pabulum, the blood, its subsequent action upon these substances, and the materials which it will return into the blood. We are not yet able to follow the steps of this process, on account of our ignorance of the intermediate stages between albumen, &c., and the principles of organized tissues. But the proposition which we are seeking to establish is evidently a corollary of the great physiological truth that *form always corresponds to function;* that is, where the functions are similar, we have similar forms or apparatus for their performance; and where they are different or special, we have different or special apparatus for their performance. Hence we need not have recourse to the supposition that there exists in any parts or tissues of the body a so-called *selective affinity*, or sort of intelligent attraction, for the substances appropriate for their nutrition; the arrangement of their capillaries necessitates the transudation of the materials required as much as the laws of chemical affinity control their combinations.

THE VEINS.

The functions of the venous system seem to be much more simple than those of the capillaries; they may be summed up in great measure as follows: They receive the blood which, having subserved the purposes of nutrition, secretion, or excretion, is to be conveyed back to the heart in order that it may be sent thence, in the case of the systemic blood, to the lungs, to be freed from part of its water, carbonic acid, &c., or in that of the aerated blood, from the lungs, to be distributed throughout the organism. To this it may be added that absorption seems to take place through the veins more readily than through any other part of the circulatory system; the capillaries also possess this power to a great extent, but it is the venous capillaries and radicles which principally perform this function. The rapidity of the blood-current through the veins is less than that through the arteries, as their surface is much greater; it is maintained principally by the *vis à tergo* of the blood in the capillaries, with the aid probably of the respiratory movements, and the onward current of the blood in the arteries as a *vis a fronte*, while the contraction of the muscular tissues surrounding many of them would propel the blood contained in them, the valves preventing its regurgitation.

REPRODUCTION.

UNDER this head are included all the phenomena which have for their object the formation of new individuals resembling in all respects the parent individuals. Throughout all organized nature, the law prevails that *every living organism has proceeded or been derived from a pre-existing organism*, i. e., is not merely the result of the unaided action of the ordinary forces of nature, occurring or not by chance, but is the direct result or effect of a vital force operative in accordance with certain laws. In the lowest orders of existence, the individuals of which are composed of cells, or aggregations of cells, the production of new individuals often takes place by the process of gemmation or subdivision; this process we shall also notice as the first step towards organization in the fecundated ovum. Advancing in the scale of existence, we find individuals composed, not as before, of similar cells, all performing the same functions, but an adaptation of certain cells to the performance of certain functions, &c. The organism is now more complex, and often passes through several stages of development before it is perfected; still we find often that it is propagated by gemmæ originating from the parent being. In these beings, on the borders of existence, we notice another phenomenon which is not observed among higher beings, at least to any extent, viz: when a portion of an individual is removed a similar portion is soon developed; indeed, the whole animal may be divided into small pieces, each of which will then grow and complete itself, so as to resemble the original animal.

But, when any degree of development is attained, we find special organs set apart for the formation of new beings and the perpetuation of the species; so universal is this proposition that it has been said "*omne vivum ab ovo*"—a law to which at present we know of no exception; the apparent one of gemmation ceases to be such if we regard the gemmated offspring as part of the original individual. Another proposition of universal applicability is, that for the formation of a new individual, it is necessary that the two opposite sexual elements should be united. These may be contained in the same individual, as in hermaphrodites, or may be formed in different individuals, the union being accomplished in various ways in the different classes of beings. These sexual elements have been designated the *germ-cell* and the *sperm-cell*. The former, which is supplied by the female, is imbedded in a mass of plastic matter, the yolk, which is capable of being assimilated by the germ-cell and transformed (when the latter has been fertilized by means of the sperm-cell or male element) into a mass of germs, from which the future organism is to be developed. For this development, as stated by Dr. Jackson in his introduction, there are necessary a due supply of oxygen, a certain temperature (differing in different classes of beings, but fixed, within certain limits, for each), a supply of proper plasma, and the presence of organic force, which is produced by this union of the contents of the sperm-cell and the germ-cell. The only apparent exception to this law is that of so-called *parthenogenesis*, or the production of one or more series of individuals without sexual intercourse. This takes place especially among the *aphides*, whose mode of propagation may be described as follows: in the autumn, sexual intercourse having taken place, ova are formed and deposited so as to be hatched in the spring; these, after passing through the larva state, are developed into perfect aphides, all of which are females; they, however, give birth to successive progenies of female aphides; the latter also possessing the same power; this continues until autumn, when males are also produced, sexual intercourse takes place, and ova are deposited as before. But this apparent exception is easily explained on the hypothesis that a quantity of superfluous germ-mass is inclosed in the body of each aphis, from which the successive individuals are developed. That superfluous germ-mass is often stored up in the organisms of the lower orders of animal life, we see demonstrated by the renewal of whole limbs, &c., after their loss, as in crabs, lobsters, &c.

Passing, then, at once to the consideration of the process of reproduction in the human species, we shall take up the phenomena which are exhibited in the development of the fœtus. The nature, appearance, &c., of the human sperm-cell, or spermatozoon, has already been sufficiently described; it only remains to state that in this microscopic molecule resides all the influence which the father exerts over the organization of his offspring. On the other hand, the mother contributes not only the essential female element, the germ-cell, but also the nutrient material for the development of the fœtus. This germ-cell, or *germinal-vesicle*, as it is generally termed, with its nucleus or *germinal spot*, occupies originally the centre of the *vitellus*, or yolk (true yolk, or germ-yolk, as distinguished from the food-yolk of the eggs of birds); but, when the ovum is mature, it approaches as nearly as possible the peritoneal covering of the ovary. The vitellus is surrounded by a membrane called the *zona pellucida*, and floats in the cavity of the *Graafian vesicle*, the interior of which is lined by a layer of epithelial cells constituting the *discus proligerus*. The ovum, then, consisting of the zona pellucida and its contents, having been matured in the Graafian vesicles of the ovary, escapes into the Fallopian tube on the rupture of the Graafian vesicle, and is thence discharged through the womb into the vagina; or being fecundated by the contact of the male element, the spermatozoon, a series of phenomena, the most wonderful in all nature ensues. As it passes through the Fallopian tubes, it receives an additional layer of a fibrino-albuminous nature, the *chorion*. This is organized primarily into fibrils and nucleate cells, the latter subsequently passing into connective tissue and bloodvessels; it is villous or shaggy on the external surface, and insinuates its villosities or tufts into the interstices of the decidua; after the development of the fœtus has reached such a point that sufficient nutriment for it can no longer be derived from the fluids thus absorbed from the matters secreted by the uterus, the vascular element of the chorion becomes excessively developed at one spot, a corresponding vascular growth taking place on the walls of the uterus. Between the fœtal and maternal blood thus brought into close approximation, intercurrents are established, carrying from the fœtal to the maternal blood the products of the tissue metamorphosis of the embryo, and from the maternal to the fœtal fresh supplies of oxygen and plasma, for the maintenance of the life-functions of the latter. In the uterus itself certain changes take place upon the occurrence of conception. The mucous lining of the uterus secretes a tough viscid mass, called the *membrana decidua*. As the ovum enters the uterus from the Fallopian tubes it pushes before it, according to the older authorities, a layer of this deciduous membrane, constituting the *decidua reflexa*; while that which covers the uterus is called the *decidua vera*: according, however, to more recent researches, the ovum is lodged upon the internal surface of the decidua, which then grows over and around it. We next come to consider the changes which take place in the fecundated ovum itself. The spermatozoids have been traced clearly in the zona pellucida, but their further progress into the germinal vesicle has not been observed; so that we must remain contented for the present with the knowledge that, in some manner (probably by endosmose), the contents of the two cells are mingled. The germinal vesicle then disappears, and in its place we have a granular mass called the yolk-mass, containing a nucleus; a fission of this mass and its nucleus into two similar masses then occurs, and this process is repeated until we have the whole of the yolk-mass (occupying the place of the original germinal vesicle) subdivided into cell-like bodies, which become true cells by the development of an investing-membrane around each of them, and then constitute a mulberry-like mass.

