Physiology

Exhaustive and Practical

A Series of Practical Lectures Delivered from Day to Day by

John Martin Littlejohn

Professor of Physiology

In the American School of Osteopathy at Kirksville, MO

Especially adapted for Students of Osteopathy

1898

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PHYSIOLOGY
EXHAUSTIVE AND PRACTICAL.

A SERIES OF PRACTICAL LECTURES DELIVERED FROM DAY TO DAY BY

J. MARTIN LITTLEJOHN,
PROFESSOR OF PHYSIOLOGY

IN THE
AMERICAN SCHOOL OF OSTEOPATHY

AT
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PREFACE.

THE publication of "Physiology, Exhaustive and Practical" in its present form is due to a continued manifestation of interest in, and a high appreciation of the value of these lectures as delivered by Prof. Littlejohn, in his daily work.

Many students who, at first, thought them beneficial only for special preparation on the different subjects, now consider them more valuable for future reference and desire to preserve the same in a handsomely bound form and give them a permanent place in their libraries.

And to the end that these "nuggets of pure gold" may be properly treasured, I commend this volume to my fellow students, and would be glad to have their criticisms, as well as suggestions.

I desire to acknowledge valuable suggestions from numerous students and invaluable aid, in the preparation of this work, from Dr. J. M. Littlejohn.

I wish to thank the publishers for the extreme care they have exercised in the mechanical execution of the work.

H. R. BNUM.
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INTRODUCTION.

In beginning the study of Physiology we must always remember that
all Science is one and that there is unity in Science that specialization can
not dispense with.

When we abstract we tend to narrowness and bigotry. Science literally
means knowledge, and it covers the whole field of knowledge but it also
implies exactness of knowledge based upon observation, experiment and
classification.

Observation and experimentation furnish the basal facts which are reason-
ably about and reduced to unity and system in the form of ideas; these
ideas in turn forming the basis upon which science is systematically built
up. Physiology is a part of science and a very essential part. Physiology
literally means, from phusis and logos, reasoning about nature, in this case,
limited to human nature, at least, in the field of human Physiology. Every
form of life has a Physiology, so that Physiology really falls back upon
Biology as the Primary Science. Biology is the science of life in general.
Physiology is the science that reasons about the nature of life, its modes of
activity and the actions of its organisms. In other words, it is the science
of organized life. Morphology as distinguished from Physiology deals with
the form and structure of living beings. Life, itself, from this standpoint,
is that science of relations, physical, chemical and vital which gives us cer-
tain phenomena that we characterize as manifestations of vitality. This, of
course, implies behind all phenomena the life principle.

Anatomy, Physiology and Pathology are the three great pillars upon
which rests the Science of Medicine. The Science of Medicine is not limited
to the prescription, and knowledge of Drugs or Physic; this is the degener-
ated idea of Medicine. The Science of Medicine deals with the preservation
and prolongation of human life and with the curing of those abnormal
conditions which tend to weaken or destroy life. Medicine in its history
craft, it consisted of certain ceremonious observances. Later it consisted of
certain charms which the superstitious character of the people encouraged.
To this day certain forms and incantations are believed to possess medi-
cal virtue. In the definition of the Science I have given, I think it is wide
enough to cover Osteopathy, because I believe Osteopathy is a part of the
Science of Medicine and Osteopathy should claim the word Medicine in its
original sense, namely, that of healing. There are three great fields of
knowledge in the Science of Medicine—Anatomy, Physiology and Pathol-
ogy. Anatomy is the Science of organization or of the structure of the
human system. Physiology is the science of organized life in its various
functions. Pathology is the science which deals with abnormal conditions
of human life. Symptomatology is the science which deals with results from
signs of diseased conditions viewed from the standpoint of the expert phy-
sician who has a correct knowledge of Anatomy, Physiology and Pathol-
ogy. To combat disease and consequently to prevent death we must have
a thorough knowledge of these sciences. These represent the normal conditions and also the abnormal conditions. To understand and meet the unhealthful conditions we must know the healthful and health-giving conditions and functions. Physiology forms the middle science in this trinity of sciences and is a most essential study in the field of Medicine. But there is a wider field in which Physiology figures. Physiology has not only a bearing on Medicine but also upon Psychology and through Psychology upon Psychological conditions; for true Psychology is founded on Physiology. The mental states and activities are of value only as the illustrations of the conditions and functions. The psychic conditions of life are brought out not alone in the field of education, in adaptations to study but also in the study and diagnosis of mental diseases, and many of the nervous diseases. The Physiology of the brain, spinal cord and of the entire nervous system is at the foundation of every true theory of life, and its preservation, prolongation and its treatment under diseased conditions or in regard to mental life and even higher moral and spiritual life.

A correct knowledge of Physiology applied in the field of Psychology has rendered obsolete older ideas and plans of education and has given rise to the modern notion of education that has done so much to evolve didactic principles and plans for educating that is leading out and up the mind to the realms of knowledge rather than piling in the material into an already overcrowded mind. May we not look for the same reform in the field of medicine when Physiology is taught in all its bearings as it teaches the true functions of a differentiated human life consisting of a number of organs all of which are independent, and yet are united to form a single life. As we step into the higher field of Psycho-physiology, we realize the fact that mind is the ascendant power and that in a healthy physical life nothing less than a healthy mind can secure that vigorous condition of body so much desired by all. We realize also that while in a purely bodily disease we must not overlook the fact that Psycho-pathy partly discloses the mental diseases and mind conditions without the removal of which it is impossible to cure bodily diseases. This wide field of Osteopathy and we think that our claim is not too great when we say in beginning this course of Physiology that Physiology is the gateway by which this immense field is to be entered. It is called the gateway upon the human life with all its functions we constantly remember that it is our purpose in teaching Physiology, to lead your minds up to that high standard of knowledge regarding Physiology which will qualify you to become efficient operators in the field of Osteopathy.

**PHYSIOLOGY.**

Physiology, as the study of the body, includes the study of both the living body and the dead body, the body of the individual and the body of the species. It is concerned with the structure and function of the human body, and with the processes by which the body maintains its normal state of health and responds to various environmental stimuli.

Physiology treats of the vital actions and functions of the various parts of the human body. In general it treats of the actions and the uses of the various parts of the living body. Everything that has life has a physiology; hence, we have vegetable, animal comparative and human Physiology. Vegetable Physiology is brought out in the science of Botany. Animal Physiology is both comparative and human and embraces the whole animal kingdom. Comparative Physiology deals with the life of the inferior races of animals. Human Physiology teaches of the various organs of the human body. In order to understand Physiology, the construction and composition of the human body must be understood. The properties or relations of the human body are chemical, physical and vital. These relations when harmoniously sustained through a succession of time constitute life from a physiological standpoint. Life consists of the manifestations of certain phenomena, depending upon these three properties. One of these manifestations is activity back of which is the will and the mind. We have much to say of life, or vital activity, but the most that we know of it is its results. What life is and its exact position in relation to what we call the body is not known. All the parts of the body are united together by a wonderful sympathy and manifest united activity. The human body is an organism, that is, each part of the human body is both cause and effect in its relation to organism as a whole; this organism of the human body is differentiated into different parts or organs which discharge their own peculiar functions, all the different parts being united so as to constitute the single human body and the individual life. The three basic principles or elements of the human system are matter, motion and mind. These are called the trinity of operations in the human system. They are named in their order from the standpoint of result and of development from the standpoint of Science. We do not speak of any first cause of these elements, we are not concerned with causation because that belongs to metaphysics. In Science we find these as facts and we deal with them as results. The lowest substratum of all development is matter; hence, Physics and Chemistry begin by discussing the fundamental properties of matter. Biology discusses the same properties in connection with life and the energy of life. Life, so far as known to us, exists solely as a manifestation of living matter the result of certain underlying causes, these causes manifesting themselves in activity through the human body and mind. Although living matter and lifeless matter are entirely distinct, yet they are closely related. Matter is constantly being taken into the body and transformed into the body substance by the functions of assimilation, absorption, etc. The living substance of the human body is the transmuted lifeless matter of food which has been taken into the body and has become animalized. The continuance of life depends upon the assimilation of this lifeless matter with the life substance of the body.
The theory of life in its continuance is that of the relation between living matter and lifeless matter and the great question is, how to accomplish the process of assimilation. The body is a living mould into which certain substances are cast to be assimilated into the system and the waste matters expelled. Prof. Huxley has said: The living organism is in a state of turmoil in connection with material molecules constantly streaming into the body and out again. The second factor of life is motion. Matter is associated with motion because all life in matter is a form of motion. The living substance of the body is a compound of certain chemical elements. This living substance contains what are known as proteins. These compounds are composed of O, H, N, C, and sometimes at least, S and P. These proteins constitute the material substratum of the human body. Each of these elements has a peculiar characteristic; O has the power of combination, H has the power of mobility, N has the inertial power, so that in the complex compound the strongest properties are allied to constitute a human, material body. The material substratum of the human body is thus found to be the proteins; these proteins affecting the chemical and mechanical processes of the human body.

There are not only material substances in the human body, but also power, capacity, function or energy. The living substance of the body has the power to manufacture new substances out of those substances taken into the body. This process of manufacturing, roughly speaking, represents the process by which the body organism renews itself for a continuance of life. The process of combustion goes on continuously producing heat which is converted into energy and motion. The bodily substance is constantly wasting away by this combustion process, and hence, needs constantly to be repaired. The repairs in the human system are effected by the characteristic development of the human body, known as nutrition; that is the power of taking in new particles and assimilating them to the bodily substance. In general there are three great functions in the development of the human system.

1st. Nutrition including assimilation; taking in and animalizing particles and nutrition proper which begins where assimilation stops.
2d. Muscular irritability. This is found in that vital property of the human body, called contractility. It is the power to respond to a stimulus.
3d. Reproduction. This is the power to separate a part of the corpuscle so as to form a new life.

There are two great centers of the body organism, the brain and the heart. The blood is life; it is bearer of the substances upon which vitality depends. The air is borne in the blood during the vitalizing process and the blood contains that which is carried through the blood in those processes which incline an animal to be considered as a tissue builder. In the bodily organism likewise, the nervous system and the special senses including also locomotion and animal movements are subservient to the preservation of the individual. Functions subservient to the preservation of the individual are divided into two great series. 1. Functions in the individual life, (A) some of which are subservient to the preservation of the individual by assimilating to its substance the food by which it is nourished. These include digestion, absorption, circulation, respiration, secretion and nutrition proper; (B) functions which tend to the inertial power, to the preservation of the individual by establishing relations with external things and beings. This includes the nervous system and the special senses including also locomotion and animal movements. Functions subservient to the preservation of the individual are divided into two great series. 1. Functions in the individual life, (A) some of which are subservient to the preservation of the individual by assimilating to its substance the food by which it is nourished. These include digestion, absorption, circulation, respiration, secretion and nutrition proper; (B) functions which tend to the inertial power, to the preservation of the individual by establishing relations with external things and beings. This includes the nervous system and the special senses including also locomotion and animal movements. Functions subservient to the preservation of the individual are divided into two great series. 1. Functions in the individual life, (A) some of which are subservient to the preservation of the individual by assimilating to its substance the food by which it is nourished. These include digestion, absorption, circulation, respiration, secretion and nutrition proper; (B) functions which tend to the inertial power, to the preservation of the individual by establishing relations with external things and beings. This includes the nervous system and the special senses including also locomotion and animal movements. Functions subservient to the preservation of the individual are divided into two great series. 1. Functions in the individual life, (A) some of which are subservient to the preservation of the individual by assimilating to its substance the food by which it is nourished. These include digestion, absorption, circulation, respiration, secretion and nutrition proper; (B) functions which tend to the inertial power, to the preservation of the individual by establishing relations with external things and beings. This includes the nervous system and the special senses including also locomotion and animal movements.
DIFFERENCE BETWEEN ANIMAL AND VEGETABLE LIFE.

of the inorganic mass is independent of the other parts to which it is united by the force of affinity of aggregations.

4th. Among the animals and vegetables all the individuals of the same class have been formed after the same model; their difference being slight. The forms of organized life, therefore, are more easily determined.

That is, these forms are determined organically.

In minerals, the veins of the substance are never alike. For example: 5th. A powerful internal cause seems to arrange the different parts of animal and vegetable bodies so as to present a surface, more or less round edges. Minerals, on the other hand, often take their shape from external bodies, and when a special cause gives to them a special form, as in crystals from similar substances often assume very different shapes.

6th. The most absolute distinction, that is, between the organized and inorganic, is that which depends upon growth and nourishment. In the plant, the outer surface, while the organic, by reason of their vital powers, receive nutrition. In the animal, as plants and animals nutrition, used in its general sense, is the effect of the internal mechanism and their growth is development from a cell which goes on successively by the addition of new surface layers.

7th. Organic bodies spring from a germ, which at first was a part of the animal and growth. Inorganic bodies have no germ, but are made up of distinct parts brought together in combinations.

8th. Organized bodies alone can die. All these have a duration determined by their own nature, and this duration is not determined as in the case of minerals by bulk and density. In man there is not the life of the oak, which is a constant change of the elements, such as fishes, whose flesh is of an inferior consistency to his own.

DIFFERENCE BETWEEN ANIMAL AND VEGETABLE LIFE.

There are much fewer and less absolute differences between vegetable and animal life. There is, in fact, very little difference between a plant and a zoophyte. There is a much wider difference between man, who stands at the head of the animals, and the species he possesses as its lowest line, than there is between the polypus and the plant. It cannot be bridged, even by the Philosopher’s lithophyte. At one end of the animal chain are found living beings, fixed like the plants on their supports; at the other end, animals Organizer and organisms are at the top and bottom, respectively, from slips, and to which is subject to different influences. In fact, all of them carry on life in their particular organs, but not organically.

2nd Difference: The constituent principles of vegetables, as they are less in number, are also less diffusible. In fact, azote (nitrogen), is predominant in animal substances, as a gaseous and volatile principle, while carbon, the base of vegetable substance, is fixed and solid. This added to the smaller quantity of liquid, explains the long duration after death of the vegetable substances.

3rd Difference: There is one difference sufficient to distinguish between the animal and vegetable life. The zoophyte, fixed on its rocky habitation, cannot change his position and is confined to partial movements which are different also by certain plants. The result is that the zoophyte has not that sensitive unity so remarkable in animals and in man. The zoophyte, whose name indicates an animal plant, is totally separated from all beings of the vegetable kingdom by the existence of a cavity in which alimentary digestion is conducted on a process of absorption. From this, the animal up to man nutrition is carried on by two surfaces—the internal and external. Especially the former: While in the plant nutrition, or rather the absorption of nutritive principles, is only on the external. Every animal considered as an abstraction has a nutritive tube, open at the extremities. The existence of a polypus is reduced to a fact of absorption, because its whole substance is used in forming an alimentary tube of which the soft surfaces are used in the absorption of substances brought into it.

From the worm up to man the alimentary canal is a long tube, open at the two extremities, at first, in the lower forms only the length of the body, from the mouth to the anus; but, in the higher forms of life, this tube turns itself in a complex fold of the two extremities. It is in the thickness of the walls of this tube that the mucous membrane that lines it internally and the skin with which the membrane is continuous is that the organs are placed which serve to transmit and modify the fluids, to gather their nerves and muscles. In fact, all that carries on life—that is processes of life. As we rise from the blooded animals to the red blooded, and blooded, and to the worms, and finally to man, we find a gradual multiplication of organs contained within the walls of this canal. If we follow the same course downward—that is from the higher to the lower—we find the structure simplified till we reach the polypus. The alimentary canal is so simply formed in its internal without interfering with the proper discharge of functions. That shows that there is nothing on the internal side of the walls of that canal peculiar to the process of absorption as we find it in animal life. That shows a very simple form of the alimentary canal. Man, therefore, and the whole animal kingdom carry about within them the supply of their subsistence and absorption by an external surface which is peculiar to the plants reproduced.

The digestive tube, that essential part of every animal, is the part of which the existence and action are the most independent of the concurrence of the other organs and to which the properties of life seem to adhere.

Haller, who has often been spoken of as the father of Physiology, states that in the heart we find irritability under the two-fold relation of lively and lasting in the highest combination. This means the heart retains life longest. He gave the second place to the intestines, the stomach, the liver, the uterus and the diaphragm. After this, that is, in the third place, all the muscles under the control of the will.

Richerand and Jurine have shown, however, that the intestines are always the last parts in which traces of life can be discovered. After the heart has ceased to beat and the rest of the body reduced to an inanimate
mass, there are certain undulatory motions in the intestinal canal. If the intestinal tube is the ultimo moriens, that is, the last organ in which life lingers, then it is to our direct stimulation in cases of asphyxia. This connects the lower to the higher animal forms, for Jurine observed to the pulex monoculus that of all the parts of this little white blooded animal, the most perfect is the reproductive organs, for, if cut into pieces, each piece becomes a new polypus.

Pile.

We shall find life to be composed, at first, of a small number of phenomena as small as the apparatus to which life is estranged. As extending these, as its organs or instruments are multiplied, and as the organs which characterize it at first are obscure, becoming more and more manifest and with all of existence enlarging, we ascend from the lower beings to the most perfect being. This perfection simply means that living beings are possessed of more numerous organs, present greater results in life and multiply the acts of existence. In the Universe every being is perfect in itself, because each being is so constituted as perfectly to fulfill its purpose. In the plant which springs up, grows and dies each year we have a being whose existence is limited to the phenomena of nutrition and reproduction; a mechanism which consists of a multitude of vessels, straight or wounding, through which the sap is filtered and other fluids necessary to vegetation in the nutritive process. These fluids ascend generally from the roots, where materials are taken up to the higher parts of the organism, in which what is left over from nutrition is evaporated through the leaves and the waste thrown off.

Two properties direct the action of this small number of functions—those we find in them in the plants—first a latent and feeble sensibility, by which each vessel is affected by the fluid with which it is brought into contact, and second a slight contractility in virtue of which the plant or its parts contract or dilate. The reproductive organs of this little life are characteristic. The male stamens bow themselves over the female pistil, shake over the stigma their fertilizing dust, and then die with the flower which is succeeded by the seed. This plant divided into many parts is reproducted also from slips, which proves this fact that each part is not absolutely dependent on each other part, and that each of the parts contains a set of organs of a simpler organs—that is simpler as compared to the more complex—and to the properties of the life in all parts, the phenomena of life being less connected than in the animals, especially in the brain.

Passing from the plant to the polypus, which forms the lowest link in the animal chain, we find a tube of a soft substance both sensitive and contractile, a life and organization as simple as that of a plant. The vessels which carry the liquid, the vessels called trachee, which give access to the air, cannot be distinctly traced in this homogeneous substance. There is of the vessels, first softens and then digests the food, the tube then spontaneously contracts and ejects the waste. The mutual dependence of parts is absolute, for, if it is cut to pieces, each piece becomes a new polypus, organized and living. These animals (gemmiparous) have the faculties of feeling and self-motion and are also capable of impressions.

Rising to the worms we have no longer animated substances, simply vegetables. These connect the lowest to the higher animal forms, and the organs of nutrition and reproduction still further limited. Gills in these—in the fishes, of course—and lungs in others are added to the heart. The action of these chief organs, however, is less frequent. The serpent, for example, passes long winters torpid with cold, without air and without life motions. This is due to the capacity to suspend the admission of air and the capacity of breathing at very long intervals. The heart and other vessels of the fish feel and act within him without consciousness. Fish have senses, nerves and a brain from which it knows what affects it; muscles by which it moves and adapts itself to surrounding environments.

Coming to the red and warm blooded animals, at the head of which we find man. This class of animals all alike, except in the less essential organs. All of them have vertebral columns, four limbs, the brain which exactly fills the cavity of skull, a spinal marrow, nerves of two kinds, five senses, muscles partly voluntary and partly involuntary. Added to these organs a long digestive tube coiled upon itself, furnished at its opening with salival and masticatory instruments, with lymphatic glands, arteries and veins, a heart with two auricles and two ventricles, and lobular lungs. These are all the organs of life, and yet some of these organs live, except while they partake in the general action of the system and are under the influence of that heart. All of them die, or at least vanish from visual observation, when separated from the animal.