Gradually, this agglomeration of cells is seen to separate itself so as to form two layers, differing considerably from each other in appearance; the external or *serous* layer is that from which are to be developed the tissues and organs of *animal life;* while the *mucous* or internal layer is devoted to the formation of the tissues and organs of *vegetative* or organic life. One spot in these layers is next noticed to be darker than the surrounding; this is called the *area germinativa;* at first of a rounded shape, it gradually becomes ovoid, and clearer near the centre; the name of area pellucida is applied to this part, and that of *area vasculosa* to the outer part of the area germinativa. A dark line is then observed in the middle of the area pellucida, the *primitive trace*, formed by a groove in the serous layer; this is gradually deepened by the growth of the adjacent sides of the serous layer so as to form the *laminæ dorsales;* these gradually approach at their summits so as to convert the primitive trace into a tube. We thus have formed the rudiment of the cranio-vertebral system. At the same time, a layer of cells is being developed between the serous and mucous layers, termed the *vascular layer;* the walls of these cells are developed into capillary bloodvessels, while their nuclei probably serve to originate the blood-discs; a distinct vascular rete is now seen to extend itself over the germinal area, and thence over the whole of the vitelline membrane, serving thus as a means for carrying the unassimilated yolk to the embryo until it is exhausted. From the laminæ dorsales, prolongations next take place outwards and downwards, to form the transverse processes of the vertebræ and the ribs, thus inclosing the abdominal cavity. A portion of the yolk is thus included in the embryo, communicating with the rest (now known as the *umbilical vesicle*) by the *vitelline duct.* The mucous layer aids in this process by rising on each side of the embryo, and arching over so as to meet and unite in the median line, thus forming the rudiment of the intestinal canal. The serous lamina beyond the area germinativa is meanwhile seen to rise up all around the embryo in a double fold until it meets, and forms thus a double investment of the embryo; this membrane is called the *amnion.* Its external layer covers the internal surface of the chorion, while the inner constitutes a distinct membranous covering of the fœtus, and contains a peculiar fluid, the liquor amnii. From the caudal extremity of the digestive tube, a mass of cells is next observed to be developed; in the centre of these a cavity is formed, and the whole vesicle, the *allantois,* is then developed until it reaches the part of the chorion which is in closest vascular connection with the decidua; the capillaries of the embryo are extended through its walls, and come thus into connection with the villous tufts of the chorion, which soon become converted into capillary loops, dipping into the substance of the membrana decidua. In the latter, bloodvessels and sinuses communicating with the circulatory system of the mother have been developed, and the fœtal blood is thus brought into close connection with that of the mother; its effete matters are absorbed, and it returns to the fœtus duly oxygenated. When the allantois has performed (in the human embryo) the office of carrying the bloodvessels to the chorion, and aided in the depurating process by its communication with a large surface of the chorion until a more direct mode of exchange is formed by the growth of the *placenta* in the same manner as just described, it shrivels up, and remains only as a minute vesicle upon the umbilical cord. The same take place with regard to the umbilical vesicle, the contents of which have now been exhausted. The circulation of the fluid in the capillaries of the embryo, and the gradual formation of the heart, arteries, and veins, are phenomena of great interest. After the formation of the vascular layer and the area vasculosa, the fluid contained in the vessels is seen first to move to the embryo; then a pulsatile movement is observed in the part of the bloodvessel walls which is to constitute the heart; this motion becomes stronger, the wall of the tube is thickened, and muscular tissue is developed in it; it is soon divided into three cavities, the *auricle* or receiving cavity, the *ventricle* or propelling cavity, and the *bulbus arteriosus*, or commencement of the aorta; it is also doubled on itself. The blood passing into the aorta is propelled mainly toward the head and upper portions of the embryo, causing them to be developed more rapidly than the inferior portions. It is also distributed, as mentioned, over the umbilical vesicle, to absorb the nutriment stored up in it, and over the allantois for the purpose of depuration and renovation by the fluids absorbed by the chorion from the decidua. After some time, however, the ventricle is divided by a septum, and the auricle also to a certain degree; the umbilical vesicle being exhausted, and the placenta being substituted for the allantois, the embryo derives its nourishment from the circulatory fluid of the mother; the three or five arches to which the bulbus aorticus gave rise are transformed into the bloodvessel distribution of the adult; the blood returned from the placenta is sent nearly unmixed by the foramen ovale to the left auricle, left ventricle, and thence to the head; while the systemic blood is directed into the right ventricle, ductus arteriosus, and descending aorta, thence to be distributed to the system, and to the placenta. For a description of the fœtal circulation, we must refer to General Anatomy. It only remains to notice the formation of the liver and other great organs of the body. The simple digestive tube already described is soon transformed and marked out so as to indicate the future stomach, small and large intestines. At one spot on the small intestine a mass of cells is seen to be formed, with a central cavity or cæcum communicating with the digestive tube; this is gradually elongated and developed so as to form the biliary duct, while the same process is continually repeated in it, and bloodvessels distributed through the mass, until the liver is formed. The pancreas, salivary glands, and lungs are developed by a repetition of the same process. The kidneys are preceded by two peculiar bodies, known as the *corporæ Wolffiana;* these commence as prolonged tubes lying on each side of the vertebral column, being gradually furnished with numerous cœcal appendages, and secreting a fluid which they discharge into the uro-genital sinus which communicates with the allantois by means of the urachus. Behind them, the kidneys are developed from a mass of blastema; at first distinctly lobulated, they gradually attain the character which they have in after life; as they are developed the Wolffian bodies are atrophied, leaving finally only the rudiment which descends with the testis into the scrotum, the excretory duct of each constituting the vas deferens. For all further account of the development we must refer to General Anatomy; our object here is not so much to give a detailed account of the development of the fœtus, as to illustrate the action of organic or formative force in bringing almost shapeless matter into the likeness of the human form divine. In the deficiency of any one of the conditions already named as essential for vital action we have corresponding deviation in the resulting fœtus; and here, as also in the *arrest of development*, are we to look for the explanation of the anomalies and monstrosities so often presented. In fact, no more convincing proof could be adduced of the regular action of the laws of vitality, and of reproduction in particular, than the recent classification and reduction to system of these very monstrosities. As, too, an imperfect being can only produce an imperfect plasma, we have explained the fact of hereditary transmission of disease, a fact inexplicable on the hypothesis that our organisms are the results of the action merely of the ordinary imponderable agents.