The human body consists of a collection of liquids and solids in the proportions of five to one, in six parts. This proportion is maintained throughout the body, which constitutes the greatest weight of the body existing before solids, for the embryo, which is at first in a gelatinous condition, may be considered a fluid. It is from the liquid that all the organs.
receive their nutriment to repair their waste. The solids formed from the
liquids return to their former state; after having for a sufficient time formed
Fluidity is thus essential to living matter, because the solids are uniformly
viscous, therefore, is an accidental condition of organized living matter. Water
fluids. It contains saline substances in solution and even animal matter, albumin
and fibrin. The first of these substances, the gelatin, solidifies, forms the basis of all the organs of a white color, such as tendons, aponen-
20. Albumin exists abundantly in all the humors.
3rd. Fibrin of the blood plasma passes successively through these three forms, gelatin, albumin, fibrin, and these three different fibers, which is ascribed a certain function. Limiting the expression of means of existence or life, there is a difference between life and existence.
we will mention these ten functions.
1st. The digestive apparatus, consisting of a canal extending from
the mouth to the anus.
2d. The absorbent or lymphatic system, which consists of vessels and
organs.
3d. The circulatory system, which is a combination of heart, arteries,
veins, and capillaries.
4th. Respiratory System.
5th. Secretory or glandular system.
6th. Sensitive system, embracing the brain, the spinal marrow and the
orgs of sense.
7th. The muscular system, that of motion and locomotion, including
muscles, tendons and aperoneuroses.
8th. The osseous system, including bones, appendages, cartilages, liga-
ments, and synovial capsules.
9th. The vocal system.
10th. The sexual system—reproductive system.
Each of these systems contains in its structure several simple tissues
besides the horny tissue which constitutes the basis of the epidermis,
These four substances may be considered as real organic elements,
becoming capable of a simple elementary element which Haller, the Father
of Physiology, sought in vain to discover, is purely imaginary. Richet, on
cluded that there were twenty elements. In the human or-
experimental organization we find the four constituent elements of tissue
substance, epithelium is one of the simplest structures of the body. It consists of one or
layers of microscopic nucleated cells, called epithelial cells,
arranged so as to form membranes which line the free surfaces of the interior
and exterior of the body, forming the free surfaces of the epidermis and of the
wall of the alimentary canal, of the skin and of the accessory trans- and
nervous membranes. Epithelial cells consist of a very fine cell
liquid of granular matter. There are four varieties of these, that is, the epi-
Each other, as in the cuticle, and are placed side by side like pavement
lymphatics and blood vessels.
2d. The granular or rounded cells which line the internal or the compound glands, like the
3d. Ciliated or pseudo-epithelial cells which consist of conical cells which line the stomach and the intestines. These
follicles and the glands of the respiratory and the gastrick
4th. Ciliated epithelial cells which are generally of the cylindrical
form, the free extremities of which are ciliated—that is lined with very fine
all the air passages and tubes down to the air cells. We find a tufted
brai and the central canal of the spinal cord.
The second form of tissue, connective, cellular or areolar tissue con-
sists of a meshwork of fibers, in which quantities of white fibrous tissue inter-
abundantly distributed throughout the body, forming a kind of a mater
very plant and elastic. The white fibrous tissue consists of parallel bands
be twisted, tough, thick, and very tough, it is formed into a great number of
connective tissues, ligaments, tendons and fibrous membrane like the
pericardium.
The yellow fibrous tissue consists of a very fine and well defined elastic
fibers about 10,000 fibers per inch. This forms the greater
connective tissue also includes adipose tissue, which consists of fat
cells distributed throughout the meshes of connective tissues. It also includes
and also osseous tissue both in its connective structure, and its
fully organized into the movable joints are tipped,
ure bars joined together like lattice work, and in its compact form, which
find in the shafts of the long bones.
3d. Form of tissues—muscular tissue, is found in two forms, the
involution and hollow muscles as the alimentary canal, bladder, the
smooth and unstriped muscular fibers, or smooth fibers which form the chief constituent of the
coats of the arteries, hollow and hollow muscled as the alimentary canal, bladder, the
virus. Its chief characteristic is its power of nervous stimulation or chemical, mechanical and elec-
trical irritation.
4d. Form is the striated muscular fiber which consists of a pale yel-
lowish fiber, each fiber having a sheath and each fiber being capable of
division into fibrillae. These fibrillae form bundles, the smaller bundle
being called the fasciculi and the sheath of connective tissues by which they are bound together, is called, fascia.

4th. Kind of tissues, nervous tissues. This comprises two distinct structures, the fibres and the ganglionic vesicular. The former kind forms the essential constituent of nerves and the interior of the brain, the latter the different ganglia, the outer layer of the brain and the inner portion of the spinal column.

The vital parts of the human body are composed of these tissues which are complexly arranged enter into the organization of the human system. Some of these organs are so essential to life that, with the cessation of their action, life becomes extinct. These vital organs are termed primary organs and regulate the other organs which are called secondary. None of these organs can act unless the heart sends into the brain a certain quantity of blood, vivified by its contact with the atmospheric air in the pulmonary tis-

The circulation of the blood and its distribution in all the organs is, therefore, the chief phenomenon on which the life of man and of all lower beings depends. This constitutes the life of man from a Phys-iological standpoint. That concludes what we have to say about life from the standpoint of Physiology.

SYMPATHY AND HABIT.

All the different parts of the body are bound together by close relations and sustain these relations by means of sensations and affections—affections used here in its Physiological sense. Now these bonds which unite all the organs by establishing perfect harmony among all the actions taking place in the animal economy are called sympathies. The cause of these sympathies we cannot state. We do not know why such organs are not interrelated in a manner which is so far as it exists in chemical affinity. Nothing in the inorganic world bears any resemblance to this sympathy, be it the magnetic or the electric fluid. In the animal life, however, the connections are apparent and the effect visible, although the cause is not known. The nerves cannot be ex-
clusive media of this sympathy for some muscles which receive branches from the same nerve do not sympathize, and some parts of the body are in close sympathize whose nerves have no connection. Each nervous system forms a separate trunk. There are different kinds of sympathy—that is Physiologically. We will analyze some of these kinds of sympathies.

1st. Functional sympathy: on the part of two organs discharging the same function or functions. Ex., the kidneys may discharge each other's duty. The uterus and the breasts during pregnancy are mutually sympa-
thetic.

2d. Membranous sympathy, which is due to the continuity of the membrane, for example: stone in the bladder associated with an itching.

3d. The irritation of the pituitary gland—which is found, as you know, a physical result of this in the contraction of the diaphragm, and, as this to reaction. When snuff produces too great an impression on the ol-

4th. The principle of life seems to sustain sympathy with habit.—Ex., the action, when irritated by exterior causes—the con-

5th. In the symmetrical organs possibly habit may explain sympathy—

6th. In the case of affections this is explained by habit. Ex., when the sight is directed toward an object as the rectus externus of the eye that acts at the same time as the habit. These examples show us that sympathy exists, but, whether it is It is by sympathy that all the organs concur to the same end and give each fact to the whole system. Sympathy is thus both a physiological and pathological condition.

General diseases always originate by associations in the isolated affec-
tion of an organ or system. This, of course, is a pathological, rather than a physiological condition. The more complex affections—physiological affections—consist really only of one, or a very small number of affections, tautonic, which act upon each other mutual aid. It also explains how local affections spread and give ep-

7th. The glands—the membranes in that case being continuous. Fluid secretion is in a sense habit: as by this sympathetic nervous system, and which tends to increase secretion. These are all examples of the mem-

8th. The irritation of the pituitary gland—which is found, as you know, a physical result of this in the contraction of the diaphragm, and, as this to reaction. When snuff produces too great an impression on the ol-

9th. In the case of affections this is explained by habit. Ex., when the sight is directed toward an object as the rectus externus of the eye that acts at the same time as the habit. These examples show us that sympathy exists, but, whether it is It is by sympathy that all the organs concur to the same end and give each fact to the whole system. Sympathy is thus both a physiological and pathological condition.

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under the influence of habit, for habitual suffering renders us insensible to pain.

The organs of the body, some of them more than others, are influenced in their actions very powerfully by habit. By some physiologists habit is carried so far that they regard death as a natural consequence of the law of sensibility. Life, according to this view, consists of the constant excitement of living solids by the fluids of the body, resulting because the sensitive parts after long habituation to this excitement cease to have the capacity of feeling.

We find a marked difference in the physiological and psychological fields, in regard to habit. The physiological axiom is that habit impairs the sensitive power, whereas the psychological principle is that habit improves judgement. Physiology says impairs and psychology proves—so that habit reduces physical sensibility and improves intelligence, giving facility to all the actions under the control of the will. That finishes what we have to say about habit. We pass on to the

VITAL FORCE.

These words do not represent a being independent of actions, but they represent the sum of those parts which animate living bodies in distinction from inert matter. From a remote antiquity the differences between organized and inorganized bodies have led to the hypothesis of a principle underlying all activity, a force harmonizing all the functions of life and directing them to the preservation of the individual life and species life. This ancient doctrine has passed down to us through the ages almost unchanged—that is the doctrine of a life-principle, subjecting animal life to laws differing from those of inanimate matter, a force that raises them above the mere chemical affinities and a free life-principle pervading the whole system, securing functional harmony and promoting unitary action on the part of the organs—this includes all the organs of the body. All the phenomena which we observe in the living human body are proofs of the existence of this life-principle which animates the body and all the functions of the animal kingdom establish it. The multitude of the phenomena in the human life are reduced to a focus by harmonies, mutual connections and mutual independence. All the powers which animate the separate organs unite themselves and are combined together in this life-principle. The vital power is in constant conflict with the powers which govern inanimate bodies. The law of individual life is always struggling against universal nature. Life is a struggle determined in favor of the individual and death is this struggle determined against the individual; when the individual falls over into the lifeless form. This vital force is constantly influencing, modifying and changing the physical laws. Although the principle of life is not seated in any one organ, or part of the living being, but animates and modifies all parts of the body, life there is in the living body certain parts which are more alive than others and from which others derive their life and motion. These central foci of vitality gradually diminish in number in the animals as we get farther away from man, so that in the lower animals, life is more generally diffused and less centralized, until we reach in the downward scale complete diffusion of life, and loss of centralization. This course is not only traced down into the vegetable life, but also into the vegetable life.

This vital force is not the soul, for this would bring us into the realm of metaphysics. We can illustrate this point by an example: If a nail is thrust into a sensitive part of the body a sharp pain is felt—that is normal-
1st. It is constantly losing energy, and as constantly replenishing its stock of energy.

2nd. In the dead body, all the liberated energy passes off in the form of heat: while in the living body, the liberated energy assumes some form of motion from the most simple movements of the body, or a part of the body, to the most violent and sudden contortions of the bodily system.

3rd. In the dead body external bodies affect it only in setting free quantities of heat which result in decomposition, while in the living body the liberated energy assumes some form of motion from the simplest movements to the most violent and sudden contortions of the bodily system.

The main problem of physiology, therefore, is to explain how the living body can do what the dead body cannot do, namely:

1st. Restore its lost energy through the renewal of its substance and
2nd. Give it out from itself, not only a certain amount of free energy but a certain kind of energy determinate and special. The human body from its earliest stages is divided into parts which are different from each other and become more different—the differentiation increases as growth advances. The cells of the body are differentiated in such a way that groups of cells unite together to form certain tissues, the whole body ultimately consisting of masses of such tissues, each tissue having its own structure. Each tissue differs, not only in structure from every other tissue, but ultimately each tissue assumes particular functions, there being an accurate division of labor among these tissues. Aside from this histological structure of tissue, physiology takes account of two divisions of tissue. You remember histology gives us four divisions, physiology reduces these to two.

The Physiological division is based upon function or use:

1st. Those which are employed in restoring lost energy by renewing the substance.
2nd. Those which are used in freeing energy to be converted into heat and motion. In the main, nervous tissue is used in the production and distribution of nervous impulses and the muscular tissue in the production and distribution of movements, these movements being directed, controlled and harmonized with the environments by nervous tissue. In any case, energy is expended, and this energy being converted into heat leaves the body either in the form of heat or mechanical work. This necessitates the replenishing of energy and the renewal of the substance. In order to assist these two main tissues in the processes of renewal and throwing off waste, all the tissues of the body are brought into service to animate the bodily substance, and so prepare it for use by muscular and nervous tissues, and also, to take up and finally eject from the body its waste. From this standpoint view, three other kinds of tissues are considered.

1st. Tissues of alimentation which take up and prepare the food, and
2nd. Tissues of excretion which clear away the waste materials in order that much of the energy of the various tissues may be used in the process of up-building. These tissues are arranged in organs, and these organs represent mechanisms, whose movements are carried on by muscular tissue under the direction of nervous tissue. Thus we have two classes of muscular tissues, the one concerned with external locomotion, and the other with internal movements. When the food substance is prepared for nutriment, it is carried to the different tissues by means of blood, which, under the control of the vascular system circulates all through the body carrying nutriment to the various tissues, and also, by the respiratory system, bearing the oxygen supply to its tissues according to their needs. This is the brief sketch of Physiology as a science, and of the physiological functions, pathology, of the vital principle which permeates the entire physiological functions, though distinct, are part of that initial arrangement by which the individual life and in the transmission of that life from generation to generation in the life and history of the species.

CHAPTER II. THE BLOOD.

SECTION I. The General Physical and Physiological Properties

The different tissues of the body are interlaced with a network of fine vessels, the capillaries, to which the blood is carried by the arteries, and through these by veins. The blood is an alkaline fluid and is kept in circulation mainly by the force of the heart's action. This blood is in reality a tissue of the body, and in its circulation is really concerned with the whole field of physiological life and in its development, carrying the animalized materials to the different tissues; carrying the oxygen absorbed by the lungs also into the tissues; carrying off its waste products, and assisting in the regulation of the animal temperature. Here we are to consider not this physiological action, but the blood of the body rather than its functions. These functions belong to the different organs of the body.

The blood in its liquid form consists of the plasma, also called the liquor sanguinis, an almost colorless fluid in which flow, at least, four different kinds of corpuscles.

The corpuscles are minute bodies, some regular and some irregular, and are known as the red corpuscles, the white corpuscles or leucocytes, the blood plates, plaque or platelets, and the granules. The blood color when it is seen in a large quantity is called the blood color. This colored substance is due to the presence of the plasma in pigment of a special kind.

The proportion of plasma to corpuscles in size is usually stated about 2 to 1. The plasma is the liquid part of the blood before coagulation and differs from the blood serum, which is the liquid part of the blood albuminous. The presence of the organic materials, physiologically, the blood of the blood rather than its functions. These functions belong to the different organs of the body.

The blood platelets, plaques or platelets and the white corpuscles, plasma is colorless when it is free from the corpuscles, or of a faint straw color when it is seen in large quantities. This straw color being due to the presence of the plasma in pigment of a special kind.

1st. The blood corpuscles are of two kinds, the red and the white, the former being the red corpuscles, or erythrocytes, the plasma of this color when it is seen in large amounts. The blood corpuscles are of two kinds, the red and the white, the former being the red corpuscles, or erythrocytes, the plasma of this color being due to the presence of the plasma in pigment of a special kind.

2nd. The blood corpuscles are of two kinds, the red and the white, the former being the red corpuscles, or erythrocytes, the plasma of this color being due to the presence of the plasma in pigment of a special kind.

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pustules when excretion is prevented, tend to sink—that is, to sink in the plasma. This specific gravity varies among these pustules themselves, and may be different in different parts of the body. The red cells in the blood of different species of mammals are of different shapes. In the red cells of the horse, the red blood corpuscles are more numerous in the horse than in the human, and the human red blood corpuscles are more numerous than in the horse.

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THE BLOOD.

There is no single formula for the composition of the blood in human beings. It varies a great deal with age, sex, and other conditions. The blood consists of corpuscles, plasma, and elements of the blood coats. The corpuscles include erythrocytes (red blood cells), leukocytes (white blood cells), and platelets. The plasma contains proteins, hormones, enzymes, and other substances.

The red blood cells contain hemoglobin, a protein that binds with oxygen and transports it throughout the body. The white blood cells play a role in the immune system, helping to fight infections and diseases. Platelets are involved in the process of blood clotting.

The blood also contains certain gases, such as oxygen and carbon dioxide, which are transported between the lungs and the tissues of the body. The blood also carries nutrients and wastes, and helps maintain the pH of the body fluids.
CHEMICAL COMPOSITION OF THE BLOOD.

The constituents of blood, chemically analyzed, are found to be as follows: Water; proteins, three kinds of which exist in the plasma; and nucleo-albumin; fats and other extractives, such as sugar, uric acid, albumen, and various substances; and lastly inorganic salts. The plasma consists of the three blood-serum and the whole blood contains about 90 parts of water, 1 to 2 parts of fatty substance and albumin. In one hundred parts of other extractives and 9 or 9 parts of the proteins. Fibrinogen: This is the substance in which the blood is dissolved by heating under proper conditions, and it is a very valuable source of nitrogenous food to different tissues, but, whether it is a solid or liquid, is a matter of some uncertainty. Serum albumin: This is a typical protein and is the chief constituent of the blood. It is used in the formation of the jelly substance and is not precipitated by the sulphate of magnesium. It is found in dilute solution in the neutral salt-solvent, and is the chief component of the blood-corpuscles.

COAGULATION OF THE BLOOD.

COAGULATION OF THE BLOOD. The process of coagulation is easily followed. The blood when shed from the vessels very soon becomes viscous and then settles into a jelly or gelatinous condition, quickly becomes more firm, thus preserving the mould of the vessel. If the blood is left in this jelly condition, however, it becomes more compact; it shrinks and yields a quantity of finely yellow colored fluid which is called the blood serum. This liquid appears first in layers on the top, then around the sides, and last on the bottom surfaces of the compact substance—the gelatinous substance. This jelly substance after shrinking assumes a more solid consistency, forming a clot, or, as it is sometimes called, its Latin form, crassamentum. In the process of clotting the upper surface becomes slightly concave; the clot itself assuming the form of a network of fine fibrils, in the midst of which are found entangled the red and white corpuscles. These fibrils are composed of fibrin, an insoluble protein not present in the normal blood. This fibrin appears in the fire threads which hold the clot in its gelatinous condition; the corpuscles being held firmly in the fibrils by the conversion into a network of the soluble phosphates. In the process of clotting the upper surface becomes slightly concave; the clot itself assuming the form of a network of fine fibrils, in the midst of which are found entangled the red and white corpuscles. These fibrils are composed of fibrin, an insoluble protein not present in the normal blood. This fibrin appears in the fire threads which hold the clot in its gelatinous condition; the corpuscles being held firmly in the fibrils by the conversion into a network of the soluble phosphates.

If the blood is vigorously whipped with a bundle of rods the fibrin will be deposited on the rods and the liquid then left will consist of serum and blood corpuscles. This whipped blood is called defibrinated blood, resembling a very blood with this exception, that it cannot clot again. The Physiological value of coagulation is that it causes hemorrhage to cease by binding up the wounded vessel. The time taken for clotting varies, but, normally in human blood, the process is completed in from two to three minutes, assuming the jelly form; in from six to ten minutes. In a few minutes more the first serum drops, representing the third stage, appear. Snedett's goes on gradually, being usually completed in from ten to forty-eight hours.

In the blood of the horse the process of coagulation is slow, allowing the red corpuscles and some of the white cell character of the blood to be observed. The red corpuscles contain about 75 per cent. of hemoglobin, 3 per cent. of potassium salts, the abundance of chlorides and the presence of phosphates or their absence in very small quantities. The blood corpuscles contain about 60 per cent. of water and 40 per cent. of solids. Water and phosphates are found in about 30 per cent. of the red corpuscles. The salts consist chiefly of potassium salts and of salicylate of magnesium. The blood of the pigeon clots almost as soon as it is shed, some say even in the process of shedding; whereas the blood of the chicken may not coagulate at all for ten or twelve days, retaining its liquid form for that length of time. The clotting may be accelerated by the following circumstances:

1st. By the presence of Oxygen, viz., the free access or the air. 2nd. By a temperature a little above that of the blood, for example, hot sponges or fomentations applied to a wound accelerate clotting.

3rd. Contact with foreign bodies, or the increase of the extent of the substance in which the blood comes into contact, for example, the entrance of the vessel in which the blood is placed. Blood will also coagulate in a vacuum, but this may be prevented by taking precautions to prevent agitation of the blood and by keeping the temperature of the vessel nearly that of the blood vessel from which the blood has been taken. Coagulation is retarded and may even be prevented altogether:

1st. By the absence of Oxygen. This may seem to conflict with the statement we made before in connection with the vacuum. But in the
COAGULATION OF THE BLOOD.

Vacuum we have a peculiar condition depending upon pressure and also the condition of the blood as we find it in the vacuum, and this is the foundation of coagulation.

In a temperature below zero or above 60 degrees centigrade. For example, blood from animals which normally clots slowly may be put into the process of coagulation in a narrow vessel surrounded with ice. This vessel may be kept for an indefinite time in a fluid condition. The corpuscles settle—that is in this condition when the blood is put in a narrow vessel surrounded by ice—and this way we get the pure plasma. The best solution to use when securing this salted plasma is magnesium sulphate, carbonates of sodium and potassium, the sulphate of soda, potass. urn, and the alkaline chlorides. In this way we get plasma that is known as salted plasma due to the presence of these a salt of 27 per cent magnesium sulphate.

By saturation of the blood with carbon dioxide (CO₂) digesting, for example, peptones and albumoses. These injected into the living vessel retard coagulation for a long time—we speak of the death of the body. The vessel will not clots after vessel death—the death of the body or after its removal from the

6th. By the use of an extract from the heads of leeches. Normally coagulation does not take place while the blood is in circulation. That is the condition of the walls of the vessels prevents this clotting in any vessel, but in addition to these conditions the blood contains certain substances in an abnormal way that are not present in the living tissue. For example, the base of the heart is usually white in color but is not normal when the blood contains fibrinogen, which is the case of fibrinogen. The blood contains certain substances in the blood plasma and in the lymph and in the blood corpuscles. These substances are caseins of fibrinogen, which when added to the globulin family of albuminous bodies, fibrin being formed by the digestion of fibrinogen with fibrinoplastin or paraglobulin—this last, also, is of the globulin family.

Schmidt, who has investigated the subject for over thirty years, has given us the most recent theory of coagulation.

At first he discovered fibrinogen (this was away back in the '60s, about 61 or 62) which he found in the blood plasma and in the lymph and in the blood corpuscles. This fibrinogen is formed by the addition of neutral salts—salted plasma. The best solution to use when securing this salted plasma is magnesium sulphate, carbonates of sodium and potassium, the sulphate of soda, potass. urn, and the alkaline chlorides. In this way we get plasma that is known as salted plasma due to the presence of these a salt of 27 per cent magnesium sulphate.

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Coagulation of the Blood.

The form of that fibrin—how the formation takes place. We also know that union of fibrinogen and thrombin under the influence of the physiological seeing vessel is that the fibrin and the platelets in the white corpuscles are both contained in the white corpuscles, and as long as these white corpuscles remain intact, none of form by union the fibrin. If this takes place, these three substances escape and the result is that the white corpuscles takes place when the blood is stoked from the living vessels, the former case we have blood coagulation, in the latter case we have intravascular clotting or thrombosis—a condition that is associated in the term may be regarded as a tissue-likethe other living elements requiring constant assimilation and elimination in order to result of certain chemical changes concomitant with the death of the blood death of the body, or the individual, but the blood lives—no such changes take place. Constant chemical interactions are required to sustain blood life, also the body life. It is the blood life that of a liquid protein found in the serum is in line with what we know that we know defective in blood nutrition is this fact that a constant wall. Coagulation does not take place when this relation is preserved; due to injury or to malnutrition, coagulation follows. During the first small vessels suffer from defective nutrition, allowing certain of the blood elements to escape, while the corpuscles adhere together and the plasma mation of the lining membrane of these large vessels destroys the capacity of keeping up the delicate relation of the blood and the vessel walls. On relation of blood to the vessel wall is subjected to great strain we often find examples, a thread introduced into the living and circulating human blood, necessary to produce intravascular clotting is long—that is to say, with Physiologists say for even more than a day, without this coagulation. This is maintained, clotting does not take place. In fact, the tissues die before that blood clot in the vessels, and the blood continues fluid as long as the vessel wall can nourish itself and the blood. In cold-blooded animals the tissue lives longer than in the warm-blooded animals; for example, the heart of a tortoise will live under favorable conditions for two or three days after its removal from the body and the blood will still continue in its fluid condition until after the death of the heart, that is, after the death of the heart tissue. Certain chemical changes must go on in the blood to preserve this integrity—the integrity of the blood, the cessation of these chemical changes results in a clotting in which you which will find fibrin. When the blood is removed from the vessel wall, and the relation is broken, the production of fibrin results—from one of two causes:—either:

1st. Because the blood elements have been destroyed, or

2nd. Because of the impossibility of the reintegration of those blood elements. In either of these cases the fibrin appears as a death element, in the case of intravascular clotting this death element is removed by the vigorous activity of the other life elements like the other body and in the tissues, while in the case of shed blood these life elements cease to exert an influence and hence complete coagulation results. This finishes the subject of coagulation of the blood.

Section 4. Quantity of Blood.

The total quantity of blood in the vascular system gained by balancing the blood supplied by the tissues which give to, and those which take away from the blood is estimated approximately by various physiologists. The method used by Welcker is called the colorimetric method, which consists in bleeding the animal as thoroughly as possible and weighing the blood thus obtained, afterwards washing the blood vessels very minutely with distilled water and estimating the amount of haemoglobin in the blood washings. The result is that, in man, 7.7 percent of the body weight is found to be blood, or about 1.13 of the body weight; for example, in the case of a man weighing 68 kilograms we find about 5,236 grams of blood in the body—that would bring it to just about 1.13 of the body weight. In the newborn child the blood is found to constitute 5.25 percent of the body weight—that is 1.19 of the body weight, compared with 1.13 in the adult. To which are so favorable in physiological experiments—the blood has been found to weight 5 percent of the body weight—that is 1.20 of the body weight. In the same individual the variation is very large at any moment, because a sudden drain upon the water of the blood, for example, by profuse perspiration is counteracted by the passage of water from the tissues to the blood, and vice versa—the reverse condition.


ABNORMAL CONDITIONS OF THE BLOOD.

This subject is sometimes excluded from physiology by physiologists because it belongs to pathology, but it is like some other subjects; the subject is excluded from physiology because it belongs to pathology and it falls down between the two. So the best way is to take it up now. Several abnormal conditions of the blood have physiological bearings; for example, in polysemia; there is an increase in the entire mass of the blood; there are several signs of this polysemic condition; for example, the blood and the hard and full pulse. When accompanied with the body weight, the increase in the arteries we find vertigo and congestion of the lungs. This polysemic condition may be produced artificially by transfusion—that is by the injection of blood of the same species into the living vessels. If the quantity of blood is increased from 80 to 90 per cent, there is no danger to life, because this increase in the arteries may be accommodated in the distended vessels. But if the cause of death would be in this case the sudden rupture of some of the vessels which distended to such an extent that it would result in rupture, most noticeable effect for the longest period—that is, there are other effects before there is an increase of blood pressure, the restoration of albumin and the chemical property of the developing corpuscles on physiological and pathological action of the blooded animal. Hemorrhage seems to have much less effect upon the life than in the case of the warm-blooded animals; for example, the frog is able to live for a period without blood. The life of the blood vessel is to be injected with a solution of 75 per cent. of sodium chloride and the vessels—the vessels were washed out. The frog continued to live for several days eliminating normally carbon dioxide. This experiment seems to indicate, physiologically, that the carbon dioxide is formed not in the blood, but in the tissues of the body.

In anemic persons it is found that proteid composition is increased, resulting in an increased excretion of urea, whereas fat decomposition is decreased. This is due to the presence of animal and vegetable parasites, most important, giving rise to abnormal conditions, which are discussed fully in Pathology. Some of these, especially the vegetable organisms have the power of multiplications very rapidly in the blood, and, as we have seen Physiologically, the blood may be rendered immune against these bacteria. That finishes the abnormal conditions of the blood.

SECTION VI. Variations in the Composition of the Blood Normally.

The blood is influenced by a great number of conditions, including diet, age, temperament and sex. The dietary conditions will be referred to later in connection with other diseases. Aristotle, one of the old Philosophers, said that to put the cattle in anemic condition artificially, that they could be more easily fattened when recovering from this condition. It is not only so in the human, but also in the animal life. Among the abnormal conditions of the blood we find the presence of animal and vegetable parasites, most important, giving rise to abnormal conditions, which are discussed fully in Pathology. Some of these, especially the vegetable organisms have the power of multiplications very rapidly in the blood, and, as we have seen Physiologically, the blood may be rendered immune against these bacteria. That finishes the abnormal conditions of the blood.

Newly born children seem to be seriously affected by a small loss of blood, whereas in the adult life, one half of the blood may be lost without any serious results. Stout and aged people bear the loss of blood with less vigor. There seems to be a connection between the fat substances of the body and the fact that explains this—something will be said of this later. The more rapid the loss of blood, the more dangerous it seems to be. If the hemoglobin is not sufficient to cause death, the fluid portion of the blood and the blood salts are restored by absorption from the tissues, followed by an increased blood pressure, the restoration of albumin and the formation, and increase in the number of red corpuscles. Regeneration—the reintroduction of the blood—sets in in a few hours after a slight hemorrhage and in from one to two days after a severe hemorrhage. During the process of regeneration the number of corpuscles in the different stages of their development increases, that is, by the formation of corpuscles containing less than a normal amount of haemoglobin. That is the physiological and chemical property of these developing corpuscles.

In the cold blooded animals hemorrhage seems to have much less effect upon the life than in the case of the warm blooded animals; for example, the frog is able to live for a period without blood. The cold blooded animals hemorrhage seems to have much less effect upon the life than in the case of the warm blooded animals; for example, the frog is able to live for a period without blood. The cold blooded animals hemorrhage seems to have much less effect upon the life than in the case of the warm blooded animals; for example, the frog is able to live for a period without blood. The cold blooded animals hemorrhage seems to have much less effect upon the life than in the case of the warm blooded animals; for example, the frog is able to live for a period without blood. The cold blooded animals hemorrhage seems to have much less effect upon the life than in the case of the warm blooded animals; for example, the frog is able to live for a period without blood. The cold blooded animals hemorrhage seems to have much less effect upon the life than in the case of the warm blooded animals; for example, the frog is able to live for a period without blood.
VARATIONS IN THE COMPOSITION OF THE BLOOD NORMALLY.

In the case of bleeding, the specific gravity of the blood—that is in hemorrhage which we spoke of before—is diminished, so much so that the blood is due to the absorption of liquid from the compressed body. Physiologically, blood is absorbed in the tissues, and hence, gives the desire for water-thirsty condition.

The composition of blood varies in different parts of the body, arterial blood differing from venous blood, and there are three special differences between arterial and venous blood.

1st. In the arterial blood we have a bright scarlet color, in the venous blood, we find a dark purplish color, due to the deoxidation. Arterial blood contains less carbon dioxide and more oxygen than the venous blood.

2d. Arterial blood coagulates more rapidly than venous blood.

3d. The normal venous blood. The other three are variations from this.

2d. Splenic venous blood—that is the blood, of course, in the splenic large amount of protein matter and yielding a fibrin in case of coagulation colorless corpuscles and the plasma is deeply colored on account of the discolored hematin. On account of the deficiency of red corpuscles, the matter seems to be greatly diminished.

3d. Portal venous blood: The blood that is carried in the portal vein to the liver, coming from the gastric and mesenteric veins which contain the digestates, and also from the splenic vein; this portal blood contains the qualities of the blood coming from the gastric mesenteric veins. Those who think that in the gastric and mesenteric veins vary according to the digestates of the digestive organs—clear in solid matters chiefly in the red corpuscles. On account of the quantity of water absorbed it contains a large proportion of proteins and gives a much less characteristic fibrin than the ordinary blood.

Hepatic Venous blood. This is found to contain a smaller proportion of water, salts and protein matter than the portal blood. At the same percentage, this group sugar found as a constant element, sometimes in the standard of blood are Physiologically of great value in connection with the alimentary function. They are mentioned here to bring them into the subject of blood, because we treat here of the general conditions of the blood.

SECTION VII. The Lymph and the Blood Glands.

It is a matter of discussion with Physiologists whether the subject should be discussed under the subject of the blood, or later. It seems to come in is no other place where it could come, except in the discussion of the different functions of the body, unless it is to come in connection with the glands.

LYMPH AND THE BLOOD GLANDS.

Lymph is a colorless fluid, resembling the blood plasma, and is found outside the capillary walls, filling the extravascular spaces of the body. All the tissue elements and the outside of the capillary walls are said to be bathed in lymph. The entire body, except the epidermis and the epidermal structures, is supplied with this blood plasma filters through the capillary walls, together with white corpuscles and in some cases the red corpuscles. These pass into the lymph and bring to the tissues of the body nutrition and oxygen and carry off the waste. This lymph fills the extravascular spaces which open into the lymphatic vessels, which unite to form larger trunks, forming thus two main trunks: the thoracic and left lymphatic duct and the larger or the right lymphatic duct. In this way a double interchange takes place from the blood to the tissues and from the tissues to the blood, the lymph.

When this is accomplished—that is this double interchange—blood enters from the blood lymph to the large lymph vessels, which in turn carry away from the tissues the products of the material coming from the blood vessels as the tissues, as well as the waste products from the tissues. In this way the changes in the lymph and in the tissues take place through the medium of the lymphatic channels in this lymph, making it, therefore, most important in connection with the blood. Lymph is essentially the same as the blood plasma, containing the three blood proteins, the extractsives, and also the salts. The extractsives, particularly larnogen, are less in amount in the lymph than in the blood. This lymph consists of a colorless fluid, containing leukocytes and small bodies of fatty substance, which are very numerous after meals. Formerly lymph was supposed to be derived from the blood plasma by a process of filtration through the capillary walls. In recent times, this process of filtration through the capillary walls has been shown to be insufficient to account for the contents and the composition of the lymph. There are two physiological opinions on this subject.

1st. Those who explain the composition of the lymph as due to filtration through the capillary walls and diffusion from the blood plasma and filtration, and they assume a process, according to the action of the cells composing the structure of the capillary walls. So that, according to these theories, filtration is the filtrate and filtration is the secretion—which would represent the metabolism of the lymph. At the present time it is impossible to say anything more on the subject than simply to quote these and no particular points on either side to show that one opinion is more physiologically correct than the other. Indications seem to point in the direction of the second opinion so far as we have the process of filtration through the capillary walls and diffusion from the blood plasma and also the secretion in connection with the blood. All of these lines of the capillaries. Blood takes in new supplies from the alimentary canal and lymphatics. From the first it receives directly through the blood vessels or indirectly through the chyle, by the latter, of course, we mean the alimentary canal; from the second—that is the lymphatics, it receives the lymph—the lymphatic vessels. Respiratory gives a fresh supply of oxygen. And finally certain elements come to the blood from different parts of the body and these processes of the body that furnish these supplies being sometimes called the blood glands. This is not a very suitable expression because most recent investigations have shown that these ductless glands are not blood glands at all. Although it is not scientifically correct, it is better to adhere to it because they are called in Physiology.
THE LYMPH AND THE BLOOD GLANDS.

These are six in number, (1) the lymphatic glands; (2) the glands of suprarenal capsules; (3) the lymphatic and the Peyer's glands; (4) the spleen; (5) the Thyroid body and (6) the parotid and submaxillary, the latter in connection with circulation and alimentation. All these glands resemble the lymph corporcles, they are also very vascular and they have no ducts, being what are called the ductless glands; they have been called blood glands; because they are supposed to be connected with the formation of blood. The lymph corporcles are supplied by the lymph and the chyle. These are chiefly from the adenoid tissue of the lymphatic glands, being washed out by the lymph corporcles in the adenoid tissue of the villi. These lymph corporcles are constantly flowing into the blood and these are identified with the colorless corpuscles in the blood. These colorless corpuscles accumulate in the blood and in some way are connected with the red corpuscles of the blood. These colorless corpuscles which exist in large numbers, in some way cause the disintegration taking place in connection with the liver and the spleen. Phosphate of iron found in the spleen is derived from the haemoglobin the large proplastic cells inclosing the corporcles and causing their decomposition. In order to supply the blood with fresh material, the process of blood formation goes on as a counteracting influence to decomposition.

The question as to the origin of the colorless corporcles is one that has been greatly discussed in the field of physiology. These colorless cells are the haematoblasts which are found in the spleen and especially in the red marrow of the bones. As found in these, the spleen and the red marrow of the bones, they are found to be colorless, granular, contractile bodies, very much like the leucocytes. The nucleus is a large, oval cell, the original blood plasmaic cell is sometimes spoken of as the cell of the red marrow. Later in the nucleus is destroyed and the colorless corporcles form the red corporcles. In mammals the red corpuscle is not therefore a modified nucleus, but it is a part of the substance of the Neumann's corpuscle.

1st. The colorless corporcles originate rapidly by the division of the lymphatic corporcles in the lymphatic glands and also in the Peyer's glands. In the anodendritic tissue of this organ being full of pale corporcles. The red bone marrow—that is the red bone marrow—forms the first formation of the colorless corporcles. It contains fere and great cells. We find these sometimes spoken of as the leucocytes of the blood. These large nucleated cells are found very abundantly in embryonic life. Up to the fourth week of that embryonic life, only such nucleated cells are found, that is, no other cells are found in the human emm

bruy up to the fourth week. After this the nucleus becomes smaller, and, in a longer time the nucleus entirely disappears, and the corpuscle assumes its final form in the urogenital life. After birth the red corporcles are formed from these nucleated colorless corporcles, especially in the red marrow of the bones; a fresh and extra-uterine life the thymus, thyroid body and the suprarenal corporcles are supposed to have blood forming functions; which later in life it is probable that their chief function is to use up and divest into simpler bodies the elements of the blood—that is, to prepare for the blood and to form the elements of the blood. As these bodies are ductless glands, new blood cannot be secreted, and, hence they pass by a relatively short period of time, the body is still for further use. These bodies, the thymus, the thyroid and the super-renial corporcles have the function of disintegration, differentiate with the action of these glands of the blood that unite and back up the process of reintegration into the formation of the blood once more.

2d. The spleen is undoubtedly a blood gland, whatever other functions it may discharge. The spleen pulp consists of a mesh-work of delicate fibrous tissue which holds to the meshes of this pulp, the lymph corporcles, and also the free or liberated red corporcles. The spleen seems to discharge a double function. (1) That of forming corporcles, and (2) of destroying the colorless corporcles. The spleen is also the seat of other operations, such as the decomposition of albuminous compounds and also of acid formation. That is still in line you will notice with the functions of the spleen as a destroyer or decomposer. The spleen, however, can be dispensed with entirely. It has been removed from the body and this removal has taken place without any cause, temporary, but when the local temporary disturbance is removed there is no permanent disadvantage following. In this case of the removal of the spleen it has been found that the lymphatic glands and the red marrow become more abundant with the colorless corporcles, and hence more active in the formation of the blood corporcles. The spleen is a kind of venous sympathie discharge the spleen function as well as their other function.

3d. In the last stages of the uterine life and the first stages of the extra-uterine life the active growth of the tissues takes place and a large supply of blood becomes necessary. In order to assist this active development of tissues and blood corporcles, the thymus gland seems to assist the red marrow of the bones, the lymphatics, and the spleen in the formation of corporcles. Later in life after this rapid development ceases the thymus gland becomes absorbed, and, in the case of man finally disappears when manhood is reached.

The thyroid gland. In the early uterine life this thyroid has a duct which opens into the foramen of the tongue, but this duct fails to develop. The thymus gland, disappears. Each lobe shows closed sacs which are filled with fluid and also the leucocytes and the red corporcles, partly disintegrated and also partly decolorized—deprived of color. This thyroid gland, if it is greatly enlarged, is often associated with a form of idiocy, Goitre and cretinism, the latter of which is often associated with a form of idiocy. Some say the removal of this gland results in mental weakening—that is, it produces an artificial cretinism. After removal certain changes have been observed bearing upon the gland function; for example, the red corporcles are found to be diminished in number and the white corporcles increase in number. The salivary glands enlarge and
the parotid gland which is normally serious, begins to secrete mucin this mucin being found even in the blood. This furnishes the only evidence that we have that the thyroid is a blood forming body.

5th. The supra-renal bodies. These bodies are found to be large in the uteri, at the end of the third month of the uterine life being as large as the kidney. The medullary part which at first is outside of the cortical part wards is exhausted by it, containing albuminous bodies and pigment. A watery blood. McMunn, a physiologist who investigated this subject, has observed hence, he claims that their function is to pick out of the circulation worn out and useless products in the formation of new coloring matter. An abnormal condition of these bodies not discharging their proper function results in the condition of Addison's disease, which is the collapse of the sallow or bronzed tinting of the skin, accompanied by giddiness and the symptoms of the visceral organs. The pituitary gland, must be classed with these other glands on account of its supposed influence upon the blood supply to the brain. The supply of new material to the brain must therefore be summed up as follows: (1) By vascular absorption through the alimentary canal; for example, water, sugar, proteins, simple sugars, salts and fats; (2) Lactase absorption, also through the alimentary canal; for example, oxygen, aqueous vapors and volatile matters; (3) Through the skin, for example, water and the lactic acid; for example, oxygen, aqueous vapors and volatile matters; (4) Through the muco-mucous membrane of the lymph or the lymphatic vessels into which the fluid matter has been brought efficiently; certain protoplasmic elements and lymph cells in which certain exchanges take place between the lymph and the blood; for example, the colored corpuscles of the blood are formed from these lymph elements, or protoplasmic cells. This furnishes the subject of the blood.

CHAPTER III. CIRCULATION OF THE BLOOD.

SECTION I. GENERAL STATEMENT.

By the circulation of the blood is meant that the fluid during life is contained in a continuous system of elastic and contractile vessels, that this fluid moves along this continuous course, always returning upon itself in the course of its flow, and that this blood, whatever may be its constitution, moves along in a definite direction, never in the opposite direction.

Harvey, the discoverer of the circulation of the blood, says, that the current of the blood is a perpetual movement of the heart, by the blood, Harvey, dates from 1616. This continuous system consists of the heart; the arteries or the veins; the veins, the arteries terminating in capillaries out of which the blood comes from the body to be passed on to the lungs, and the left half containing the blood passed from the lungs to the left pulmonary artery. The circulation of the blood is said to be two fold; the blood from the right side of the heart through the pulmonary artery to the lungs, through the lung capillaries and back again to the left side of the heart through the pulmonary veins. In this way we have, the direction of the circulation is determined toward the lesser pressure. The blood which is the entire system, mainly through the capillaries whose fine walls are so delicate that the different elements from the circulating blood pass through the walls of the capillaries, while certain elements of the tissues pass through the walls of the blood and tissues by the medium of the lymph. This constant inter-
change accounts for the fact that there is scarcely ever, if any, appreciable change in the volume of blood. There is as much absorption one way as the other and the difference of the volume of absorption would cause an abnormal condition, and so we have in the venous circulation, no difference in the volume of blood, from what we find in the arterial circulation. If there is a difference it is very slight. The vascular mechanism is so designed that the blood must pass through the minute vessels where the chief work of the blood is done—that is in the capillaries, in such a way as to secure the efficient interchange of these elements. From this general statement we find that the circulation consists of four distinct elements: (1) The heart, whose chief function is to force the blood into the arteries, through the capillaries and thence into the veins. We speak of this first function, because there are other functions, of course, which the heart discharges. This being the case, it is evident that the heart is the chief organ of the circulation. (2). The arteries, whose chief function is to convey the blood from the heart to the capillaries. (3) The veins, whose chief function is to convey the blood from the capillaries to the heart. (4) The capillaries, including the minute arteries and minute veins, beginning in the capillaries, whose chief function is to perform the double interchange we have just spoken of, between the tissues and the blood, and the blood and the tissues.