LIFE-PHENOMENA.

HITHERTO we have considered the constituents of the animal organism, the proximate principles which are found therein, their products of decomposition, and the modes of their entrance into, and exit from the economy. We have studied the arrangements of the organs, and the results of their actions. We have not, however, hereby studied Physiology; we have only learned the apparatus, the tools, the mechanism by means of which, and in which, nature guides the series of processes which we call Life. We must look further, and seek to investigate the *forces* which control and act through this mechanism. In this effort, however, we are met by the difficulty that the source of these forces, as well as the evidences of their subsequent action, is to be sought in the organism itself; so that in the living body we have presented the phenomenon of a machine which organizes itself from materials furnished to it, produces the forces necessary for its action, repairs its own waste, and provides for the creation of similar machines; finally ceasing to act, and restoring the material appropriated by it when the original cause of the action is exhausted, or when it is checked by some countervailing force. Are the ordinary forces of nature adequate to this task? We can observe their action in organic bodies, and have seen that it is precisely analogous to their action in the inorganic world, allowance being made for the difference in the substances acted upon; but in all the phenomena of life there is a difference, real and essential, which shows itself even in the term *vital*, as applied to distinguish them from the ordinary results of natural forces. Can the latter form an organic cell, endowed with the properties of nutrition, development, secretion, excretion, and reproduction? No one pretends ever to have seen a single instance in which this has occurred. And yet we are told that it is unphilosophical to suppose that when all known causes are insufficient to account for a series of phenomena, there must be some other cause still unknown which produces them. If none but the ordinary forces of nature are concerned in the production of life-phenomena, why do we find that, suddenly or slowly, without the appreciable diminution of any one of these forces, the whole of these phenomena cease, and, instead of them, the *ordinary results of the action of these forces* take place? When we find a certain series of phenomena taking place in a fixed sequence, and capable of being formularized into certain laws, we infer that there must be a certain force which produces them; this is pre-eminently the case with life-phenomena. It would have been less irrational and unphilosophical to have maintained, in the days of the alchemists, that no such force as chemical affinity could exist, because its laws were very imperfectly known, than to insist, at the present day, that vital force is an unnecessary assumption because we cannot fully unravel all the mysteries of its action. The common object which all life-phenomena tend to accomplish is, *the maintenance of form with the change of material.* Whenever deviations occur from this, they are the consequences of external influences; and *death* is nothing more than the cessation of this process. Other general laws of life might be adduced, as the one previously referred to, *that the structure of organs corresponds closely with their function*—or the one, that *each individual seeks to repeat the type of the parent;* but the discussion of these points is foreign to the object of this work, and we think that sufficient has been said to convince any thinking man that the supposition of a *vital force* is not unnecessary; and that it acts uniformly in accordance with definite laws. It is not the sole cause of the operations of the organism, but acts in it *with* the other forces which act everywhere throughout nature, and *controlling* them in the same sense as magnetism may be said to control the gravity of a piece of iron suspended to a magnet.

The phenomena of life presented for our consideration in the human organism may be arranged in three classes, viz: those of vegetativity, animality, and spirituality. Those of the first are common to all organic nature, vegetable as well as animal; those of the second are peculiar to animals; while the consideration of the third class belongs to metaphysics.

The phenomena of organic life, or vegetativity, are nutrition, secretion, excretion, reproduction, and irritability. These take place by the agency of the organic cell, under the conditions mentioned in the Introductory Essay of Dr. Jackson, viz: when there are present a sufficient supply of germ force, heat, oxygen, and the proper plasma or organizable material. The deficiency or absence of any one of these four conditions is accompanied by other phenomena, but not by those of vegetativity. The property of irritability belongs to all organized beings, and may be defined as that property which causes them to contract on the application of appropriate stimuli; it must be distinguished from muscular contractility, and from sensibility, which imply the action of special organs, and are properties only of animal tissues. The remaining phenomena of vegetativity are fully discussed by Dr. Lehmann.

The phenomena of animality occur only in the animal kingdom, and may be divided into general and special. The first class consists of the phenomena of sensibility, which depend upon an irritation communicated to the nerves supplying the tissues which then cause them to contract; this property of the tissues gives rise to their *tonicity*. It is probable that we are to seek in the sympathetic system for the source of this property as well as (in some measure) for that of the chemical actions which take place in the animal body. That the sympathetic system influences materially the chemical processes seems to be indicated by the results of numerous vivisectional experiments. The special phenomena of animality may be arranged under the heads of Muscular Contraction, Volition, Voice, Hearing, Vision, Smell, Taste, and Touch. For each of these a special apparatus is required, the structure of which is learned from General Anatomy; we now enter upon the consideration of them individually.

Muscular Contraction.

The muscles of animals are divided into two classes, the voluntary or muscles of animal life, and involuntary, or muscles of organic life. These differ in their structure as well as in their function: thus corresponding with the general law already alluded to. The nervous system may be divided into the cerebral, cerebro-spinal, and ganglionic systems, each of which has its special functions: the cerebral system, consisting of the cerebral hemispheres, seems to be the instrument of the intellectual faculties; the cerebro-spinal, consisting of the cerebellum, medulla oblongata, and spinal marrow, regulates muscular action; and the sympathetic (closely connected, however, with the cerebro-spinal), presides over the various organic movements. From this it will be seen that muscular contraction seems to depend, in the living body, upon the action of the cerebro-spinal axis. When an impression is made upon a surface, intelligence of it (so to speak) is conveyed to the nerve centres corresponding with the surface, by means of the nervous communication, when an influence is immediately sent to the muscles of the part, determining their action. Supposing a nerve to be destined for each of these functions, the one performing the first would be called the afferent or excitor nerve; the other, the efferent or motor nerve. The existence of this circuit (so to speak) is clearly proved by vivisections, and the muscular contractions are more striking when the influence of the will is removed. The seat of the sensation seems to be in the posterior columns of the spinal marrow, and that of the motor force in the anterior columns. In all cases, the ganglia, composed of gray neurine, seem to be the originators of nerve-force, the tubules, composed of white neurine, acting merely as its conductors, and as commissures to the ganglia, promoting their consentaneous action. The performance of the functions necessary to life depends upon the conveyance to the different organs of the force necessary to direct and control their actions. If anything prevents this conveyance from the proper centre, as the interruption of the communication, or of the generation of the requisite force, death results. Thus, injury of the respiratory tract of the medulla oblongata, or section of the pneumogastric nerves on both sides, destroys life by putting a stop to respiration. The apparatus is perfect, but the *force* is wanting to set it in motion. Puncture of the medulla oblongata at the point of the calamus scriptorius, is also followed by instantaneous death.

The division of muscles into voluntary and involuntary, cannot be strictly maintained: for the will is not without influence over the contraction of involuntary muscles, and further, the voluntary muscles often act independently of the will. A marked difference occurs in their mode of contraction: in voluntary muscles parallel bundles of fasciculi contract alternately, while in involuntary, the contraction occurs consecutively, as in the peristaltic contraction of the muscular coat of the intestine. The phenomena of muscular contraction on the application of galvanic stimuli are still too little investigated to allow of our giving here any account of them. Much light has recently been thrown upon them, but much still remains to be cleared up. The amount of muscular force expended daily in maintaining the various functions of the economy has been already alluded to by Dr. Jackson; and the structure of muscular tissue, the chemical changes occurring in connection with its activity, are fully discussed by Dr. Lehmann.

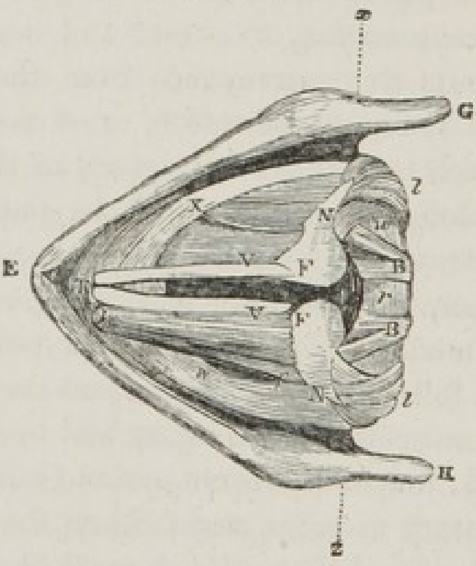
Volition.

The phenomena connected with this subject are too complicated, and too closely associated with the phenomena of intellect, to permit our entering upon them in this connection: they lie beyond the aim of the present work. Suffice it to say that they embrace the reception of the impressions made by the outer world upon our senses, the action of the mind upon these impressions, and the consequent determination of the individual.

Voice.

The voice is produced in the larynx by means of the vibration of the vocal chords. For a description of the mechanism of the

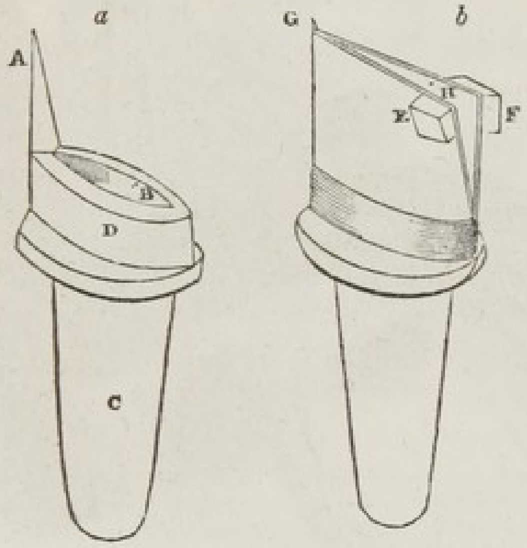
Fig. 34.



BIRD'S-EYE VIEW OF LARYNX FROM ABOVE:—G, E, H. The thyroid cartilage, embracing the ring of the cricoid *r*, *u*, X, *w*, and turning upon the axis *x z*, which passes through the lower horns, not visible from above. N, F, N, F. The arytenoid cartilages, connected by the arytenoideus transversus. T, V, T, V. The vocal ligaments. N, X. The right crico-arytenoideus lateralis (the left being removed). V, *k*, *f*. The left thyro-arytenoideus (the right being removed). N, *l*, N, *l*. The crico-arytenei postici. B, B. The crico-arytenoid ligaments.

larynx we must refer the reader to descriptive anatomy: suffice it to say, that experiments have clearly demonstrated the fact that sounds may be produced by instruments resembling the larynx in construction: *i. e.* with chords or membranes so extended that a current of air shall be made to pass between them, the tone produced depending upon the tension and elasticity of the chords, as well as their length and thickness. The vocal chords are composed of yellow elastic tissue, and as we possess no substance of equal elastic properties, we cannot construct an artificial larynx with a scale equal to the human larynx: an approximation has however been obtained by Mr. Willis, as follows:—

Fig. 35.



Artificial glottis.