To understand the circulation is to follow out the blood in its course along this blood path noticing the phenomena manifested at each point and the influences bearing upon the circulation at any one point and on the circulation in general. For convenience the circulation of the blood may be divided into three parts. 1st. The heart as the center of the vascular mechanism. 2d. The blood vessels, and 3d the general circulation, its mechanism and action, including the blood and lymph. Some Physiologists discuss first the capillary circulation because the all important phenomena in connection with blood and tissue interchange are found there. It is better however in systematically discussing the circulation to commence at the great force which represents the center of the circulatory system.

SECTION 2. General Physiology of the Heart.

The heart is a hollow muscle, covered on the external surface with a serous membrane, the pericardium, and on the interior is lined also with a serous membrane, the endocardium, continuous with the lining of the blood vessels. The heart is thus enclosed in a membranous sac and lies behind the sternum and costal cartilages, the base rising upward, falling backward to the right and reaching from the fifth to the eighth dorsal vertebra. The apex reaches downward to the left and its base is in the living subject in the interspace between the fifth and sixth ribs slightly below and to the central side of the nipple. Thus the heart lies obliquely in the chest cavity projecting into the left side of the cavity.

The heart is composed of a special tissue together with connective tissue, vessels, that is, blood vessels, lymphatics, nerves and ganglia. The cardiac fibers are intermediate, both in structure and in function, between the striated and the striated fibers. The muscular mass of the heart is called myocardium. A considerable mass of fibrous tissue and fibro-cartilage is seen at the base of the heart between the openings of the aorta and the two auriculo-ventricular orifices from which pass different processes forming the base of those tendinous rings at the auriculo-ventricular and the arterial openings. To these bands or rings are attached the muscular fibers laid out in layers. In the embryonic life the heart is tubular in shape, or form, its fibers being arranged in an external circular and an internal longitudinal lam. As the heart develops during the embryonic life the longitudinal form becomes less pronounced and the venous portion being doubled over upon the arterial portion, the fibers being in the single cavity of the auricle and the ventricle, such as we find in the embryonic life becomes divided into two, when the septum is formed, dividing the original single chamber into two. In the case of the auricle, the fibers remain less complicated than the e of the ventricle, the fibers of the ventricles being arranged in a spiral form. The fibers of the auricles are perfectly distinct from those of the ventricles, being separated by tendinous rings, these fibers forming two layers; an inner longitudinal set for each auricle and an outer transverse set for both auricles. The pericardium is a conical shaped sac, its base resting on the diaphragm and its upper part encompassing the root of the aorta and the brachio-cephalic, subclavian and the one or the two lower layers of the thoracic aorta.

The heart is thus enclosed in a membranous sac and lies behind the sternum, the pericardium being the serous membrane which covers the outer surface of the heart. The pericardium includes the heart, the blood and the lymph. The blood and the lymph contain the blood and the tissues. It is better however in systematically discussing the circulation to commence at the great force which represents the center of the circulatory system.

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tinuous with the last internal layer, the second external with the second last internal layer, and the third external and the third internal layer. The pericardium is a conical shaped sac, its base resting on the diaphragm and its upper part encompassing the root of the aorta and the brachio-cephalic, subclavian and the one or the two lower layers of the thoracic aorta.

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in the walls of the ventricles upon contraction give rise to it great force, so that the blood can be driven out with force. The valvular arrangement is of great value, physiologically, in connection with the action of the heart. The tricuspid valve protects the right auriculo-ventricular opening. The tricuspid valve consists of three flaps, hence, the name, tricuspid valve, of fibrous and of the heart. These surround the opening and are kept in place by the tricuspid opening and consists as its name indicates of two sections or segments of a pointed character and of the same composition as the tricuspid valves. In extending from the atriales to the sections of the valves. In this way the valves become shorter at the base and so a larger orifice is presented functionally of great importance. At the base of the segments or cusps the base of the valves. The aortic and pulmonary orifices are protected by the aortic and semilunar valves. Each of these segments consists of a layer of concentric fibers which act with a constriction force towards the aortic and pulmonary valve. Each of these segments or cusps is bound by its external surface to the aortic semilunar valve and the exposed part on the inner side of the heart substance. The aorta, coronary artery, and the large vessels of the chest, and the character of which are of importance in the diagnosis of disease. Some physiologists have ligatured the coronary arteries in dogs and found that in two minutes cardiac contractions give place to twitching of the muscle first the ventricle, then the other ventricle and finally the aorta.

THE PHYSIOLOGY OF THE HEART'S ACTION.

In the case of hardening of the coronary arteries found in old age, there is diminished action with heart weakness. This hardening is sometimes from the cessation of the heart simply due to old age. Death may occur sudden, estimated according to Lennec to be about equal to the closed hands. In the about 5 grams to one kilogram. When the body weight is from 50 to 90 kilo grams the proportion is 4 grams to one kilogram, and when the body weight is heart weight to body weight according to this would be 1 to 150 or 1 to 270, mean weight of the heart in the adult male is from 309 to 313 grams. In the 270. The two ventricles seem to be about equal in their capacity, although ventricle is larger than the left ventricle, but this is due to the fact that the left ventricle is usually empty of blood, while the right ventricle is filled with wall of the right ventricle. The thickness of the left ventricle at this middle portion is about 11.25 to 11.40 millimeters; in the female it is slightly smaller, 11.15. In the case of the right ventricle the average thickness in the male 3.8 to 4.1 and in the female 3.6. These represent the physical properties connected with the heart.

SECTION III.—The Physiology of the Heart's Action.

If the heart is placed on the chest between the 5th and 6th ribs below and internal to the central part of the left nipple and is examined in this way, it is palpated. The method over the heart or in connection with the stethoscope certain sounds are heard, method of percussion is called auscultation. By means of percussion the relation to the lungs and the presence or the absence of the fluids in the pericardium is also used for the purpose of registering the action of the heart. The movements of the heart are found to consist of a series of contractions occurring systole while the condition of relaxation is called diastole. The two auricles and the auriculo-ventricular contractions and the vibrations of the ventricles. This gives us a systole and diastole of both the auricles and ventricles.

As we have seen the heart is a double organ with an auricle and a ventricle in each lateral half. In each part the contraction and relaxation of the auricle is followed by the successive contraction and relaxation of the ventricle. Following this succession of contractions and relaxations there is said to be in the systolic; the diastolic; the diastole of the closing with the diastole of the whole heart is called the period of the period of revolution or the cycle of a cardiac cycle. An auricular systole occupies 1-5 of the entire period of revolution. One-fifth would correspond with the systole, the ventricular systole, 2-5 of the entire period of revolution followed by the period of rest, which
occupies the balance of the 5-5, which would be 2-5. These correspond with
the three periods of the cardiac cycle. The auricular systole immediately pre-
duced the ventricular systole and the commencement of the ventricular systole is
simultaneous with the beginning of the auricular diastole. The auricles
and the ventricles being thus in diastole 2-5 of the whole period of revolution
which would be 2-5. The two physiologists who have investigated this subject,
Marey and Chauveau, have made use of the cardiac sound in connection with the tracing of the move-
ments of the heart—a notch on the heart in this case. This cardiac
sound is very much like the surgeon's sound which is used in connection with
the bladder.

This sound is passed into the right side of the heart through the jugular
vein in the direcetor vein—a horse is supposed to be still living—the lower
end of the sound with its elastic bag being passed down into the heart
while the upper end of the sound, also with an elastic bag, remains in the
auricle. The bag is placed in connection with a recording instrument—in this
case it was tambour of Marey—and along with the cardigraph, which is applied
externally upon the apex of the beating heart, they are attached to a revolving
cylinder, the variation in diameter, of course, the variations found in connection with the elas-
tic bag being regarded as a tracing on the black cylinder. If there are
two tracings present, the one representing the lower elastic bag, the upper
elastic bag, and then the one that represents the cardigraph from the
apex of the heart. As a result of this experiment the following points have
been noted physiologically.

1st. Auricular contraction is more sudden than ventricular contraction.

The tracing gives as a ventricular set of curves and an auricular.

2nd. The ventricular contraction lasts longer than the auricular con-
traction.

3rd. Auricular contraction and relaxation occupies almost equal periods,
whereas, ventricular relaxation is almost twice the length of ventricular con-
traction.

4th. As a result of what is contained in the third point, auricular move-
ments are found to be uniform and present a wave like appearance, whereas,
there are auricular irregularities in the ventricles.

5th. Auricular movement precedes the ventricular and the impulse of the
neck against the chest wall occurs during the ventricular movement.

6th. Ventricular contraction influences the pressure in the ventricle.

7th. During the ventricular contraction, there is a marked pressure in the
ventricle at least to the pressure of the blood from the veins out side of the
chest to those inside of the chest and thus promoting circulation towards
the heart—not into the heart but in the direction of the heart. While this takes
place the ventricles being emptiing blood through the auriculo-ventri-
cular opening, before the ventricles are distended because the auricular capacity
is traction of the auricular walls and the emptying of its cavity—auricular cavity—
pressure into the auricles. These movements rapidly pass over the auricular val-
ves. This wave of contraction running along the ventricular orbi-
olar artery in the auricular systole drives the

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THE PHYSIOLOGY OF THE HEART'S ACTION.
section IV.—Changes in the Heart.

Changes in the active beating heart are so rapid that they cannot be observed so as to form any adequate conception of the exact nature of these changes. The ventricles are constantly changing in their form. For example: the cone shaped cylinder is pouring into their cavities from the heart by the auriculo-ventricular openings during the increase of the pressure on the sides, while the wave of pressure contraction is passing along the walls; while that pressure is acting upon the blood contained within these cavities in driving it into the arteries; and finally during the relaxation of the walls after the expulsion of the blood.

During systole the ventricles become tense, being larger during diastole, the difference in size being measured by the blood that is driven out. The whole contents are driven out at each stroke, the emptying varying in different individuals.

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close contact with, retires from the chest wall and pericardial attachments of the mediastimum draws the chest wall after it.

In this space which becomes protruded by the impulse, the soft parts are found to be slightly drawn in, this attraction, caused by the lessened size of the contracting ventricles, being called the negative pressure. During the ventricular systole, the heart-form changes. During rest the heart is an oblique cone with an elliptical base, during systole it becomes regularly conical and the base becomes circular. During contraction the apex inclines upward and forward, being driven into the intercostal space, the ventricles turning on the long axis from left to right partially exposing the left ventricle. This twisting motion gives the impulse which is produced by the contraction of the obliquely placed fibers of the ventricles drawing up the apex, this movement being assisted by the spiral form of the aortic and the pulmonary arteries. It has been stated by some Physiologists that the impulse is partly due to the reaction of the ventricles, producing a recoil when the cavities are emptied of blood so that the apex is pushed outward and downward. Other Physiologists assign the impulse in part to the elongation of the aorta and pulmonary artery on account of the negative pressure exerted by this artery on the aorta. The negative pressure is pushed outward and downward towards the chest wall. These actions may assist in producing the impulse, but the main cause is the twitching movement of the ventricles. That this twitching movement is the cause of the impulse is evident, (1st), from the fact that the impulse takes place, even when the heart cavity is empty of blood; as, for example, in case of severe hemorrhage. Even in this case—of severe hemorrhage—the ventricle seems to harden and this hardening changes the direction of the heart, turning it around and producing a twitching against the cavity of the chest wall. (2d). This is still more evident from the fact that an empty heart entirely removed from the body and placed upon a table or some flat surface raising its apex as it hardens in the systole, the same impulse being felt in the case of the heart under these conditions if the finger is placed over the rising apex. In the fact that it is a change in the heart itself—raising the question of the presence of the blood and not the question of recoil, but simply the twitching movement of the heart itself.

In order to produce the tracing of the apex beat, or a cardiogram (the instrument is the cardiogram and the tracing on the instrument is the cardiogram,) various instruments called cardiographs have been invented. The improved cardiograph of Marey consists essentially of a tambour with a button attachment to the membrane, which is applied over the apex beat. The motions of the air inside the capsule—in this case it is air motion—are communicated by means of a tube to a recording tambour. The tracings which are obtained give distinctly the contraction of the auricles contracting in the direction of the axis of heart from the right upwards toward the left downwards and causing the apex to move slightly towards the chest wall. Smaller contractions give slight curve elevations. These smaller contractions being due to the contraction which takes place at the ends of the veins and the atrial appendages. This lower follows the curve representing the greatest impulse which is caused by the contraction of the ventricles. This contraction is synchronous with the first sound, these sounds will be discussed in connection with the cardiac sounds. The curve then rapidly falls when the ventricles relax, the blood in the aorta and pulmonary artery being driven back by the recoil of the arterial walls, thus closing the semilunar valves. This impulse is communicated to the apex of the ventricles causing oscillation of the intercostal space. It would seem from the tracing of the curves that the aortic and pulmonary valves do not close simultaneously—the aortic valve closing first and then about 1-100 of a second later the pulmonary valve. This difference is due to the greater aortic pressure—the aortic is greater than the pulmonary pressure and in this case the aortic closes before the pulmonary valve. The tracings as found by Landois and Marey by his improved cardiograph show the same very much like that; that is, the tracing which represents the normal movements or movements in connection with the condition of elements in the cardiac cycle.

The heart seems to exist chiefly for the purpose of exerting a pressure upon the blood in its cavities so as to secure the normal circulation. It is difficult to state these movements because the mercurial manometer fails us in this case. The most convenient instrument to use is a long tube open at the top end and filled with a flotation of sodium carbonate. This tube may be introduced through the jugular vein into the right auricle and the right ventricle, by establishing a communication between this tube and the mercurial manometer, in this case it is the maximum and minimum instrument, records the pressure of the pressure of these three cavities; the right auricle, the left auricle and the right ventricle. In this case we get the maximum and minimum pressure attained in each one of these cavities. As a result of this it is found that the maximum pressure in the left ventricle is greater than the normal pressure in the aorta, that the maximum in the left ventricle is also greater than the maximum pressure in the right ventricle and in the right auricle the pressure is greatly diminished. In connection with the minimum records it is found that there is a negative pressure, that is a pressure less than the atmosphere. This negative pressure may be partly due to aspiration in the respiratory processes but even when we take account respiration it is found that there exists still a negative pressure, at least, a negative pressure in the left ventricle which is very distinctly marked. This means that at some point in the cardiac cycle there must be a negative pressure normally. This negative pressure may arise in one of the following ways:--

When the blood is driven out very quickly from the ventricle into the aorta a negative pressure seems to arise. This pressure partially accounts for the closure of the semilunar valves and therefore, this negative pressure would be greatest at the orifices of these valves. The manometer is so formed that this negative pressure temporarily indicated that the reverse of this is true in the case of abnormal negative pressure. That the greatest negative pressure seems to exist within the cavity of the ventricle itself. For this reason this could not satisfactorily account for the negative pressure, therefore, we have the second explanation.

It is, in all probability from the rapidity of the ventricular process of relaxation, representing in the rapidity of the relaxation of the aortic and pulmonary valves, from its contraction to its normal condition. This will also account for the greater negative pressure that is found in the left ventricle because the thickness of the wall of the left ventricle is much greater than that of the aorta and therefore the rapid contraction of the left ventricle will produce a greater negative pressure. This negative pressure assists the circulation of the blood by setting up a suction which is communicated to the blood that has been collected in the auricle into the ventricle, using up almost instantly the negative pressure and preventing it from exercising any disadvantageous influence upon the circulation. The only effect of this negative pressure is to lower, and practically to exhaust the negative pressure in the auricles without extending backward to the veins. In regard to the cardiac pressure in the ventricles we may conclude, therefore, that there are four different phases.
DURATION OF THE CARDIAC MOVEMENTS.

1. The rapid growth of pressure in the ventricles greatly increases until it becomes greater than the aortic pressure when the aortic valves are thrown open.

2. Following this the blood escapes into the aorta while the contraction of the ventricular walls still continues.

3. This continued contraction of the ventricular walls secures the complete emptying of the cavities of the auricles.

4. The sudden relaxation of the ventricular wall, during which there is set up the negative pressure, this negative pressure establishing the connection between the ventricle and the auricle by which the blood is induced to pass from the auricle to the ventricle.

DURATION OF THE CARDIAC MOVEMENTS.

The whole cardiac movement is termed a cardiac cycle and consists of three phases, the systole of the auricles, the systole of the ventricles and the pause or diastole of the auricles and ventricles, which consists of the diastole of the ventricles, including the period between the commencement of contraction again; and of the diastole of the whole heart, including the period amounted from the end of the ventricular relaxation to the beginning of auricular contraction, during which the walls are neither contracting nor relaxing, the cavities being passively filled with blood. By using the instrument (cardiograph) in connection with the kymograph, the velocity of the surface on which the tracings are made can be estimated and thus approximation made to the time occupied by the cardiac movements. It is found that the systole of the auricles is very short, whereas that of the ventricles is much longer, occupying a considerable part of the cycle period and the diastole of the whole heart varies considerably, in slowly beating hearts being longer and in quick beating hearts, shorter. From this we would conclude that the faster the heart beats, the briefer the diastole and that the ventricular systole.

The chief data used is that in connection with the first and second sounds. This period has been found to vary from .225 to .340 of a second, the variation being small, indicating that the variation takes place — in the pause — in the first and second sounds represent the ventricular systole. During this ventricular systole the contraction continued 30 as to empty the auricle; the contractile pulsations in the adult male vary from .65 to 75 per minute, in the new born child about .450. There is some relation between the quantity of blood in the circulation and the frequency of the pulsation. Thus, as the pulsation increases, the expulsion of the blood and the contraction is greater than that of the actual beats. The first sound takes place along with the systole of the auricles and the second sound which marks the close of the ventricular systole. Thus the period between the commencement of the contraction and the second sound represents the ventricular systole. During this ventricular systole the contraction continued so as to empty the cavity. The cardiac pulsations in the adult male vary from 65 to 75 per minute, in the new born child about .450.

The first sound is caused by the closure of the aortic valves. The second sound is due to the closure of the pulmonary valves. The first sound is caused by the ventricular systole, and the second sound is caused by the auricular systole.

The heart is composed of two sides, the right and the left, each side having two chambers, the auricles and ventricles. The blood enters the heart through the auricles and is pumped out through the ventricles.

Duration of the Cardiac Movements.

The duration of the cardiac movements is divided into three periods: systole, diastole, and isovolumetric period.

1. Systole: The period during which the ventricles contract and pump blood into the aorta. The duration of systole is approximately 0.3 to 0.4 seconds.

2. Diastole: The period during which the ventricles relax and the auricles fill with blood. The duration of diastole is approximately 0.7 to 0.8 seconds.

3. Isovolumetric Period: This period occurs at the end of diastole and the beginning of systole, during which the ventricles are closed and the pressure in the ventricles is equal to the pressure in the aorta. The duration of the isovolumetric period is approximately 0.1 to 0.2 seconds.

The total duration of the cardiac cycle, from the beginning of one systole to the beginning of the next, is approximately 0.8 to 0.9 seconds. This is divided into two phases: the systolic phase, which is the period of ventricular systole, and the diastolic phase, which is the period of ventricular diastole.

The duration of the cardiac cycle is regulated by the autonomic nervous system, which adjusts the heart rate and the strength of the heart's contractions in response to the body's needs. Variations in the duration of the cardiac cycle can be caused by factors such as physical activity, emotional stress, and medication.
DURATION OF THE CARDIAC MOVEMENTS.

correspond with the period of latent stimulation but coincides with the period from the beginning of the initial stage to the beginning of the terminal stage.

The total period of the initial stage has been found to average about 0.12 upon the initial stage but to increase stimulation to that extent. The transmission of the stage of excitation was found to be about 125 mm per second, negative to all the other parts, the wave of stimulation being transmitted in all directions at the rate of 125 mm per second. Immediately after this stimulation wave passes there follows a contraction of the fibers, giving rise to a wave of contraction passing over the heart. This wave of contraction in the mammalian heart is found to begin at the apex.

The contraction of a cardiac contraction commences near the orifices of the larger veins in the right and left auricles. The question that arises is whether the cardiac movements are dependent upon molecular changes in the muscular tissue or in the nerve tissue. It is a known fact that rhythmic movements take place in tissues that are not nervous, e.g., the beating organs of many invertebrates, the embryonic heart, the unstripped muscles of the ureter. In these cases there is a movement of structure of muscle and nerve. Both muscular and nervous tissues, under definite conditions, give rhythmic movements. It is, however, believed by many that the rhythm of muscular tissue takes its rise from the impulse of nervous tissue. Several experiments have been made which show that the rhythm of the auricles is altogether independent of the rhythm of the ventricles, the ventricular rhythm being found in the apex where no nerve cells are found.