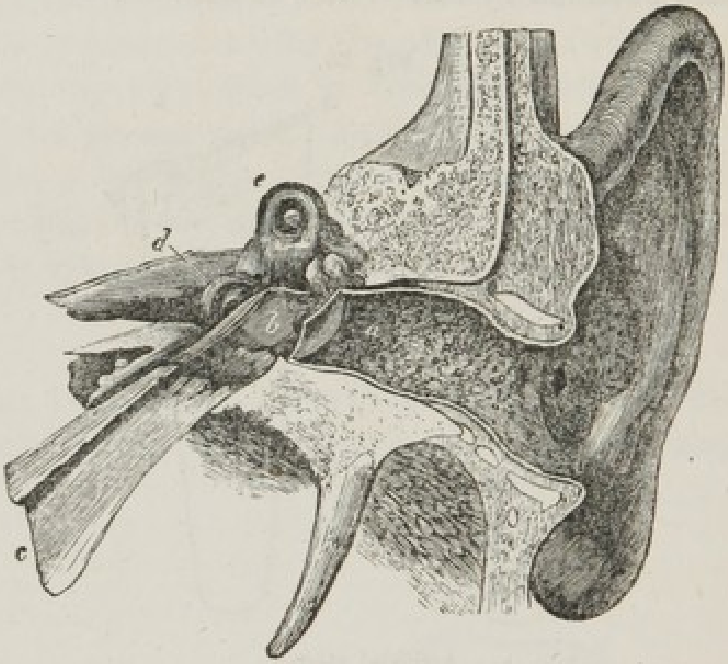
"A wooden pipe of the form *a* should be prepared, having a foot *C*, like that of an organ pipe, and an upper opening, long and narrow, as at *B*, with a point *A*, rising at one end of it. If a piece of leather, or, still better, of sheet India rubber, be doubled round this point and secured by being bound round the pipe at *D*, with strong thread, as in *b*, it will give us an artificial glottis with its upper edges *G*, *H*, which may be made to vibrate or not at pleasure, by inclining the planes of the edges: a couple of pieces of cork, *E*, *F*, may be glued to the corners to make them more manageable. From this machine various notes may be obtained by stretching the edges in their length *G*, *H*: the notes rising in pitch through the length of the vibrating edges is increased."—*Articulation* is the result of the modification of the sounds produced in the larynx by means of the different parts of the oral cavity.

Hearing.

This may be defined to be the cognizance taken by a peculiar nerve-structure of the vibrations or undulations constituting sound.

For the performance of this function, a special apparatus is necessary, varying in its structure and complexity with the degree of perfection required. The anatomy of the human ear may be described as follows: The organ of hearing is composed of three parts, the external, middle, and internal ear. The *external ear*

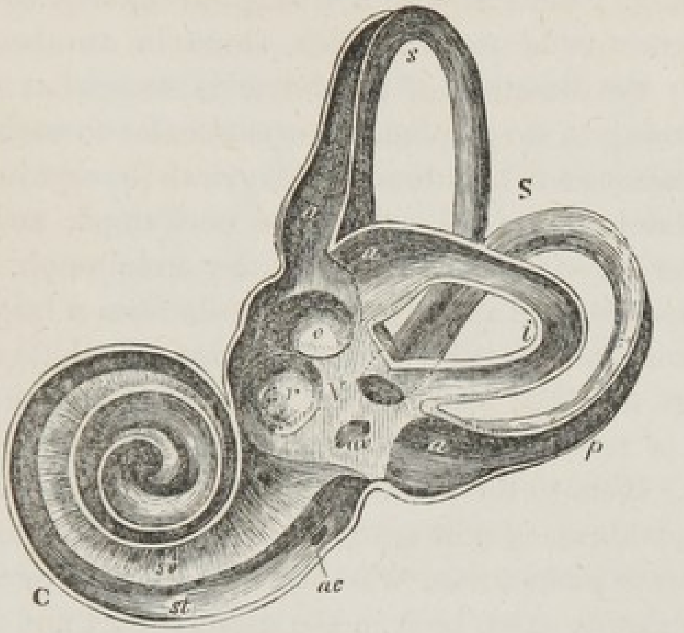
Fig. 36.



General view of the external, middle, and internal Ear, as seen in a prepared section through *a*, the auditory canal. *b*. The tympanum, or middle ear. *c*. Eustachian tube, leading to the pharynx. *d*. Cochlea; and *e*. Semicircular canals and vestibule, seen on their exterior, as brought into view by dissecting away the surrounding petrous bone. The styloid process projects below; and the inner surface of the carotid canal is seen above the Eustachian tube.

consists of a cartilaginous and fibrous tube, widely spread externally and thrown into various curves and converging into the meatus auditorius internus in such a manner as to collect and convey the sonorous vibrations towards the membrana tympani which separates the external from the middle ear. The latter is comprised in the tympanic cavity, and is contained (as also the internal ear) in the petrous portion of the temporal bone. It is limited by the membrana tympani, the walls of the tympanum, and the fenestra rotunda and the fenestra ovalis—these being covered by a membrane; the cavity communicates with the fauces by means of the Eustachian tube. It contains the ossicula of the ear—a chain of small bones articulated together, and so attached by means of muscles and ligaments to the membrana tympani and fenestra ovalis, that the membrana tympani may be rendered more or less tense by their motion, which is of the highest importance in rendering the membrane susceptible to graver or acuter vibrations. The internal ear is affected by the undulations of the air in the tym-

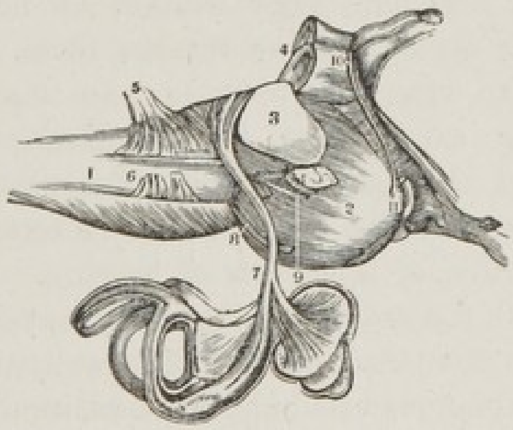
Fig. 37.



INTERIOR OF THE OSSEOUS LABYRINTH.—V. Vestibule. *a, v.* Aqueduct of the vestibule. *o.* Fovea semi-elliptica. *r.* Fovea hemispherica. S. Semicircular canals. *s.* Superior. *p.* Posterior. *i.* Inferior. *a, a, a.* The ampullar extremity of each. C. Cochlea. *a, c.* Aqueduct of the cochlea. *s, v.* Osseous zone of the lamina spiralis, above which is the scala vestibuli, communicating with the vestibule. *st.* Scala tympani below the spiral lamina.

panum (communicated to it by the membrana tympani), only through the fenestra rotunda and fenestra ovalis. The *internal ear* consists of the osseous and membranous labyrinth (the latter lining

Fig. 38.



A VIEW OF THE ORIGIN AND DISTRIBUTION OF THE PORTIO MOLLIS OF THE SEVENTH PAIR, OR AUDITORY NERVE.—1. The medulla oblongata. 2. The pons Varolii. 3, 4. The crura cerebelli of the right side. 5. The eighth pair of nerves. 6. The ninth pair. 7. The auditory nerve distributed to the cochlea and labyrinth. 8. The sixth pair of nerves. 9. The portio dura of the seventh pair. 10. The fourth pair. 11. The fifth pair.

the former and corresponding exactly to it) which is composed of three parts: the *cochlea*, a double spiral communicating at the top and opening at the bottom into the vestibule, and having spread upon the lamina which separates the spirals, the fibrils of the auditory nerve; the *vestibule*, a triangular cavity communicating with the *semicircular canals*, which, three in number, are placed posteriorly; the direction of the latter is somewhat fancifully described as being in three planes perpendicular to each other. Between the osseous and membranous labyrinth (except in the cochlea), there is contained a fluid called the perilymph, and within the membranous labyrinth another fluid, the endolymph. It has been recently demonstrated that ganglionic cells form a large part of the nervous tissue distributed over the cochlea, vestibule and ampullæ (or openings into the semicircular canals); these are supposed to be capable of receiving impressions from sonorous vibrations, and transmitting them to the nervous centres by the portio mollis. In fact, the hypothesis is now generally received, that for the occurrence of nerve phenomena, whether of sensation or motion, ganglionic cells must exist, both in the sentient part and in the nerve-centre, whence corresponding action proceeds; this we shall see exemplified also in the senses of vision and touch. The following extract from Dr. Jackson's lecture on this subject, as published in a note to *Carpenter's Human Physiology*, last edition, p. 699, explains more satisfactorily than any other hypothesis which has been advanced, the functions of the different portions of the internal ear. He says:—

"The semicircular canals have no direct agency in the production of sound or hearing. They contain no nervous structure: no portion of the acoustic nerve reaches them. They are small appendages to the vestibule, opening into it and the ampullæ. The membranous canals, like the membranous vestibule, are floated in a fluid, the perilymph, and are filled with a similar fluid, the endolymph. The membranous structure constitutes the essential solid portion of the organ of hearing. It is nowhere in direct contact with the osseous walls of the corresponding cavities excavated in the temporal bone. The perilymph is interposed between the membranous vestibule, the semicircular canals, and the surrounding osseous walls. In the Petromyzon, this membranous structure (vestibule and semicircular canals) is contained in a common cavity, uninclosed in corresponding excavations in bone substance.[1] As Müller observes, this is "a fact of great physiological importance." It proves the membranous portion of the apparatus of hearing and its fluid to be independent of the bony structure in the excitation of the sense of sound or hearing.

"The semicircular canals are evidently intended to perfect the sense of hearing or sound, as executed in its most complete manifestations, in the higher development of this apparatus of sense in man and the superior animals.

"The hypothesis of Scarpa has been adopted as the most plausible in this point of view. He supposed the semicircular canals to be intended to increase the intensity of the sonorous impressions on the acoustic nerve, and thus to make hearing more distinct. They effect this operation by receiving and collecting the vibrations of the solid parietes of the cranium transmitted to the lymph-fluid, and through it to the nervous expansion of the acoustic nerve.

"This hypothesis cannot be entertained. In the first place, it is very doubtful whether the aerial vibrations, in ordinary hearing, can or do communicate vibrations to the hard parts of the cranium. When a light carriage passes rapidly over the rough pavement with a sharp, rattling noise, if the ears be completely closed, not a sound is heard; nor is a single note of a large orchestra to be distinguished when the ears are pressed with the fingers. When sound is attended with concussion, a noise may then be distinguished, but this differs from the ordinary sense of hearing. If vibrations are excited in the solid parts of the cranium by sonorous vibrations of the air, they are obviously too feeble to make an impression on the nerves of sense, and incapable of reinforcing the vibrations transmitted through the stapes.

"In the second place, vibrations, if excited in the lymph-fluid of the semicircular canals, would move in a direction the reverse of the molecular vibrations of the lymph-fluid of the vestibule and ampullæ, the real excitors of the sense of hearing or sound. These vibrations are transmitted through the fenestra ovalis by the stapes, and radiate from that point in expanding waves through the vestibular lymph-fluid into the ampullæ and semicircular canals. Vibrations proceeding from the solid walls of the semicircular canals, to reach the nerve expansions, would come in conflict with those proceeding from the stapes, and either interference, and consequent

[1] "Müller's Physiology," Baly's translation, vol. ii. p. 1288.

suppression and silence would ensue, or the effect of an echo, or noise, or simple sound be the result. The hypothesis of Scarpa, it appears to me, cannot be sustained, though ably advocated by Müller.

"The hypothesis that assigns to the semicircular canals the perception of the direction of sound does not merit an investigation. The notion of the direction of sound, like that of distance, is a mental action; a conclusion to which the mind arrives, from certain phenomena or facts acquired by experience.

"As to the manner in which the semicircular canals perfect the sense of hearing, my conclusion is the opposite to that of Scarpa. Instead of increasing the sonorous undulations or vibrations of the lymph of the vestibule, the immediate excitants of the sense of hearing, they serve to suppress them. They arrest the waves of reflexion which would necessarily occur in a simple cavity, wholly limited by plane surfaces, as the vestibule would be without these appendages. Such is the rudimentary vestibule or internal ear of the invertebrata. The consequence of reflected undulating vibrations, maintained in the labyrinthic fluid, would be the production of mere sound or noise of different intensities. The perception of the immense number of fine and delicate tones, and other qualities of sound of which the ear has cognizance, would be utterly impossible in the confusion of sonorous vibrations in the fluid of the labyrinth continuously reflected to and fro, unless some provision is made for their suppression. The molecules of a fluid contained in a closed vessel continue in undulatory vibration until the impetus exciting their motion is expended or suppressed. The semicircular canals accomplish this purpose. They are, in the apparatus of hearing, what the pigmentum nigrum of the choroid coat is in that of vision.

"The two senses and their apparatus are homologous. The essential phenomena and laws of each are identical. The knowledge of those of the one sense demonstrates those of the other. The conditions of perfect vision and perfect hearing are the same. They are, for vision: 1st. The existence of separate, independent, sensitive spaces or sections of the retina for distinct images and perceptions of visual impressions. Volkmann estimates these to be $0^{mm\cdot}0005$;[1] and others at 0·000005 of an inch.[2] 2d. A single distinct impres-

[1] "Annual Report of the Progress of Chemistry and Allied Sciences," by Liebig and Kopp, vol. iii. p. 98.