This peculiarity, while purely myogenic, is in part, and may be overcome by the complexity of the ventricular and auricular rhythm. The fact that a ventricular cell, being excited, may arise by the propagation of the rhythm from the auricles to the ventricles, which are distant from the auricles, it is difficult to see how the muscle cells are affected at the site of the stimulus. The fact that the muscle cells are affected is most difficult to understand. These impulses could not be transmitted from the ventricles to the auricles, as the auricles seem to be overstimulated in such experiments. However, the possibility of storing energy to be used at intervals in the ventricular movement seems to be an alternative, and the contraction of the auricles could be the result of the rhythm of the auricles. The question of the auricles and the auriculo-ventricular movements of the auricular wall seems to be overstimulated by the muscular fibers. The result of such experiments is as follows: (1) Independent rhythmic contraction is observed as well as the sine from the ventricles, the ventricular pressure being transmitted by the apex to a perfect diastole. Muscarin producing almost the same result. Gaskell draws some interesting conclusions from these experiments. (2) Rhythmic contraction varying inversely with the distance of the part from the sinus node. (3) An excitation wave of contraction transmitted by the auricles produces ventricular contraction, after passing through the auriculo-ventricular groove. (4) By dividing the auricle so as to leave one part in connection with the sinus and another in connection with the ventricle, a contraction wave passes up the strip extending from the sinus to the bridge, passes over and then after a brief pause goes down traction, and then the auriculo-ventricular contraction is transmitted. The action of the auricles produces no response being transmitted. The passage of contraction between auricle and ventricle, no response being transmitted. The passage of contraction between auricle and ventricle, no response being transmitted. The passage of contraction between auricle and ventricle, no response being transmitted.

The persistence of cardiac movements, in the case of the experimental animal, is perfectly developed. Hence it is concluded that the apparently opposite actions of the sympathetic and the vagus—upon the heart depends upon their connection with the process of heart nutrition.

The vagus exerts a chollic influence, leading to and directing the processes of repair in the heart substance, while the sympathetic exerts a katabolic influence, directing the processes of decomposition by which the complex muscular tissue is decomposed into the termino-skeletal tissues. These represent the molecular changes taking place in connection with the cardiac muscle, and result in the rhythm being rather of a tropic nature. According to this idea, the rhythmic contraction of the cardiac muscle is its periodic transformation. This rhythmic tendency is found most fully developed towards the base in the muscular contraction of the base of the large veins and in the auricle. This rhythm, originated in the region of the venous openings is transmitted through the auricles to the auriculo-ventricular groove; the rhythmic contraction of the venous tissue being produced by the electric variation arising from the rhythmic auricular, assisted by the increased cardiac pressure. In the human heart these tropic influences are exerted by the nerve ganglia, these in turn being influenced by the electric cardiac nerves. These nervous influences are exerted by the veins and arteries of the energy which manifests itself indirectly in this way that the heart is actuated by the cardiac pressure, and hence to the production of the heart. This way the action of the cardiac rhythm depends upon the trophic influence of the nervous system upon the cardiac muscles.

PERSISTENCY OF CARDIAC MOVEMENT.

The heart continues to beat after it has been removed from the body. This movement continues longer in cold blooded animals, as the frog, than in warm blooded animals. The heart of the frog will continue to beat for two or three days; a rabbit's heart from three to seventy-two minutes; in the case of the
right auricle, which is the ultimate moribund. The last trace of beating has been found in the rabbit 15 hours, and in the dog 26 hours after death. In the human embryo the heart has been found to pulsate for four hours after death.

The venous contraction weakened first, then the contraction of the auricle is not followed by contraction of the ventricle, the ventricles contract slowly, then ceasing to contract while the auricles continue to contract. Finally the auricle ceases to contract. Even after stimulation fails to produce any contraction in the case of the heart by the injection of arterial blood into the coronary arteries the heart may be restored to pulsation.

Influence of Respiration Upon Cardiac Action. The terms are usually contained within it, as an air tight compartment, the heart and the lungs. As the chest increases or decreases in size during inspiration and expiration, a certain amount of pressure is exerted upon the heart, and in some extent, its movements. During inspiration the diaphragm descends and the ribs are raised while the lungs expand, thus increase the chest cavity. The pressure upon the external surface is less, the pressure is removed from the large veins entering the chest at the right side of the heart, and the flow of venous blood toward the heart is assisted. If after fresh air is taken in, and if the chest be then distended by a very strong inspiration, the heart becomes dilated, this dilatation being increased by the elastic drawing of the lungs. The venous blood flows into the right side of the heart, the blood is sent on to the lungs and thus the lungs become gorged.

The pressure in the lungs is increased and also on the external surface of the large veins while only a small quantity of blood flows into the heart at its right side, immediately a powerful expiration is made, contracting the cavities of the heart and so as temporarily to interfere with the blood circulation, and thoracic cavity. The blood in the lungs is under high pressure and it acts strongly on the wall of the left auricle, causing weakness. This is increased in value, there is a large quantity of blood. The heart sounds favoring the flow of blood into the heart and diastolic dilatation; whereas, in expiration the pressure is higher, favoring the flow of blood out of the heart into the aorta and thus aiding the systolic empying of the heart.

CARDIAC SOUNDS. When the ear is applied over the chest, either by the ear itself simply, or by the use of the stethoscope, two sounds are heard, one directly from the apex. This is a dull, long and boomy sound. The second sound that is heard from the beat, is shorter, sharper, much louder and more clear. The second sound that is heard during the apex beat and corresponds with the ventricular systole; hence, called the systolic sound, and the third sound that is heard after an almost inappreciable period of pause, and it corresponds with the period of rest, or the long pause, called lasting till the commencement of the first sound in the next succeeding ventricular beat. This sound corresponds with the latter period of the ventricular diastole, and also, with the systole of the auricle of the chest and these two sounds differ in their character, high and distinct. A difference is noticeable when the sounds are accentuated, while over the base the second sound is accentuated. The first sound is upper represented by the meaningless words, lupp dopp, pause, lupp dopp, pause, representing the character of the listener, that is, he is subjectively rather than objectively. Walsh has stated that sound occupies 4 parts of the 10, then the short pause occupies 1 part, the second sound, which occupies 4 parts, the 3d sound three parts.

Much difference of opinion exists as to the cause of the first sound; this first sound may be heard distinctly after the removal of the chest wall, indicating that the heart beat does not produce this sound. Some Physiologists ascribe this sound to vibrations in connection with the close of the mitral and aortic valves. Others regard it as due to the muscular contraction of the
CARCJAL SOUNDS.

The hear in isolation.

not close simultaneously, they have a brief, a very brief, interval of time between their close second and interval be lengthened, we have what is called a split second sound—one sound from the auricle and the other sound from the pulmonary valve.

During the first we find the following phenomena: (1) Ventricular contraction, (2) closure of the tricuspid and the mitral, valves, (3) the flow of blood filling with blood. During the second sound we find the following phenomena: (1) The closure of the semilunar valves, (2) relaxing of the walls of the ventricles, (3) opening of the semilunar valves, (4) diastole commences, (5) the apex pressure against the chest wall. Then the pulmonic valve is closed and the atrium is filling up, all the blood from the ventricle, the. The atrium is filling up, all the blood from the ventricle, the. The atrium is filling up, all the blood from the ventricle, the. The atrium is filling up, all the blood from the ventricle, the. The atrium is filling up, all the blood from the ventricle, the. The atrium is filling up, all the blood from the ventricle, the.
Nutrition of the Heart.

The heart is nourished by means of nutrient fluid carried to the different parts of the heart through the circulation. In the lower vertebrates this is secured, for example, in the frog, by passages going out irregularly from the heart cavities through the midline of the heart muscle close to the peripheral surfaces. These passages act as blood vessels, filling at each diastole and emptying at each systole, and, of course, conveying the blood to the cardiac muscle. In the rabbit, the cat, and the dog, heart nutrition takes place by means of the well developed cardiac circulation, the cardiac circulation being carried on through the coronary arteries and veins. In the case of the dog the coronary arteries and veins are very close to the heart surface, the pericardium furnishing their covering. The left coronary artery originates at the aortic orifice, dividing into two branches, called the circumflex and the descendent branches. These branches pass transversely in the left auriculo-ventricular furrow, passing around the left side of the heart to the posterior surface and supplying with blood the left auricle and the upper anterior and posterior parts of the left ventricle. The descendent branch runs down the anterior inter-ventricular furrow to the apex of the heart giving out a number of branches to the left ventricle and to the anterior portion of the septum; supplying with blood the septum and the inferior anterior portion of the left ventricle. The right coronary artery arises from the aorta just short of the free margin of the anterior semilunar valve, passing to the right auriculo-ventricular furrow or groove around the right side of the heart running as far as the posterior inter-ventricular furrow, where it divides into two branches. The right coronary artery supplies the right auricle and the right ventricle with blood. The small branches of the coronary arteries enter the cardiac substance ending in the capillary plexus which carries the blood to different heart substance. Out of these routes originate the cardiac veins which convey the venous blood to the right auricle by means of the anterior cardiac veins and also the smaller veins, the foramina Thebesi.

Before entering the auricle, the large coronary vein becomes dilated, forming what is called the coronary sinus. At the junction of the vein with the sinus there is a valve, the other coronary veins which enter this large coronary sinus also have valves. The coronary arteries are terminal, at least, in man, that is, the anastomosis of the arteries does not produce a collateral circulation. This terminal character of the coronary arteries is of the greatest importance in connection with heart nutrition. The rapid closure of one of the large coronary branches in the case of the dog, for example, has been found to have little effect, some say, no effect at all, on the heart’s action; others say it has a temporary effect in producing an irregular action of the heart, or after a few seconds it may affect the ventricular action, producing what are called fibillary movements. There fibillary movements result from the shortening of the cells found in the cardiac substance. This arrest or shortening of the cardiac substance results from the action of the nervous system regulating the activities of the different parts of the body, while in turn, the heart is regulated by the nervous system. It is by means of the nervous system that a fuller heart is so moderated as to meet and overcome the constant strain upon the heart.
It has been known for a long time that the heart of the frog can be kept beating after its entire removal from the body for many hours—normal beating, we mean—and even after the cavities are entirely empty of blood. This has been accomplished in the case of the heart of the dog and cat and the rabbit, indicating this fact, that the cause of the rhythmic heart beat must be somewhere in the pulmonary system, and not in its connection with the central nervous system. We have already discussed the causes producing this cardiac movement and we have found that it is due to the muscular contraction, a muscular contraction kept sustained by the impulses found either stored in the ganglia or communicated by the nerve fibres. This muscular contraction then is dependent upon the tropic influence of the nervous system. The heart, therefore, the normal action of the cardiac substance and the nutrition of the heart substance depends upon the nervous system and hence shows the importance of the careful study of the innervation of the heart. The view has been maintained that as the pulsations cease—that is of the heart—under ordinary circumstances in the following order: the lower part of the ventricle toward the apex, the entire ventricle, the auricles and then the sinus venosus, and as these parts in an inverse order represent a series of ganglia, much more numerous in the sinus, and altogether absent in the lower ventricle; therefore, it is concluded that the rhythmic heart beat depends upon the nervous impulses originating in these ganglionic nerve cells, passing down different fibres to the different parts of the heart, causing the rhythmic fiber contraction, which coordinate by the cooperation of the different ganglia. This would make the muscular fiber passive in the hands of the ganglia centers, but as we have seen this is not the case. The strongest impulse in contraction being muscular, this being sustained by the tropic influence of the nervous system. In the innervation of the heart we have to consider: (1) the extrinsic or extra-cardiac nervous mechanism, including the nerve centers and the great nerves connecting the heart with the central nervous system; and (2) the intrinsic or intra-cardiac nervous mechanism, including the nervous arrangement of the heart.

**EXTRINSIC NERVOUS MECHANISM.**

This mechanism consists of nerves branching off from the cerebro-spinal and sympathetic systems so that the cardiac nerves are branches of the vagus and sympathetic, arising in the region of the inferior cervical ganglion. These nerves form two groups, one internal and one external. The internal group comprises a medium sized nerve, springing from the inferior cervical ganglion, a thick nerve springing from the trunk of the vagus near to the origin of the inferior laryngeal nerve and several fine nerves which arise from the vagus terminating in the cervical plexuses. The external group consists of an upper nerve originating in the inferior cervical ganglion or in the vagus trunk close to the inferior laryngeal ganglion, and a lower nerve arising in the lower part of the annulus of Vonmesser or sometimes, from the vagus close to the anulus.

In the year 1815, the Weber brothers discovered that the stimulation of the vagus in the neck or at its deep origin in the gray matter on the floor of the fourth ventricle, produces in the case of a feeble excitation a lessening of the number of heart-beats and in the case of a strong excitation it arrests the entire heart as its action is transmitted to the heart by a section of the pneumogastric it was found that the action of the heart was accelerated, while on stimulating the cut end of the peripheral portion, the heart's action was slowed, and in some cases completely suspended. The influence of the pneumogastric fibers, therefore, is inhibitory or restraining. From this experiment we conclude the action of the vagus upon the heart is inhibitory or restraining. The slowing and arresting of the heart's action may be produced by different agents, the heart for example: chemical stimulation, or mechanical, as well as electrical stimulation. One Physiologist has shown that the pressure of the carotid artery at the anterior margin of the sterno-mastoid would result in slowing of the action of the heart which he supposed to be produced by the stimulation of the pneumogastric. During this arrest of the heart, the heart does not cease to be subject to irritation, for during this heart action is not due to reflex action, but is direct, because this is an arterial hemorrhage. This inhibition is not due to the action of the peripheral end of the cut nerve.

The right vagus seems to have a greater influence on the heart than the left vagus, and it is found, on excitation of the vagus, the auricle of the heart in particular is affected—that is the part of the heart affected by stimulation of the frequency of the heart's pulsations, but also, the strength or the force of these pulsations. This is evident from the fact that on the stimulation of the vagus, the pulsations become fewer in number and, also, each pulsation becomes more feeble. This stimulation of the vagus may be increased by the section of the spinal cord, and also of the sympathetic in the upper portion of the neck. This excitation of the vagus affects the periodicity of the ventricular action, particularly the ventricular systole; the feeble stimulation of the vagus greatly increases, on the other hand, both the periods of the systole and diastole.

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EXTRINSIC NERVOUS MECHANISM.

It is probable, however, that the same intra-cardiac terminal acts for the two vagi, for when one vagus is stimulated till the heart overcomes the effect of stimulation with the excitation or stimulation of the other vagus has no effect upon the heart at all. Gaskell, who has devoted much time to investigation of this subject, accounts for the medium of the inhibition by the fact that the vagus nerve is the sympathetic nerve of the heart. He thinks that after the stimulation is over, the heart becomes more vigorous, this being according to Gaskell the proof that the excitation of the heart through the stimulation of the vagus has nourished and made it stronger than it was before and, therefore, is considered to act more vigorously. As yet, however, the experiments have not sufficiently established this point, although it seems very probable.

Besold discovered that after a section of the spinal cord between the first and second thoracic vertebrae the stimulation of the sympathetic or the vagus, produces an acceleration of the heart's action. This stimulation he found was carried or conducted from the cord to the inferior cervical ganglion, from which it passed through the nerve fibres to the heart. These nerve fibres enter the sympathetic from the spinal cord, coming from the inferior cervical and the first thoracic ganglia, dividing so as to form the annulus of Vienesens and then joining the vagus nerve. From the superior cervical ganglia the fibres pass into the vagus, passing down the trunk into the cardiac plexus between the superior and inferior laryngeal nerves. The spinal nerves, from the 2nd to the 11th and possibly to the 12th, send out fibres to the superior cervical ganglia, the sympathetic trunk and the first thoracic ganglia. This sympathetic acts as an accelerator, the section of the sympathetic even on one side being followed by the slowing of the heart's action, the heart being left to the action of the pneumogastric. If the cut end of the distal portion of the nerve be stimulated the heart will beart more quickly. The excitation also, of the fine fibres of the heart from the inferior cervical ganglion accelerates the action of the heart or heart. These delicate fibres originate in the spinal cord. These inhibitory heart from the cerebro-spinal system and leaving the axons of the sympathetic fibres; the stimulation of the higher part of the spinal cord also causes acceleration of the heart. The chief result of the stimulation is the increase in the heart pulsations, that increase being according to some Physiologists, from 10 to 70 per cent of an increase. The force of the venous substitution increases. The ventricle becomes filled more completely with blood and the quantity of blood that is ejected from the ventricle is also increased. The stimulation of the nerves on both sides of the heart does not increase the heart action more than the stimulation of one.

Auricular contractions also increase in strength and in volume, this latter increase in volume depending upon the increased elasticity of the auricle. These changes, accelerator changes, give rise to an increased blood pressure in the systemic circulation of the arteries and to a fall of blood pressure in the pulmonary veins and venous circulation to the heart. In the vagi, the inhibitory nerves, are stimulated at the same time as the sympathetic; the auricular and the inhibitory or the vagi action will overbear the action of the sympathetic, resulting in that inhibition is stronger than acceleration. Even if the stimulation of the sympathetic is continued for a long time, and even if the stimulation is very strong and severe, the heart will not pass into a state of tetanus, but increase in volume and its rate for a short period it will return to its normal rate. This indicates that the accelerator fibres or nerves are not motor nerves of the heart. The sympathetic nerves fibres do not act directly on the heart muscle, but act on that in the intra-cardiac ganglia causing them to give out their entire reserve stock of energy. When this stock of energy is exhausted

EXTRINSIC NERVOUS MECHANISM.

the stimulation of the sympathetic will fail to accelerate the heart's action.

This difference in rate, however, indicates one line of proof in the direction of Gaskell's idea that nerves are not irritable, hence Gaskell says we should not speak of a motor action of the vagi. In the trunk of the vago-sympathetic and from the loop of the annulus of either inhibitory or accelerator nerves. For example, it has been observed that the excitation of the vago-sympathetic trunk will result in a marked increase in the heart's action or beat. These changes are not purely inhibitory. Pawlow has shown that inhibition and the accelerator nerves under certain circumstances
3. Those that increase the heart's action or heart beat. 2. Those which inhibit the force of contraction of the heart. Thus we have the inhibitory and accelerator nerves, both of which have the same effect on the heart muscle. For example: It was found that in certain stages of poison by convallaria majalis that the stimulation of the vagus at the neck when divided, that the blood pressure was lessened without affecting the heart beat. The heart was found to produce in some cases a diminished blood pressure, and in pressure independent of any other results. This seems to lead to the conclusion that the vagus produces the same action on the heart rhythm and others upon the vagus nerve. The stimulation of different branches from the annulus of Vienesens leading to cases of other branches a reduced heart beat, and in others an increased blood that certain nerves act upon the heart rhythm and others upon the contraction of the distal branch of the sub-diaphragmatic sub-diaphragm of Pawlow already mentioned.

THE REFLEX ACTION OF SOME SYMPATHETIC FIBERS AND OF THE CEREBRAL SPINAL NERVES.

In the sympathetic there are fibers which excite reflex action through the vagi. If the sympathetic nerve is divided at the neck and partially stimulated, the heart's action becomes slow. This is explained by the fact that the cardiac fibers of the sympathetic communicate through a center of the sympathetic cardiac ganglia, in this case, being inhibited and hence, the action of the diaphragm is increased. Gotz, one of the German Physiologists, has proved this by several experiences in connection with the vagus nerve. The chest-wall was cut by conduction of the vagus, through which the heart pulsations could heart was gradually slowed, and finally the heart ceased to beat. By dividing the abdomen with the end of the scalp, the cat was bled, and then bled to more quickly than in its normal condition. Thus the fibers of the sympathetic in the abdomen, on being artificially stimulated—produce the rejoicing of the heart through the vagus. The excitation of the central end of the spinal cord is heart's action. According to some Physiologists, spinal cord stimulation produces not a simple but a compound result; the stimulation resulting in increase due to the acceleration and inhibition toward the close of the stimulation. It has been found that a severe blow on the epigastrum or the sud-

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The dilatation of the stomach has been found to produce an inhibition of the heart. The dilatation of the sensory nerves seems to affect both the accelerator and inhibitory fibers. In the case of a weak stimulation the accelerator influence tends to be in case of a strong stimulation the inhibitory influence prevails. The stimulation of the nerves of the special senses, sometimes increases and sometimes diminishes the action of the heart.

64, SYMPATHETIC FIBERS AND THE CEREBRO-SPINAL NERVES.

Sympathetic Fibers and the Cerebro-Spinal Nerves.