[2] "Lardner's Handbook of Optics," p. 155.

sion made by the molecular vibration of the Ether—the excitor of the sense of sight.

"The above conditions are obtained, *a*, by the special anatomical arrangement of the retina: *b*, by the refracting apparatus of the globe of the eye that concentrates the undulatory rays of the Ether proceeding from every point of a visual object on the distinct sensitive points or spaces of the retina: *c*, by the suppression of the undulatory vibrations immediately they have excited an impression in the retina, by the black pigment of the choroid coat. Their reflection from the exterior surface of the sclerotic coat, and reiterated excitement of the retinal surface, is in this way prevented. In Albinos the pigment of the choroid is either deficient or absent, and the consequence is indistinct vision in daylight, from the general excitement of the retina by the reflected undulations of the Ether occupying the globe of the eye.

"Similar conditions are obtained in hearing: 1st. By the auditive nerve being decomposed into its separate filaments and ganglionic vesicles, amounting to some thousands, and spread out in a manner to receive single, individual impressions, in the membranous vestibule, ampullæ, and on the lamina spiralis of the cochlea. 2d. By the molecular undulations or vibrations excited in the fluids—peri- and endo-lymph—by the sonorous undulations communicated by the stapes, occupying the fenestra ovalis. From this point they radiate in expanding waves of undulations, strike on and pass through the membranous vestibule and ampullæ, on which the filaments of the vestibular branch of the auditive nerve are arranged, producing a single, distinct impression, reinforced by the resonance of the superimposed otoconiæ, acting like the sounding board of the piano, and exciting a single and distinct impulse, and perception of sound. The sonorous vibration having thus completed its office, the specific excitation of the sense of hearing must, like that of the visual vibration, cease or be suppressed. This occurs in part in the ampullæ, but mostly in the semicircular canals.

"The vibrations of the endolymph reaching the ampullæ are partially broken and weakened at their openings; those entering the ampullæ again expand, losing thereby their impetus, and either die away against the membranous walls, or come in conflict with the vibrations of the perilymph on their exterior. The two can scarcely be in perfect consonance of expansion or condensation, and interference ensues by which they are suppressed. In this mode all the feebler vibrations are terminated. Those of greater force enter simultaneously the two opposite openings of the semicircular canals. The orifices and the commencement of each canal differ as to size and form, and consequently each entering wave of undulatory vibrations is modified, thus losing their consonance of expansion, and when they meet interference and suppression result. Reflexion of sonorous vibrations is completely provided against.

"Parallel conditions exist in the cochlea. Its two canals—the superior scala vestibuli, and the inferior scala tympani—are filled with lymph-fluid continuous and identical with that of the vestibule. The first, the scala vestibuli, according to the latest investigations of Kölliker,[1] is the principal seat of hearing. On its lamina spiralis is expanded a sentient, nervous structure, the recipient of the sonorous vibrations excitative of the sense of hearing. It is the homotype of the retina of the eye. The scala tympani furnishes space for spreading out the filaments of the nerve, but the terminal extremities pass through the membranous spiral lamina, to be incorporated with the sentient organ of hearing in the superior canal or scala vestibuli. The filaments of the inferior canal or scala tympani are mere conductors of the nervous excitement of the auditive sentient membrane. The scala tympani, similar to the semicircular canals, has no direct connection with the production of hearing. It is the homotype of the semicircular canals, and performs the same office.

"The sonorous vibrations, starting from the stapes and fenestra ovalis, rushing into the adjacent opening of the scala vestibuli, excite, by their impulse, the auditory membrane or retina, spread over its lamina spiralis, and reach its termination where it opens into the scala tympani. Feeble vibrations may subside spontaneously by exhaustion from their extension. The stronger pass on into the scala tympani, where they fade away, or are suppressed by the interference of vibrations entering the inferior canal by the fenestra rotunda from the tympanum. The condition for perfect hearing, for the distinct perception and appreciation of the finest tones and notes, so that each vibration shall make but one, single, distinct impression, and then be suppressed, is thus amply fulfilled.

"Analogous provisions are perceived to exist in the tympanum, to preserve in that cavity perfect wave-systems of undulations,

[1] "Human Microscopical Anatomy." Da-Costa's translation. Note, p. 175.

indispensable to the perfection of the sense of hearing. Vibrations existing in air contained in a cavity with plane walls, would continue to be reflected from side to side, producing confused sounds or noise. The air in the tympanum is thrown into vibrations by impulses of the membrana tympani. They are communicated pure and in perfect accord to the membrane of the fenestra rotunda. This curious and beautiful result is effected in the following manner: on one side the tympanum communicates by numerous openings with the mastoid cells communicating with one another. All the vibrations impinging on this side are suppressed in the mastoid cells. Those that reach the opposite side are swallowed up and lost in the Eustachian tube. All resonance and reflexion of vibrations are suppressed, and the wave-systems of sonorous vibrations traverse the tympanum undisturbed, enter with augmented force the lymph-fluid of the scala tympani, and meet the corresponding undulations coming from the scala vestibuli, from which both systems are suppressed by interference.

"In the 'Annual Report' by Justus Liebig and H. Kopp, vol. iii. p. 53, is the following observation: 'It is certain that the ear is capable of receiving and distinguishing many notes, the vibrations of which reach it simultaneously. As the atmospheric particles which convey the various wave-systems to the ear can never receive from them more than one resulting motion, it follows necessarily that the ear possesses the power of distinguishing in this resulting motion, the periods of the component wave-trains. For the present we are, however, unable to explain upon what this power depends.'

"The preceding theory furnishes an explanation of the above problem, considered as inexplicable by Liebig and Kopp, in 1852. It demonstrates the manner in which the wave-systems of sonorous vibrations pass through the fluid of the labyrinth undisturbed, preserving their relations to each other and their special qualities of sound. Each separate vibration of the molecules of the lymph-fluid are shown to produce a special, distinct impression on the nerve structure, and excite a corresponding perception of sound.