Depressor Nerve.—This nerve is sometimes called after the names of the parties who discovered it, Ludwig and Cyon. These two physiologists found that the stimulation of the nerves passing from the central nervous system to the heart side from and independent of the vagus produced no effect upon the heart rate or the blood pressure. On the contrary, it was found that this was due to the fact that the excitation was limited to the end of the divided nerve still in connection with the heart. They thought that stimulation of the end connected with the brain would produce, not negative, but positive results. In their investigations in connection with these nerves in the rabbit, they found an afferent nerve springing from the vagus, high up in the neck, the stimulation of a peripheral end produces a fall in the blood pressure. On account of this action, it was called the depressor nerve. This depressor nerve arises from two or more nerve roots, one of which springs from the vagus, high up in the neck, and another from one of the vagi branches of the superior laryngeal nerve. If this nerve is divided, it ceases to produce a fall in the blood pressure, whereas the stimulation of the peripheral end of the divided depressor nerve causes a fall of the blood pressure. The depression of the blood pressure by lessening the toxic constriction of the arteries under the influence of the splanchic nerve, resulting in arterial dilatation and the lessening of peripheral resistance. The depressor fibers connect the heart with the vaso-motor center, these fibers coming into connection with the vaso-motor center being stimulated when the heart becomes overfilled with blood, this stimulation passing through the vaso-motor center and affecting the arteries under the influence of the splanchic nerve, lessening the resistance and thus aiding the overfilled heart to empty itself again. Thus the function of the depressor nerve is to become very much dilated just in the same way as the vessels in the limb.

Centers of the Cardiac Nerves.

In connection with the heart there are three great centers: 1. An inhibitory center, connected with the inhibitory fibers of the vagus. 2. An accelerator center, connected with the sympathetic fibers, and 3. The higher centers, which influence these other centers and explains in some way the relation of the emotions to the heart and the heart’s action.

Inhibitory Center. The Webers, two brothers who have been referred to already, found that this inhibitory center was located in the medulla oblongata. Its exact location in the medulla oblongata is not yet accurately defined but results, it is difficult to distinguish the effects that are produced by the excitation of the center itself, and by the action of the nerves lessening the blood pressure. Laborde has localized this center at the level of the nucleus of the second nerve (the 2nd nerve), which is the vagus and spinal accessory, in the grey matter on the floor of the 2nd ventricle. It was found that by separating the hypoglossal nerve from the vagus and spinal accessory, the hypo-glossal nerve supplying the muscles of the tongue, the reflex action could be diminished, while the reflex action resulting from the excitation of the hypoglossal nerve remained unaltered. From this it is concluded that the inhibitory center is contained somewhere in the medulla oblongata but exactly where is not known. The center of the inhibition seems to be
always active, for if the vagi are divided the heart-beat increases. This constant activity of the center may be due to constant impulses conveyed along the afferent fibers or to the independent activity of the center, independent from these afferent impulses. It would seem that the division of the vagi after all the afferent impulses have been destroyed by section of the spinal cord below the bulb does not increase the heart action. These nervous impulses are carried to the center of inhibition by sensory nerves from the periphery, the spinalchusis, from the abdominal cavity and also through the depressor nerve from the heart. If the spinalchus nerve be cut the afferent impulses are suspended and the heart rate is increased. The origin of the cardial inhibitory fibers is uncertain though it is generally believed that they enter the vagi from the spinal accessory nerves, (the 11th pair of nerves), and then to the case because on removing the spinal accessory before it joins the vagus trunk and following the fibers in the vagus to degenerate, cardial inhibition is destroyed. This, however, is disputed by some physiologists.

3. ACCELERATOR CENTER.—The accelerator fibers are believed to originate in the lower portion of the spinal cord, the situation of the center being unknown, although it is probably in the thoracic region. This center seems to be always active. This is evident from the fact that the heart rate is lowered after division of the vagi followed by the removal of the inferior cervical ganglion and the first dorsal ganglion. The same result is produced—that is, the lowering of the heart rate—by the section of the spinal cord of the upper cervical portion after the division of the vagi. There is a reflex acceleration of the heart action that arises from changes in the cardiac inhibitory center and not due to the direct accelerator stimulation. If the accelerator fibers are divided, the heart rate remains perfect so that the stimulation of afferent nerves increases the heart's activity. It makes no difference, then, whether the accelerator nerve is divided or solid, the stimulation of the afferent nerves produces the same result.

3. THE HIGHER CENTERS.—Various efforts have been made to localize as well as to discover higher centers, especially in the cortex cerebri connected in various ways with the inhibitory and accelerator action of these centers. Such attempts, so far, have been unsuccessful. There is no doubt that there is some connection between the heart rate and the central effects so far as the cardiac centers, but the nature of these connections is as yet unknown.

INTRA-CARDIAC NERVOUS ARRANGEMENTS.—This subject has been investigated chiefly in connection with the frog's heart. This arrangement is a subject of cardiac regulation than the mammalian heart that is not constant, but only under extraordinary circumstances. When the frog is dissected, there is no change in the heart rate. The nervous mechanism in the case of the frog's heart is due to the pericardium and a ligature. From the endocardium a number of fine nerves pass beneath the endocardium and into the muscular tissue. In the mammalian heart, a large number of non-medullated nerves appear, forming their way into the network, and running underneath the pericardium from the base to the apex of the ventricle, running always in a slanting and oblique direction. These nerves can be traced to the cardiac plexus, situated at the base of the heart, distributing these cardiac nerves the characteristic inhibition and stimulation follow, in the heart rate, or in the blood pressure; but by the stimulation of the sympathetic indicating that these nerves—convey impulses to the central nervous system, and the impulses are carried not from the cardiac nerves to the peripheral ganglia, but to the central nervous system. This raises the question whether the peripheral ganglia do, or do not, act as centers of the reflex activity. The excitation of the central ganglia inside the first dorsal ganglion, into a motor influence becomes changed entirely into a central influence of the afferent and efferent impulses. This impulse, thus changed, produces an influence become changed in the sympathetic, particularly in the cardiac ganglia.

EXPERIMENTS IN CONNECTION WITH THE HEART.

After the removal of the frog's heart from the body and the breaking of beat for some time. If then the apex of the heart is moved it (the apex) will continuously divided into transverse sections it will continue to beat until it is divided. If the heart is divided at the auriculo-ventricular furrow when the ventricle will cease to beat by a single contraction even after they have ceased to beat. If the heart continues to beat, the auricle will cease to beat. If, however, this division is made partially, if the septum be preserved intact partially representing the auricle to the ventricle of an impulsion, Gaskell is able to block entirely the nervous influences from the heart of the frog. The division of connective tissue between the pericardium and a ligature passed around exactly between right auricle and the ventricle is connected with the ventricle. The sino-auricular currents, the atria and ventricle being crossed in a single line. The auricle begins to beat again and posed that the ganglion in the sinus-affects in some way in the normal heart, the case in the furrow. When the sino-ganglion is cut off, the auricle and keep up the activity. The stimulation of the last ganglion causes both auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again. If any part of the ganglion is connected with the auras and ventricles to beat again.
EXPERIMENTS IN CONNECTION WITH THE HEART.

The ventricle of a frog's heart is divided into sectors, each part connected by muscle to each other part, stimulation of one part will cause the other parts to beat. In this case the rhythm is not transmitted by nervous impulses. This indicates that the rhythm takes place in structures which have no nervous ganglia, as in the apex of the heart and in the heart of the fetus in its earliest stages of development.

OTHER CIRCUMSTANCES INFLUENCING THE HEART RHYTHM. While the nervous system affects the heart, there are other influences which affects it. These are two fold: 1. Influences depending on nutrition, and 2. Physical, mechanical and chemical influences.

1. The heart substance needs nourishment; for this the blood supply of a necessary quantity and quality is required. In the case of the frog's heart, the coronary circulation is reduced to a minimum; it may be reduced to a point where the heart may be starved of blood. Soon the beating ceases. This will be aided by washing out the tissues with a saline solution. If after washing a heart in this way it be attached to a perfusion caudal to a perfusion cannula, the heart may be restored artificially and kept up for a long time. When fed in this way the heart--two found that the heart must be brought into contact with the heart substance through the capillaries in order to maintain the heart beat.

2. Physical and Chemical Influences. These influences affect the heart in one way or another, for example: the presence of inhibitory or acceleratory impulses. The rhythm thus produced by artificial feeding becomes generally very soon intermittent, due to both the formation of certain chemical substances and to the fact that artificial feeding is not as perfect as natural. Thus influences arise, concomitant with the heart nutrition, which affect the heart by influencing in some way the muscular tissue and also the nervous tissue, producing variations in the heart rhythm.

During the life of the heart beat is maintained by the constant supply of arterialized blood. The blood is so complex that all its elements are vital to the heart for its nutrition. Various experiments have been employed by different investigators to discover the composition of blood necessary for heart nutrition. A frog's heart, for example, is supplied with a normal saline solution, six per cent solution of sodium chloride, ceases to beat sooner than an empty heart. The addition of the salts that are found in the blood are required to sustain the action of the heart. For example: Sodium chloride solution, one per cent is isotonic. A calcium salt added to the heart after the addition of sodium chloride initiates the heart beating, although at the same time it alters the contraction, specially in the contractions of the ventricles, which falls into what is called a condition of tonic contraction. By the addition of potassium salt, the normal condition of contraction may be restored.

Ringer recommends the following compounds for artificial feeding:

1. Sodium chloride, 0.6 per cent solution, saturated with tribasic calcium phosphate, and cubital centimetres. Potassium chloride, 0.1 per cent solution or acid phosphate also 0.1 per cent solution of acid phosphate. In regard to the mammalian heart, little has been discovered except that the blood of the same species is the best nourishment to supply the heart. It seems that in supplying the mammalian heart with the blood of a different species the heart is causes to cease beating sooner, edema being set up in the lungs resulting in the gorging of the right side of the heart and the obstruction of the pulmonary circulation, resulting finally in the injury of the thelactic cardiac muscle, causing dis- tension, so that the diastole of the heart is impossible.

2. PHYSICAL AND CHEMICAL INFLUENCES.

These influences affect the structure of the heart, both muscular and nervous, however, to the heart-beat. For if the ventricle of a frog's heart is divided into sections, each part connected by muscle to each other part, stimulation of one part will cause the other parts to beat. In this case the rhythm is not transmitted by nervous impulses. This indicates that the rhythm takes place in structures which have no nervous ganglia, as in the apex of the heart and in the heart of the fetus in its earliest stages of development.

CIRCULATION OF THE BLOOD IN THE BLOOD VESSELS.

We have seen already that the beat of the frog's heart is affected very materially by the heart beat, increasing the pulsations. The number of pulsations in a condition of thermal rigor. Up to 20 degrees centigrade, the extent of the contraction more rapid and also of shorter duration. The cooling of the heart—as we have seen the process the heart is normally restored until it reaches 35 or 40 degrees centigrade. When the application of heat gradually as so to thaw out the heart will revive and begin to pulse after a few moments, nourishment and pouring into the heart warm blood, better, whereas, it beats slower if a cold solution as cold blood, is poured into the heart. Blood in the capillaries of the heart in order to effect this increase, inhibiting the blood in order to effect this increase. This idea of great value in considering the abnormal conditions represented by fever pulsations, which become very rapid.

If an electric current is applied to the heart, of a moderate strength, the heart passes into the condition of fibrillation. A minimal stimulus produces a stimulation will depend upon the length of time that the heart has been stopped since the last contraction. If the stimulus is applied to the heart the effect of the contraction of the heart. If the time that has elapsed since the last contraction, stimulation applied will result in still further contraction. If the artificical stimulation will call forth the stimuli, a strong stimulus produces a stimulation will depend upon the length of time that the heart has been stopped since the last contraction. If the time has not been sufficient to allow the heart to recover itself, a strong stimulus will produce the contractions of the heart. If the time, however, has not been sufficient to allow the heart to recover itself, a strong stimulus will produce an arrest of the heart. Chloroform also inhibits the heart beat. Carbonic oxide and sulfuric acid do not affect the heart's action. It has been found that the blood of ether can be overcome by the addition of fresh blood, the phlebotomised hydrogen act upon the heart so as to paralyse it. Excessive carbonic action of the heart altogether. This heart force, if the solution is weak, stimulates the heart's action, whereas, if the solution is strong, it diminishes the action of the heart altogether.

SECTION VIII.—I. Circulation of Blood in the Blood Vessels.

The circulation of the blood in the blood vessels depends upon certain phy- and rigid. In the circulation of the blood in these vessels, we have to take into account, first of all, the heart force, as we have seen, to take into account the long stretch of elastic tubing reaching from the heart.
CIRCULATION OF THE BLOOD IN THE BLOOD VESSELS.

both backward and forward to the peripheries, and 3d. In the minute vessels there is a peripheral force which constitutes a constant resisting force, acting upon the blood as it passes from the heart to the peripheries. Apart from the heart rhythm, the elasticity of the arterial walls and the peripheral resistance offered by the minute capillary vessels, there are certain physical principles which explain many, perhaps all, the phenomena of the circulation. The heart force meets the peripheral resistance set in the capillaries, and sent back from these minute vessels in such a way as to promote the circulation through the entire vascular mechanism. In Physical Science the law of the equal transmission of pressure is as follows: That the pressure upon any region of the surface of a fluid, is transmitted equally, and always at right angles to any part of the surface of the fluid normal to the area.

If we take a vessel filled with water, the pressure at the bottom of the vessel will be equal to the weight of a perpendicular column of water equal to the height of the fluid, and with a base equal to that of the bottom of the fluid. At any point along the side of the vessel, or tube, in which the vessel is maintained, the pressure will be equal to the weight of a column, equal to the depth of the point below the surface of the fluid with a base whose area is equal to the area of the side of the vessel.

The rapidity of the flow out of such tubular vessels of fluids is in direct proportion to the cross section area and in inverse proportion to the length of the tube. If the tube in which the liquid is contained be uniform, the fluid will run through each cross section with a certain rapidity, this rapidity diminishing with the ratio of the length of the tube and also the amount of resistance that is met with the fluid within the flow. The rapidity of the flow of the fluid will depend upon a number of considerations: 1. The caliber of the tube. 2. The nature of the liquid, the glutinous fluids flowing slower than the limpid fluids. 3. The pressure velocity increasing with the square root of the pressure except in small tubes, which tube the pressure is directly with the pressure. 4. The temperature, the velocity increasing with the rise of temperature, falling with the fall of temperature. 6th. The resistance. The flow is slower where resistance is greater and vice versa. Where resistance is increased by the curving, joining or the folding of the tubules, and also increases by the branching of the tube. In the latter case the branching of the tube where the tube branches off into a number of divisions, the same liquid volume passes through the same cross section area, therefore diminishing as the cross section area increases. These are principles that we apply to the circulation, principles that explain the circulation of the blood. In passing from the arteries to the minute blood vessels this cross section area is constantly increasing. The blood starting from the heart has to begin with the force of the beating heart's action. This force is not constantly exerted, but only at intervals represented by the heart beat or the heart beat pressure. These intermittent pulsations being compensated for by the elasticity of the arterial walls so that when the blood reaches the capillaries it is a continuous stream. This continuous current along the elastic arteries bears along with it the wave of contraction, representing the amplitude of the heart pulsations, the current being slower than the wave which passes along the walls. Several experiments have been made by Marey and others in connection with elastic tubes through which a fluid is passed intermittently as in the case of the blood. The results may be summarized:

- A fluid on entering the elastic tube intermittently and quickly arose a series of waves transmitted with a velocity independent of the current of the fluid.
- The velocity of transmission in proportion to the elasticity of the tube and in an inverse proportion to the fluid density.
- The extent of the wave depends upon the amount of fluid and the rapidity with which it is thrown into the tube. If a fluid volume there is a backward oscillation which causes secondary waves.

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PHYSIOLOGY OF THE STRUCTURE OF THE BLOOD VESSELS.

The walls of the arteries are both elastic and muscular. In the smaller arteries the muscular element and in the larger arteries the elastic one predominate. In the case of the large elastic arteries the blood enters with an intermittent flow from the heart, caused, of course, by the Ventricular beat being changed through the course of the larger arterial vessels. At each contraction of the ventricle a volume of blood is thrown into the aorta which expands on all sides. When the ventricular diastole begins the aorta recoils the valve atergata, the force is thus being withdrawn; the sigmoidal valves being closed and the blood pushed along

SECTION X.—Arterial System.

The walls of the arteries are both elastic and muscular. In the smaller arteries there is a predominance of the elastic fibres, and in the smaller arteries of the muscular fibres—giving to the larger and to the smaller arteries their characteristic property respectively of elasticity and muscularity.

The arteries branch out from the aorta to the capillaries, becoming at the capillaries a very large region. The capillaries are vessels of microscopic minuteness, about 1,000 of an inch in diameter. The capillary wall consists of a multilayered homogenous membrane continuous with the tunica adventitia. This membrane being lined by a single layer of endothelial cells, these cells being joined together at their borders or margins. These walls are elastic, constituting a network of almost uniform microscopical size. These capillaries the blood current is slow, being more rapid at the center of the vessel. The delicate endothelial walls widen when the blood current is increased, and narrow again when the pressure is removed. This thin wall admits of the passage of water, gas and even of corpiacula, particularly the white corpuscles—in the interchange that takes place between the blood and the tissues through the medium of the lymph. The veins carry the blood back again from the capillaries to the heart. They have much thinner walls than the arteries and when cut across they collapse. The tunica intima of the veins is similar to and the tunica adventitia is identical with the arterial coats. The tunica media is different, consisting of white fibrous tissue with a few muscle-fibrous cells, and a little if any, elastic tissue. On account of this the veins when empty collapse. These veins are very little elastic being simply channels through which the blood passes with only a certain amount of elasticity so as to be able to pass a certain quantity of blood necessary for the circulation. The sectional area of the veins like that of the arteries diminishes from the capillaries to the heart. The venous capacity is very much greater than the arterial capacity, the veins being able to hold all the blood normally found throughout the body. The delicate endothelial walls of the veins being found in the tunica adventitia. These blood vessels are supplied with nerve fibers distributed among the muscle fibers.

the arterial circulation, the arteries expand as the blood flow increases and re contracts with diminished intensity as the blood flow diminishes. These movements of expansion and recoil are transmitted to the arteriolar branches and further on to the capillaries. Two forces, first force, the ventricular force of the systole, and the force that is produced by the elastic recoil of the vessel walls, taking place between the systole and the diastole of the ventricle. The two forces are constantly kept in balance by the elasticity and muscularity of the vessel walls. As we have seen in the branching of the arteries, the cross sectional area of the small arteries increases constantly as the blood flows through them. The elastic recoil of the walls of the large veins is so much greater than the elastic recoil of the walls of the small arteries that the expansion of the smaller ones toward the peripheral branches of the capillaries is much greater than the elastic recoil of the walls of the large veins. The resistance increases as the blood flows through the capillaries from the arterial system to the venous system. The shortening of the elastic arteries is also accompanied by the shortening of the elastic arteries. As the bends or curves in the elastic artery, the blood produces greater muscularity, producing the twisting and shortening of the elastic arteries. This is sometimes confused with the pulse. It is not the pulse. It is in the blood. This wave gradually lessens from the heart to the capillaries. The blood circulates in the blood vessels and the lymphatic vessels. The blood circulates in the blood vessels and the lymphatic vessels. The blood circulates in the blood vessels and the lymphatic vessels. The blood circulates in the blood vessels and the lymphatic vessels. The blood circulates in the blood vessels and the lymphatic vessels. The blood circulates in the blood vessels and the lymphatic vessels.

ARTERIAL SYSTEM.

The arterial system is a system of blood vessels which conveys blood from the heart to the capillaries. The blood vessels are divided into two main groups: the arteries and the veins. The arteries carry blood away from the heart, while the veins carry blood back to the heart. The arteries are responsible for the delivery of oxygen and nutrients to the tissues, while the veins are responsible for the removal of waste products and carbon dioxide from the tissues. The arteries are divided into three main categories: the aorta, the arteries, and the arterioles. The aorta is the largest artery in the body and it is responsible for distributing blood throughout the body. The arteries are smaller than the aorta and they are responsible for distributing blood to specific regions of the body. The arterioles are the smallest arteries and they are responsible for distributing blood to the capillaries.
ARTERIAL SYSTEM. 73

causing an intermittent action, or by some irregularity. The pulse of high tension on an incompressible pulse, exists when an unusual amount of force is necessary in order to extinguish it. That, of course, means temporary. A pulse of low tension or a compressible one is one that may be easily extinguished. The appearance of the pulse is the pulse. A large pulse
aries from the increase of the arterial calibre. If the pulse is very large it is called a bounding pulse. A small pulse, on the other hand, represents little if any increase in the calibre—the arterial calibre, and if the pulse is very small it is called a thready pulse. This does not mean lumenerness or smallness of the artery, but that the moving arterial pressure is large or small as compared, at least, with the mean blood pressure. As the blood moves along the artery the arterial pressure will be less according as the blood contents are otherwise the pressure upon the walls will be less when the walls give place more freely to the pressure. Hence a large pressure is often associated with a low mean pressure. In this case it is found, e.g., after severe hemorrhage—loss of blood. The pulse movements, as we have said, may be recorded by means of the sphygmograph. The best form of the sphygmograph is that invented by Marey. It consists of a long lever moving by a screw working on a horizontal wheel; from the axis of which there is projected a light lever. The screw point rests on a flat disc at the end of an elastic spring, which presses the disc upon the artery. The lever arm records the tracing on a blackened surface carried in front of the lever point by means of a clock work arrangement.