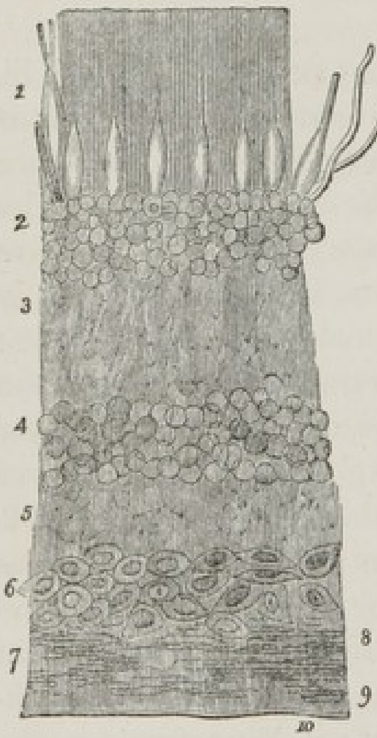
"The small space through which the vibrations pass, and the rapidity of their movements in fluids, cause the impressions they make on the nervous sentient organ, and the perceptions they excite, to appear as an instantaneous act. The mind has cognizance of them, however diversified they may be, as a unity of sounds simultaneously instant in action: whence it forms the compound idea of a perfect harmony.

"An analogous phenomenon occurs in vision. When a body composed of different forms and colors is presented to the eye, as a bouquet of flowers, a landscape, or picture, each different form, color, tint and shading, are perceived blended, but perfect and distinct, forming the image of a single object. Yet thousands of Ether vibrations are traversing the eye, and are exciting each a separate, distinct impression, without confusion, on the retina, and as many distinct and separate perceptions, from which a corresponding compound idea of a single object is formed by the mind."

Vision.

This may be defined to be the impression made upon the retina by rays of light, or undulatory luminous vibrations excited in the all-pervading æther. The mechanism of the eye is so constantly presented in all works upon Optics and Anatomy, that we think it unnecessary to introduce it here, but will enter at once upon the consideration of the function of the retina. Here, as in the ear, we find a special nervous apparatus provided for the performance of a special function, *i. e.*, recognition of luminous impressions. We find the fibrils of the optic nerve, after its entrance into the globe of the eye, forming a plexus over the interior surface of the choroid coat; between this plexus and the choroid coat there exists a layer of ganglionic cells similar to those of the encephalon, and upon these again a granular and fibrous layer; while finally upon the latter are found the "rods" and "cones" of the membrana Jacobi. These are in connection with the granular cells by means of prolongations or fibrils, which again extend as far as the ganglionic cells. The "rods" and "cones" are so placed that the rays of light reaching the retina strike vertically upon

Fig. 39.



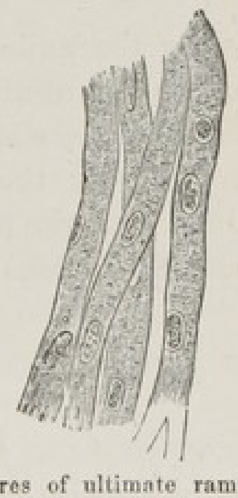
VERTICAL SECTION OF RETINA OF THE HUMAN EYE.—1. Basilar layer. 2. Outer layer, granular. 3. Intermediate, fibrous layer. 4. Inner granular layer. 5. Finely granular gray layer. 6. Layer of nerve-cells. 7. Layer of fibres of optic nerve. 8. Limitary membrane.

them in the direction of their long axis, and a close correspondence is said to exist between their diameter and that of the smallest object perceptible by the eye. Be this as it may, their absence from that point of the retina where the optic nerve enters the eye which is comparatively insensate to light, together with their abundance in the "yellow spot of Sœmmering" (yellow from the deficiency of the granular layer which allows the choroid partially to appear), where vision is most intense, renders it probable that they are the immediate agents of the perception of light. As in the ear we have provision made for the suppression of the sonorous undulations when the effect has been produced upon the acoustic nerve, so also in the eye, the choroid coat, with its black pigment-cells, absorbs the luminous undulations as soon as they have acted upon the optic nerve. The iris acts as a diaphragm, allowing only a certain quantity of luminous rays to pass through it; it is essentially a sphincter muscle, containing two sets of contractile fibre-cells, an internal circular and external radiating layer. The adaptation of the eye to the perception of objects at different distances is effected by the movement of the lens; actual experiments have proved that the extent of motion required hardly exceeds one line.

Smell.

This is the perception of odors by means of the olfactory nerve. The immediate nerve structure instrumental in this perception has not been so thoroughly investigated as that of the other sensory organs; the only difference clearly established is, that the nerve-fibres resemble more the gelatiniform nerve-fibres than the ordinary fibres. The portions of the nasal cavity upon which they are distributed are lined with a peculiar sepia-brown tessellated epithelium.

Fig. 40.



Fibres of ultimate ramifications of *Olfactory Nerve* of Dog.

Taste.

This is the function of certain nervous structures distributed principally upon the surface of the tongue; their construction has not been clearly made out, but is probably closely allied to that of the tactile corpuscles, as the papillæ in which they are contained closely resemble those of the skin. This special sense seems to stand in an intermediate position between smell and touch; but many phenomena prove that it is not to be confounded with them, such as the obliteration of one, while the other is maintained, &c.

Touch.

The structure which has for its object our acquaintance with the form, resistance, &c., of external bodies, is not confined to a small portion of the body, but is distributed over its whole surface, more or less closely. In those parts which possess this sense in a higher degree, as the palms of the hands, the lips, &c., we find papillæ, which, in addition to bloodvessels, contain nervous loops, and also peculiar ovoid bodies, called "axile corpuscles," which possess (according to some) gray ganglionic vesicles or cells; this is, indeed, denied by some eminent microscopists, who consider the axile corpuscles as nothing more than a thickened neurilemma; at all events a peculiar development of nerve-tissue is found here, which, probably, gives rise to the sensations communicated by the nerves to the nerve-centres; thus showing an analogy with the facts found relatively to the transmission of luminous and sonorous vibrations.

Fig. 41.

VERTICAL SECTION OF SKIN OF FINGER (palmar surface), treated with caustic soda.—*a*, *b*. Cutaneous nerves, forming a terminal plexus, and finally passing into the papillæ *c*, *c*, *c*.

INDEX.

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ERRATA.

Page 62, *for* "magaritic," *read* "margaritic."
" 69, 9th line from bottom, *for* "yelk," *read* "yolk."
" 193, 11th " " " "quinine," *read* "quinone."
" 161, 4th " top " "15.2 grammes," *read* "234.5 grains."
" 161, 4th " " " "23.9 grammes," *read* "368.8 grains."

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* Communications are invited from gentlemen in all parts of the country. Elaborate articles inserted by the Editor are paid for by the Publisher.

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