In the sphygmograph, by modern adjustments of this instrument, the amount of pressure on the disc made by the artery may be closely and almost exactly preserved so that at different times tracings may be taken either with the same or different pressures. The best instrument is a sphygmograph with pressure graduated arrangement by Mahomed and Bramwell. Various other instruments have been devised, e.g., the sphygmoscopes, a small camera obscura, suspended bottom to which is attached an inlet and outlet tube to convey the gas, the outlet being connected with a gas burner, the membrane being placed over the pulse, the flame will show the pulse beat. By the use of sensitized glass on the pulse a photograph may be obtained by the reflection of the pulse volume by clockwork on a dial. When the artery pulse is taken (1) it is expanded and shortly lengthened, and (2) the blood pressure rises—the artery giving rise to the resistance that is felt when the finger presses upon the artery. In connection with the sphygmograph tracing we notice: 1. An ascending line, with the upstroke or the stroke of percussion, representing the arterial pressure, and resulting from the ventricular systole. 2. A descending line representing the arterial elastic recoil called the diastole. In a normal pulse the expansion and recoil are successive without any rest, the pulsations being about equal. Variations take place, however, in the pulsations according to the blood pressure as it rises or falls. The quickness or slowness of the pulse is dependent upon the proportion of time occupied by these periods. If the systolic expansion diminishes, the pulse is rapid, if it increases the pulse is slow. The quickness of the pulse is increased by increasing the heart rate, a free blood flow, proximity to the heart and considerable yielding of the walls of the artery. The different parts represented on the pulse tracing are accounted for as follows: 1. The upstroke, which is the most steady, represents the ventricular systole, the systolic wave, the opening of the semilunar valves and the rapid flow of blood from the ventricle into the aorta and arteries, causing expansion of the arteries. 2. The diastolic wave represents the blood flow from the arteries to the capillaries. It is prolonged, gradual and vibratory. 3. The large dicrotic wave on the diastolic wave represents the closure of the semilunar valves. 4. Following the upstroke or systolic wave during ventricular contraction we have the pre-dicrotic or first systolic wave represented in the curve tracing at a point corresponding to the pressure generated by the action of the ventricular systole from the elastic vibrations of the arterial walls. The vibrations of the pressure are more or less constant. Sometimes the vibration becomes so irregular that it produces a partial upstroke of the pulse during the downstroke, causing a double beat during each ventricular beat. This is called the dicrotic pulse. The pulse always dicrotic normally and hence the slight dicrotic wave. Much discussion has taken place as to the cause of this wave.

Much discussion has taken place among Physiologists, as to the origin or cause of this pulse wave. These opinions may be summarized under three heads:

1. Some Physiologists claim that there are two reflected secondary waves: one originating from the closure of the semilunar valves and another from the smaller arteries at the periphery starting backward, as a reflection of the main pulse wave. This wave is supposed to be reflected backward from the periphery and travels toward the heart, reaching a given point in the arterial blood path after the main pulse wave has passed that point traveling in the opposite direction. If this is the case, then, in the tracing from the peripheral artery the dicrotic wave should arise nearer to the close of the upstroke, representing, therefore, the highest point that is reached by the pulsation, than in the case of an artery nearer to the heart. Measurements have shown that the difference between the primary and the secondary waves is greater in the smaller arteries than in the larger arteries nearer to the heart. This would prove that the dicrotic wave cannot be due to any secondary backward wave; hence, this explanation is improbable.

2. The opinion that is supported by most of the Physiologists is that it is due to the slight rise of the arterial pressure arising from the closure of the sigmoid valves, and that this secondary wave follows after the main pulse wave from the opening into the aorta as a secondary wave. In this way the reflection takes place wholly from the heart, and it moves contrary to the periphery, being modified in its course and giving rise to vibrations. This would make the closure of the aortic valve simultaneous with the beginning of the dicrotic wave. When the ventricular contraction takes place simultaneously with the beginning of the arterial pressure, the wave is transmitted along the arteries to the capillaries where it is destroyed. By the reaction of the walls of the aorta, the aortic valves close; by the closure of these valves the secondary wave is reflected from the aorta to the periphery. Similarly the dicrotic wave passes gradually along the arteries from the heart. If this secondary wave is marked farther down the curve, the farther the artery is from the heart, the nearer the point marked as it travels farther from the origin—the origin in the aorta—hence, the wave becomes less distinct toward the periphery.

The dicrotic wave is more marked, as the primary wave is stronger, both of these depending on the strength of the ventricular systole. When the blood pressure of the small arteries becomes less, the dicrotic wave is greater as the wall of the vessels is able to yield more freely. The more full an artery is of
blood, there is less yielding in the vessel wall, and the dicrotic wave becomes less marked and more steady. Other secondary waves may also arise, rendering irregular the primary wave. Where there are three of these waves it is called tricrotic. If these secondary waves appear, only, in the down stroke, the curve becomes more regular until the main curve, in which case it is called monochrotic. If the tricuspid wave is more pronounced, it is called polychrotic. Foster explains the dicrotic without any reference to the closure of the «millimetric» valves. This closure, he says, is an effect not of the pulse of the dicrotic wave. On the sudden cessation of the flow of the blood from the heart, a negative pressure is set up posterior to the blood, blowing the caliber of the smaller vessels due to the vessels' elasticity, instead of the arteries. The pulse strikes — particularly the vessel wall. This shrinkage becomes more frequent, that is, you have an excessive shrinkage of the arterial wall, and when that excess shrinkage comes into contact with the inertia of the vessel wall, the flow of the blood is arrested. This is assisted by the viscid substance of the blood, traveling from the root of the aorta along the arterial walls with gradually diminishing force, and produces the dicrotic wave. This dicrotic wave, thus produced, produces, after it the blood that has been, by refus action, drawn back toward the heart and resulting in arterial expansion, and recurred flowing to the venous arteries.

The sphygmograph cannot give a perfect tracing of the pulse, particularly lying between the surface of the skin and the arterial wall. On account of this the sphygmograph is relative, not absolute. The normal pulse rate in the man is about 72 per minute, and in the female from 68 to 76. The pulse, he says, is to be taken simply as an average, because in the healthy individual, it may vary all the same from 50 to 100. In the new born child it varies from 130 to 140, gradually diminishing till about the fifteenth year, when it drops from 75 to 78. From sixty years of age it tends to rise gradually toward 80. The pulse is said, by some Physiologists, to be affected by the body, the heart being quicker, as they say, in the short body, in the longer being slower.

The pulse is affected by different bodily conditions, such as active exercise, a rise in the blood pressure, nervousness tending to raise the temperature, which will also quicken the pulse. When the individual is lying down it is slower and when standing or walking it becomes faster. In the morning after rising it is slower, gradually rising until mid day, after which it decreases unless it is raised by active exercise or some other exciting cause. Too much exercise, he says, may produce more, slowly becoming slower during sleep until about midnight, and after midnight it gradually becomes faster. The pulse beat affects more or less the entire body system, causing oscillations of the blood which may be noted in some circumstances very distinctly. The pulse beats also, visibly affect the teeth, the nasal cavity, the tympanum of the ear, and the eyes, producing certain movements in the internal parts of the eye, especially manifest in the vibratory movements of the membrane at the junction of the cranial bones in the case of the child.

In the smaller arteries there is a considerable quantity of unstriated muscle which produces contractile movements. These contractile movements are independent of the pulse and may be either temporary or permanent, but the rhythmic contraction usually results from the action of the nervous system on the blood circulation. This contraction, muscular contraction, affects, more or less, the arterial blood pressure, either assisting or hindering the blood flow and normally regulating the blood supply to the capillaries under the influence of the arteries. These contractions of the different arteries supply the capillaries with a series of small waves which are called, a series of local circulations which balance each other, producing the natural blood flow to the different capillary regions.

In this way the circulation of the blood is maintained uniform. In the minute vessels of the brain, the minute vessels of the abdomen, of the liver and of the spleen, and especially the correlated circulation being regulated in such a way as to be a balance between the liver and spleen, the abdomen and lower parts of the body, the brain and thyroid glands. They are regular in order to preserve equilibrium. If the stethoscope is placed over a large artery a sound may be heard; this sound being shrinkage of the arterial wall, and when the wave passes beyond this pressure, the rapidity of the blood flow causes oscillations of the sounds are not produced by the occlusion of the arterial walls, although the elasticity of the arterial walls assists by lessened peripheral resistance, aids the blood current, the blood passing away very freely and rapidly.

**SECTION XI. Capillary Circulation**

The capillary circulation may be easily studied in connection with the frog's foot, the lung of the frog and any other of the organs in which fine capillaries are found. Each capillary of this minute network extending through the body constitutes a tube, the diameter of the finest of these tubes being from 0.002 to 0.005 millimeter and extending in length from 1 to 5 mm. The number of these small capillaries depends upon the activity of the tissue, being more numerous in the active organs and active tissues. The minute capillaries may be divided into two groups, going to and from the capillaries, with the minute network that vary in the different parts of the body. The circulation in the capillaries, small arteries and veins, being continuous, there being normally no pulse, the intermittency of action arising in the capillaries and vessels. The blood reaches the minute vessels. The walls of the minute vessels are very delicate, the caliber of the vessels varying so that in the lungs and muscular tissues where the blood performs its most important functions, the blood is collected in very minute vessels, moving very slowly and over a very large surface. The capillary walls are composed of a very fine layer of muscle and nervous tissue where the blood performs its most important functions. These delicate cellular walls become thicker as we approach toward the small veins and arteries. This fine cellular character of the wall is of great importance in the circulation. The chief vital characteristic of the capillaries is that which depends on the daily interchange of matter between the blood and the tissue. On the application of stimulation the walls contract, the power of contraction residing in the endothelial cells lining the capillaries. This contraction is intimately connected with the fixation of the blood supply and capillaries. The vessels constrict or relax according to the requirements of the tissues. The existence and arrangement of these capillaries in the different tissues is such as to promote efficient functional activity. If the tissue or organ is very active the muscles of the body of the capillaries are arranged in long meshes, in the capillaries are very closely connected into a plexus; if the tissue organ is less active the arrangement is less minute and extensive. This arrangement is
always in harmony with the structure of the tissue or organs, e.g., in the connective tissues they assume irregular shapes, in the small cutaneous papillae they form little circles. The capillary circulation is due to the heart force which is sustained and modulated by the circulation through the vessels. Some physiologists consider that it is also influenced by the drawing action of a tissue through which the capillaries pass. This is proved by the increased amount of blood attracted to a tissue that is very active, in order to sustain its nutrition, e.g., in the lactation of the mammary glands. This force represents the need of blood and may be considered as an active element along with the heart force sustaining the circulation.

In the capillary circulation there is no pulse, the pulse movement transmitted along the arterial vessels being extinguished mainly before the blood flow enters the capillaries, and finally, by the great resistance, arising from the minute subdivision of the capillaries. In the case of great distension of the smaller arteries and veins, there is a venous pulse. There may be, also, an abnormal capillary pulse. This is produced by the compression of the muscles in which the capillaries are situated, as for example, in the muscles of the hand, the abdomen, and the legs due to inflammation in which a capillary pulse produces throbbing.

The increase of blood varies in its velocity being more rapid in the smaller capillaries than in the smallest. The capillaries which are farthest from the heart. These capillaries the current seems to be almost uniform, at least in the vessels of the same size. This, however, is subject to variation even in the smallest vessels on account of the variation in the intensity of the带动. In the larger capillaries the red corpuscles travel with great rapidity along the center of the stream. Sometimes two or three of these red corpuscles travel abreast of each other while the white corpuscles move along the slower part of the stream close to the vessel walls. The red corpuscles, as we have said, move along the central part of the stream keeping separate, normally, from each other, unless in the case of their passing into the smaller capillaries, in which they move through the minute channels in single file assuming its bending and elastic substance through the narrow bore of the vessel, afterwards regaining its original normal shape. The colorless corpuscles move chiefly in close contact with one another and with the vessel wall, moving much slower than the red corpuscles and adhering together, and closely adhering to the vessel wall even after the red corpuscles have dispersed themselves past the white corpuscles. This fact, that is, their moving less rapidly than the red corpuscles—those corpuscles which are due to their lighter specific gravity—that is, of the white corpuscles—the more dense corpuscles being driven out into the middle of the stream, the red corpuscles being slightly denser than the corpuscles and the white corpuscles slightly less dense than the plasma. In addition to the density of the blood corpuscles the friction is always less at the middle of the stream than at the sides. This is evident from the fact that the colorless corpuscles along the sides of the stream are clearly separated from the red corpuscles in the middle of the stream by a narrow channel of blood plasma. In some cases the white corpuscles in addition to adhering to the vessel wall pass through the vessel walls, this process of migration taking place between the minute cells of the endothelium lining of the walls of the case of the capillary circulation it is the same as in the capillary circulation. This process may be seen in active operation under the microscope, by setting up an artificial inflammation in the mesentry of a frog by exposing it to the air for some time. In normal, healthy condition it would support the following: there exists a close relation between the vessel walls and the blood, according to which the adhesion of the corpuscles to the vessel walls is regulated, determin-
only, or at least the chief check in the case of the veins is the action of the muscles which drive the blood in the direction of the heart. The valvular arrangement of the veins prevents any recurrent blood flow. The veins are found to possess no valves where the external pressure is abnormal, for example, in the brain and the internal portion of the bosome. This valvular arrangement in connection with the vertical position of the body, as these valves prevent the blood from passing down to the lower extremities of the body, and also, promoting the circulation toward the heart. In addition to this the force of the blood presses the valves open toward the heart, at the same time preventing the blood from making its way backward to the peripheral extremities of the veins. In some cases we find the blood pressure is insufficient to drive the blood into the circulation, the veins in such a case setting up a pulsation which has been called the secondary heart. Normally, as we said, there is no venous pulse, sometimes, however, the pulse wave passes on through the veins into the veins.

This pulse, as seen, for example, in the veins of the neck, is supposed to be produced by some obstacle that prevents the passage of the blood from the right side of the right ventricle to the right ventricle, these values, in this case, is uniform in its time with the systole of the auricle. During the rise ventricular systole the right auriculo-ventricular valve closed. Sometimes, however, this valve does not close sufficiently and as a result there is an undulatory movement transmitted along the wall of the superior vena cava to the veins of the neck, in this way producing the pulse of the venous circulation. When the auricle and ventricle are in diastole, the blood passes to the heart. This pulse arises from the imperfect activity of the jugular valve permitting the wave of pressure from the jugular veins causing the venous pulse of the neck. On the other hand, when the left auriculo-ventricular valve is weakened in some way, the right auricle becomes engorged with blood, and as a result a wave of contraction is sometimes produced. In connection with the veins, there is an expansion of the capillaries that which originates from the ventricle, the arterial side of the capillaries and the venous side of the capillaries. From the ventricle, the veins conveying the venous blood the aorta and the left ventricle, has a very thin wall, indicating the lessening of the pressure. This, however, is counterbalanced to a large extent by the structure of the walls of capillaries and the pulmonary veins are greatly assisted in freely circulating the blood by this pressure, whereas, the pulmonary artery is weakened in its action. This is due in inspiration to an increase of the caliber of the pulmonary vessels that have been dilated particularly by the increased caliber of the pulmonary veins that are richly supplied with arterial blood. When the heart begins to act freely, for example, in inspiration, the blood rate of the pulmonary is greater than of the systemic circulation, and it is necessary in order to accommodate the same volume of blood in the pulmonary as in the systemic circulation. The right ventricle has sufficient force within itself to perform its work. This is evident from the fact that apart from the normal chest contraction, if the thoracic cavity be opened, the heart can perform its work without any respiratory action. If the inspiration is preserved artificially, the pulmonary circulation, therefore, is much more simple than the systemic circulation. 

PULMONARY AND PORTAL CIRCULATION.

In the pulmonary circulation the venous blood is returned by the veins to and on contraction of the ventricle, is passed along the pulmonary artery to the lungs in order to be cleansed. After having passed through the lung circuit it returns pure as arterial blood to the left auricle through the left veins. This pulmonary circulation, although essentially the same as the systemic circulation, differs in some particulars. In the pulmonary circulation is small in extent, compared with the systemic. As the pulmonary capillaries empty simultaneously and are of equal capacity, it is interesting to follow the circulation in the lungs. In the pulmonary circulation as compared with the systemic, the resistance is less, and therefore of the vascular contraction there is less resistance to be overcome by the right than by the left ventricle. The structure of the heart in this respect is prepared for this. The muscular wall of the left ventricle is very much thicker than that of the right. Hence the force of contraction in the case of the right ventricle is very much less than that of the left ventricle. It is impossible to estimate the blood pressure or the rate of the blood flow in connection with the pulmonary. The pulmonary pressure cannot be reached unless after destroying the respiratory mechanism, and artificial respiration is not sufficient even if such artificial respiration could be produced to give a normal pulmonary circulation. The pulmonary artery, like the right ventricle as compared with the heart and left ventricle, has a very thin wall, indicating the lessening of the pulmonary artery, which is divided into a number of branches, the very minute vessels passing into the plexuses of the capillaries on the walls of the air vessels of the lungs. Arising from these plexuses are the valves which collect the blood, passing through four larger veins, two for each lung, bringing the pulmonary veins to the heart. The pressure of the pulmonary artery is much greater than that in the aorta, the proportion being estimated about 2 to 5. The pulmonary system lies inside the thoracic cavity, although outside of the lungs, except in the case of the lung capillaries, hence, when the lungs are filled with air the ventilation of the lungs becomes expanded while the capillaries lining the surface of the lungs are subject to the same amount of pressure as the surface of the lungs upon which the entire air in the lung may act. In this way the capillaries and the pulmonary veins are greatly assisted in freely circulating the blood by this pressure, whereas, the pulmonary artery is weakened in its action. This, however, is counterbalanced to a large extent by the structure of the walls of the arteries as compared with the veins, the arteries being much more firm and solid. In this way the lung contraction in connection with the muscle of respiration materially aids the process of circulation in the pulmonary system, especially the activity of the right ventricle. The lungs expand on account of the internal pressure being greater than the external pressure in the pleural cavities. If this expansion is to destroy elasticity and the elastic action exerted by them amounts to 30 mm of mercury. External to the lungs there is a pressure in the thoracic cavity bearing upon the surface of the heart and other organs equal to the pressure of the atmosphere minus the elastic force of the lungs, themselves, that is, 730 mm. The fine walls of the veins will yield with very little elasticity during inspiration, lessening the pressure, while the thicker walls of the arteries will yield less, and in this way the blood flow from the lung capillaries to the heart is promoted.Expiration will have an opposite effect. The effect of inspiration upon the pulmonary capillaries and smaller vessels of the lung will be assisted the blood flow while expiration hinders it. This is due in inspiration to an increase of the caliber of the pulmonary capillaries, while in expiration to a decrease of the caliber of the pulmonary capillaries. The blood rate of the pulmonary is greater than of the systemic circulation, and it is greater in the pulmonary veins than in the heart. This is necessary in order to accommodate the same volume of blood in the pulmonary as in the systemic circulation. The right ventricle has sufficient force within itself to perform its work. This is evident from the fact that apart from the normal chest contraction, if the thoracic cavity be opened, the heart can perform its work without any respiratory action. If the inspiration is preserved artificially, the pulmonary circulation, therefore, is much more simple than the systemic circulation. 

PORTAL CIRCULATION.

In the portal circulation there is one fact that requires particular notice, the passage of the blood through two capillary circulations in the abdomen and
the liver. The branches of the abdominal arteries carry the blood to the stom- 
ach, spleen, pancreas and the intestines, these branching off in different 
veins joining together to form larger vessels, the blood flowing through two 
veins to the liver which it is circulated by means of unbranched capillaries. 
The origins of the hepatic vein, through which the blood is carried from the 
abdominal vessels become expanded, causing congestion of the abdomen, pro-
ducing rapid diminution of blood pressure and death. Sometimes a wave of contraction which is transmitted through the 
veins follows the action of the heart in the inverse order contracting with each 
diastole, and distends with each systole of the heart.

**SECTION XIV. Innervation of the Blood Vessels.**

In the case of all the arteries it is found that muscular fibers are part of 
the lining of the vessel wall chiefly in the media. This musculature 
present among the arteries, being collected around the muscular walls in 
the impulse along the muscular wall, producing contraction, resulting in 
veins, although there is much greater variation among the veins. The nerves 
contractile fibers, being distributed among the veins, also, convey impulses resulting in 
the vessels themselves, under the control of the nervous system, are 
arteries of the body there is a nervous influence imparted to the muscular 
in the veins. These nerves are called the vaso-motor nerves. The vaso-
Contractions of the muscle constricting the artery. 2d. Moderate contractions of the muscle, in which 
the artery is not greatly constricted or greatly dilated. This latter is 
contraction of any artery, even the main artery of veins, and it is not 
light. The time question in Physiology. It is not known with certainty which 
arterial or veins. The middle, of the arteries was established. Hence the position that 
artery depends on the blood vessels. It was known that the walls of these 
the blood vessels on the heart, its distribution was 
contraction and that the nerves terminated in the muscular 
by the nerves and that these nerves under stimulation influenced the contractil-
ity. It was discovered that by dividing the cervical sympathetic ganglion the circulation was increased on the left 
arterial is dilatation of the vessels and a rise in the temperature. If the right 
arterial are constricted, it is found that the dilated vessels of the face soon 
and soon passing away. On the other hand, the stimulus, the veins 
pathetic influence the contractility of the vessels by constriction.

The spinal cord is found to originate certain fibers that produce the same

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**INNERRATION OF THE BLOOD VESSELS**

The submaxillary gland is well supplied with blood vessels, being 
supplied with nerves from the cervical sympathetic and from the 
vago-constrictor nerve, arising from the seventh cranial nerve and joining the lingual branch of the 
nerve, as the blood vessels of the submaxillary gland are supplied with the nerves into the 
the gland, the vein was opened and the blood to the neck, between the gland and ligature, 
cleaning the blood to the neck, between the gland and ligature, and the end in connection with the gland stimulated, the vaso-
there must be, therefore, vaso-motor fibers producing dilatation of the vessels, vaso-
nerve fibers producing constriction of the vessels, vaso-constrictor nerves and 
arterial end stimulated, the vaso-constrictor nerves and vessels. The nerve 
by the capillaries of the liver. The crural artery is ligatured and the sciatic nerve is divided, the vaso-
noted in the case of the stimulation of the cervical artery, the vaso-constrictor nerve is 
the nerves to the arteries in connection with the vaso-
the arteries in the way in this way are 
referred to the sympathetic nervous system. Nearly all the nerves of the body in this way are 
the blood vessels. It was known that the walls of these vessels 
the term was taken as proved that the blood vessels were 
abdominal arteries, being collected around the 
arteries, being collected around the muscle walls in 
the heart, its distribution was 
arteries to the muscular 
arteries. The middle, of the arteries was established. Hence the position that 
artery depends on the blood vessels. It was known that the walls of these 
the blood vessels on the heart, its distribution was 
contraction and that the nerves terminated in the muscular 
by the nerves and that these nerves under stimulation influenced the contractil-
ity. It was discovered that by dividing the cervical sympathetic ganglion the circulation was increased on the left 
arterial is dilatation of the vessels and a rise in the temperature. If the right 
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and soon passing away. On the other hand, the stimulus, the veins 
pathetic influence the contractility of the vessels by constriction.

The spinal cord is found to originate certain fibers that produce the same
INNERVATION OF THE BLOOD VESSELS.

thought by some Physiologists that the dilator fibers pass directly through the anastomoses of the arterial system, and that the blood vessels are innervated by a general vasodilator nerve. This theory has been disproved by the experiments of Pflüger, who showed that the arterial and venous systems are mediated by different nerves.

The sympathetic ganglia, those ganglia being subject to the influences of the spinal cord, whose fibers, lying at different levels in the spinal cord, are under the control of the medullary centers. There are thus found to be three motor centers, namely, the sympathetic ganglia representing the 2nd center communicating with the thoracic, of which the spinal cord is the 3rd center, namely, the sympathetic ganglia sending out branches to the muscular walls of the vessels.

(a) The vaso-constrictor fibers have been found to arise from the middle portion of the spinal cord, passing into the sympathetic ganglia from which they pass to the viscera and the extremities, and in which they are distributed to the skin, the muscles, and the organs of the chest and limbs. They are distributed in a similar manner to the vaso-constrictor fibers of the cranial nerves, and are distributed to the skin and muscles of the head and extremities.

(b) The vaso-dilator fibers are distributed to the skin, the muscles, and the organs of the chest and limbs. They are distributed in a similar manner to the vaso-dilator fibers of the cranial nerves, and are distributed to the skin and muscles of the head and extremities.

(c) The sympathetic ganglia of the abdominal region, of which the spinal cord is the 3rd center, namely, the sympathetic ganglia sending out branches to the muscular walls of the vessels.

The sympathetic ganglia, those ganglia being subject to the influences of the spinal cord, whose fibers, lying at different levels in the spinal cord, are under the control of the medullary centers. There are thus found to be three motor centers, namely, the sympathetic ganglia representing the 2nd center communicating with the thoracic, of which the spinal cord is the 3rd center, namely, the sympathetic ganglia sending out branches to the muscular walls of the vessels.
the blood pressure arises from constriction. If the sensory nerves in any limb be stimulated after the section of the spinal cord in the middle thoracic region reflex contraction of the muscular elements of the spinal cord is observed. It is said by some Physiologists that even after the extirpation of the spinal cord. It is said by some Physiologists that even after the extirpation of the spinal cord. In addition to these two centers we have also observed that the dilator fibers are being aroused to activity by stimuli, which produce reflex dilatation of the vessels. This is the case with the sympathetic ganglia, where the sympathetic fibers are influenced by various stimuli. One of the branches of the chain of the sympathetic ganglia is placed in the thoracic region, and nerve fibers, which are concerned with the dilatation of the blood vessels, are present in the sympathetic ganglia. These centers are also influenced by reflex action, acting as the seat of the sympathetic ganglia, where the sympathetic fibers are influenced by various stimuli. They are known as sympathetic centers as well as the spinal centers and not simply parasympathetic centers, but in a sense independent centers of vaso-motor action. In connection with some blood vessels certain rhythmic contractions are noticeable, these being entirely independent of the white rabbit and are said to originate in the emission of impulses from the vaso-motor centers. If the thoracic cavity be opened and the vago divided, certain vibro-motor movements are noticed in connection with the blood pressure. These vibrations are complicated and are probably due to irritation in the recuperative center acting upon the vaso-motor centers through a process of irritation.

There is a certain relation between the cerebrum and the vaso-motor centers. The application of stimulation to the cortex cerebri, and the other portions of the brain, is found to influence the blood pressure. In this case irritation in the blood pressure is believed by some Physiologists to be the result of afferent actions, the cerebrum centers originating impulses that are sent to the vago-motor nerve fibers. Afferent nerve fibers originating in the central portion of the brain, and the brain, and the blood pressure is increased. When the cerebrum is subjected to stimulation, that is used in the case in the present, the application of continuous stimulation is followed by an increase of blood pressure, and pressure being due to the stimulation conveyed by afferent nerves in the vaso-motor centers. The cerebrum, therefore, of the sensory nerves produces reflexly vaso-motor action. If food is placed in the mouth the nerves of taste originate certain impulses, producing efficient impulses in the centers, which pass out along the chorda tympani and other nerves to the salivary glands. The result is that the sensory nerve fibers may be transmitted along the vagus and any of the sensory nerves to the center, producing activity of the dilator fibers in the chorda tympani or other nerves, resulting in an increased blood supply to the salivary glands. The muscular elements of the vessels, that tend by the motor influences, the dilator fibers being aroused to activity by stimuli, which produce reflex dilatation of the blood vessels, and a consequent fall in the blood pressure. For example, of ice, then by the application of a stimulation to the peripheral end of this vaso-motor nerve, there is a fall in the blood pressure. If the cerebrum is applied, it is found that there is a decrease in the blood pressure. If an animal is subjected to chloroform or ether, the cerebrum without any corresponding increase in the action of the heart, there is no alteration in the blood pressure. If the cerebrum is applied, it is found that there is a decrease in the blood pressure. If an animal is placed under the influence of chloroform, ether or curare, a fall in the blood pressure takes place instead of an increase. This seems to indicate that the result depends upon the cerebral cortex. Thus the depressor nerve acts as an inhibitory nerve fiber, in connection with the blood vessels by controlling the peripheral elements of the vaso-motor nerves. We have seen that there are two kinds of vaso-motor fibers, the vaso-constrictor producing contraction of the vessels, and the vaso-dilator producing dilatation of the vessels. The question is asked in Physiology, "How does this action take place?" The only answer that can be given is that the fibers do not act directly upon the muscular elements of the vaso-motor action. In the vessel walls we find the large vessels, in the walls of the small vessels, there are pass nerve branches into the muscular wall of the vessel, and into the local inhibitory fibers. Gaskell, on the other hand, thinks that these fibers exert a trophic influence, the constrictor fibers influencing vasoconstriction and the dilator fibers influencing the anabolism of the blood vessels. Blushing is a result of vaso-motor-
action, certain emotions originate impulses in the brain which powerfully inhibit the vaso-motor center, governing the vaso-constrictor region of the head, influenced by the cervical sympathetic. The relaxation of the muscular walls of the vessels and arteries, the heart being deprived and suffusion taking place. Sometimes paller—often referred to as the skin, is also produced in the reverse manner, that is, palor is sometimes also the result of vaso-motor action. It results from the constriction of the arteries through the sympathetic and the vaso motor center. The pressure is also influenced by the respiratory action. Inspiration takes away the pressure from the external surface of the vessels allowing the large veins and arteries to expand as the veins are more expon sible during inspiration, the blood tends to collect in these large veins next the heart, ensuing, therefore, a fall of blood pressure in the aorta. In expiration, on the other hand, the reverse of the process takes place, the blood pressure being increased at the aorta. This, however, is not scientifically, because during inspiration there are two moments or stages. During the first stage the blood pressure falls. During the second stage the blood pressure rises. This is due in part, at least, to vaso-motor action. During the second part of inspiration certain influences are sent from the center, causing the contraction of the small vessels producing a rise in the blood pressure in the arteries. During the first part of inspiration the cardio-inhibitory center acts, and the heart, as a result, beats more slowly. Thus, the vaso-motor influence, acts upon the blood vessel in connection with respiration. Some attempts have been made to specify and localize all the nerves in connection with the different regions of the body. This, however, is topographic rather than physiological and therefore belongs to the field, not of Physiology, but of Anatomy.


PRESSURE—We have studied specially the organs of circulation and their physiological bearing. There are still two points left that belong to circulation, not specially, but in general. The circulatory system, and we have said, may be ideally considered as a tubular arrangement. If the blood is regularly distributed, it may be an equilibrium in the circulation, and pressure would be impossible. As in the case of the ventricular contraction the blood will be thrown out of that place with greater pressure to the part in the circulation with the lower pressure, and hence the circulation will be normally promoted. If the heart action, on the other hand, is arrested, then the pressure is diminished. This diminution takes place gradually until the blood ceases altogether to circulate. Thus, beginning with the heart beating slowly the blood pressure diminishes, and the blood pressure is restored as soon as the heart begins to beat again. Consequently the blood flow is from the heart through the arteries, capillaries and veins to the heart again. Each heart beat ejects as much as possible of blood into the arteries and capillaries into the heart from the veins and as the opening into the heart from the veins. The blood flow is from the heart through the arteries, capillaries and veins to the heart again. Each heart beat ejects as much as possible into the capillaries and venous into the heart. Each method, however, is unsatisfactory on account of the length of the tube required and the readiness of the blood from the heart. In 1728 Poinsinl devised the bell tube in the U shape and put mercury in the heart. This was also an improved form of this instrument. It consists of a glass tube bent in V shape, open at the two ends, held in position by a metallic frame. Mercury is placed in the vessel as to occupy the bend. The one end fitted into the blood vessel is capped with a stopcock. The blood is then passed into the tube a solution passed into the tube to prevent the blood from clotting. 

GENERAL CIRCULATION.
magnesium sulphate. On account of the cardiac and respiratory changes this medicament has been found very useful. On the other hand, the arterial blood pressure is a measure of the resistance met by the blood as it flows through the vessels. The arterial blood pressure is the pressure which is exerted on the walls of the arteries due to the force of the blood being driven through them. This pressure is measured by the cuff and stethoscope method described above. The arterial blood pressure is a direct measure of the force of the heart's contraction, and is therefore a direct measure of the heart's work. The arterial blood pressure is also a measure of the elasticity of the arterial walls. The arterial blood pressure is affected by many factors, including the heart rate, the heart's force of contraction, the peripheral resistance, and the volume of blood in the circulation. The arterial blood pressure is important in the regulation of blood flow to the various organs of the body, and in the maintenance of the normal functioning of the circulatory system.
is estimated by calculating the mean pressure at the different points along the arterial system and then striking an average between these different mean pressures of blood pressure at the arterial system, for example, in plethora and in the case of mean blood pressure. The mean blood pressure increases with the force of the mean blood pressure. If, on the other hand, the action of the heart is weak, the venous blood pressure will become lessened. As an example, in the case of fever, and in the case of anaemic conditions, for example, in the case of anemia, the pressure of the blood in the arteries diminishes, and the blood pressure will be lessened. The mean blood pressure is lessened, as in an anemic condition, and in the case of the loss of blood by abnormal conditions, for example, it is in the case of hemorrhage and in phthisis, the pressure of the blood will be very low. In certain cases of hemorrhage, in connection with the capillary blood pressure, therefore, of the capillary system is low, as compared with the blood pressure in the arteries. When we have seen, the force that drives the blood into, and through the capillaries, is the force of the heart imparted to the arterial walls, manifesting in the recoil or contraction of the arterial walls, following distension, by the force transmitted from the heart at the preceding systole. This force produce the capillary circulation are, first of all, the heart force, and the peripheral resistance, and also its high pressure. There is much less resistance in the veins, than in the case of the entrance of the blood from the capillaries into the veins. This resistance is constantly diminishing through the course of the capillary circulation. The force of the heart beat is also greatly diminished with respect to the preserving the arterial blood pressure. Thus, a lessened force meeting with a lessened resistance, is what we find in the capillary circulation. The blood flow is, therefore, slow and steady, and this slow flow has a function in that in the venous circuladion, there is a volume of blood thrown into the capillaries during the ventricular systole. At the arterial recoil, as we saw before, the diastole, equal to the volume of blood displaced during the ventricular systole, altogether at or about, the close of the arterial system, leaving the blood in a state of readiness for the venous capillary circulation. Any condition that favors the venous blood pressure, for example, a distressing or an excess in the volume of blood passing away from the heart, or the reduction of the heart force, will cause the blood pressure in the capillaries to be lessened. The blood pressure, preventing the volume of blood passing away from the heart in that peculiar net work among the muscular fibers together with the constriction of the muscles bearing upon the capillaries, will influence the capillary pressure.

3 Venous Blood Pressure—The venous blood pressure is lower in the minute veins than in the capillaries, gradually diminishing, as we saw, toward the heart. In the larger veins or at near the heart the pressure ranges from a slight positive value to a slight negative. This negative pressure is dependent upon respiratory action. This diminishing blood pressure in the veins arises from the same causes as the low blood pressure in the capillaries. It is the heart force transmitted along the arterial walls and through the veins, that forces the blood into the veins. There is still, as we have said, a certain amount of resistance in the venous circulation, although the resistance is gradually lessening all the way toward the heart. The capacity of the walls of the veins is very slight, and hence the blood moves freely along the venous blood path with no greater internal pressure than the external atmospheric pressure. While the heart force is sufficient to drive the blood through the veins, there are certain forces which assist the blood through the venous circulation toward the heart. These forces are in number, first of all, the aid brought about by the lungs in the venous circulation. The force of the muscles of inspiration, and third, the force that arises from the skeletal muscles. (1) The lungs exert an influence upon the venous circulation. During inspiration, the two sides of respiration, the lungs are stretched, the lung fibers drawing on the ribs, the diaphragm, the heart and the other organs in the thoracic cavity. This distending force acts upon the heart during the ventricular diastole. This same drawing force generates in the superior and inferior veins cava suction force which affects the venous circulation. This suction action tends to draw blood without the thoracic cavity inside the chest. As we have seen there is a negative pressure always found in the veins close to the chest, this negative pressure giving place to a positive pressure farther away from the chest in the venous blood path. Thus the elastic traction of the lungs is constantly exerting a drawing influence upon the venous blood toward the heart. (2) This force of aspiration in connection with the blood flowing in the veins, is materially aided by the muscles of inspiration which by their contraction strengthen the traction force of the lungs. At each dilatation of the chest there is a force generated which sucks the blood into the chest. This contraction takes place this force is suspended so that the muscular force which draws upon the venous circulation is not constant but is marked by the successive contractions. (3) There is an influence exerted temporarily by the skeletal muscles. When these muscles contract, compression is brought to bear upon the veins in close proximity to these muscles, so that the blood, by this compression, is driven out of the veins, and the venous blood pressure is overcome. Here the muscular compression may temporarily assist in promoting the venous circulation. This is not constant, but only temporary, because if the compression is continued for a long time it would result in the destruction of the vein, or the obstruction of the circulation, not by causing the blood to pass away from the heart, but by destruction of the veins or arteries in this region. The diminution in the blood pressure is so great that in the large veins near to the heart it is estimated that the pressure is only about one-twentieth part of the pressure in the arteries next to the capillaries and there are no great variations in the venous blood pressure, unless in those large veins close to the heart in which the pressure increases during the auricular contraction and diminishes during the auricular expansion. Great activity in the heart produces a lowered pressure, all through the venous circulation. Anaemic blood conditions for example, produce a diminution
VELOCITY OF THE BLOOD CIRCULATION.

The measurement of the velocity of the blood has long been the concern of physiologists. Hagen, Poiseuille, and others have investigated the subject, and the velocity of the blood has been measured with great accuracy. However, the measurement of the velocity of the blood has been made in the past by the use of various instruments, such as the anemoscope and the anemometer.

The anemoscope is a device that consists of a series of thin, parallel metal plates, each of which is connected to a sensitive galvanometer. The plates are arranged in a series of parallel rows, and the blood flows between them. The deflection of the galvanometer, which is proportional to the velocity of the blood, is measured by an electromagnetic balance.

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The velocity of the blood can also be measured by the use of the micrometer head.
in connection with the microscope. Some Physiologists have measured the speed of the blood in the capillaries of the retina in their own eyes. It is found that the velocity of the blood in the case of the capillaries is very less than the in case of the arteries. Weber estimates the velocity in the case of the foot at 51-100 mm. per second, and in the case of the mammalian capillaries, 8-10 mm. per second. Other Physiologists estimate that in the human subject there is a normal capillary velocity varying from 6-10 to 9-10 mm. per second. Volkmann states that in the human subject the velocity of the blood in the aorta is 600 times the velocity of the blood in the capillaries, and the velocity of the minute arteries is 10 times the velocity of the capillaries. In the case of the veins the velocity is small in the minute veins leaving the capillaries, increasing gradually as the veins become larger, until in the larger veins close to the heart it is found to be from 200 to 225 mm. per second, for example, the jugular vein of the dog and also of a horse; these are estimated 200 to 235 mm. per second. The venous velocity increases, therefore, from the capillaries to the heart. This acceleration in the venous velocity is due partly to the diminished resistance. Comparing the velocity of the blood with the blood pressure, there are certain conditions that we find to be noted. In the case of the artery, the velocity and accompany each other, both in rising and in falling, both the velocity and the blood pressure gradually diminishing from the heart to the capillaries. In the capillaries the velocity and the blood pressure are low. In the veins, on the other hand, there is a low blood pressure, diminishing gradually all along the veins, whereas, the speed is higher than we have had in the capillaries, and it increases all the way toward the heart. There is no relation, therefore, between the velocity of the blood and the blood pressure, being in direct relation to one another in the case of the arteries, and in the capillaries, and in inverse relation to one another throughout the venous blood path. The velocity in the capillaries is very slow, compared, at least, with the large veins and with the large arteries, whereas the minute veins and the minute arteries have a greater velocity than that found in the capillaries. This fact is of great physiological value, because in the capillaries the great function of supplying the tissues is performed. The whole volume of blood being required to do this, and that the blood must pass slowly in order to permit the blood entering into the tissues and to allow the blood interchange.

The circulation of the blood requires that an equal volume of blood must pass at two points in the circulation, in equal periods of time except in cases of abnormal disturbance. This, of course, does not mean that the rate requires to be uniform in all the arteries, capillaries and veins, because the rapidity in one is compensated for by a lower rate in the others. This is easily explained because the large arteries and veins are few in number and small in their cross-section area as compared with the small vessels and the capillary capillaries. The cross-sectional area increases with the subdivision of the vessels. This sectional area, therefore, is gradually increasing from the heart to the capillaries; hence, the smaller the blood vessels, the larger the blood pressure at that region, the wider the path being in the most minute capillaries. Vierordt, a German Physiologist, states that the cross-sectional area of the capillaries is eight hundred times that of the arteries at the root of the arteries, and four hundred times that of the veins at the venous orifices. Thus the venous circulation is much greater in calibre, than the arterial system. The arterial and the venous ones lie with their narrow ends toward the heart, and are connected together at the two bases by the capillaries. An equal volume of blood passes in the same, or equal periods of time, any two points in the blood path, so that in the narrow path the blood must flow very rapidly, and in the wider path, more slowly. The velocity, therefore, diminishes on account of the width of the blood path toward the capillaries, causing the velocity to be lowest in these capillaries where the blood path is the widest. In the venous blood path, the gradual narrowing of the path toward heart causes the increase of the speed, and the fall in blood pressure, the speed being so much lower in the venous system, because the venous blood path is so much larger than the arterial blood path. The blood flows, therefore, much more slowly into the right auricle, as it moves out of the left ventricle, because the path is wider, although the volume is about the same. The calibre is very much larger at the venous orifices. This corresponds with what we have found in connection with the heart, that the blood pours in during the long auricular diastole, and leaves it in the auricular systole. It is found, therefore, in this standpoint, that the velocity of the blood flow depends upon the width of the path, being greatest at the aorta, diminishing toward the capillaries and then increasing again toward the heart in the venous system. The resistance in the capillaries plays only a very small part in determining the velocity, at least in the capillaries, but the increased sectional area is the element which determines the velocity all the way around the blood path. The ventricular force produces the blood flow through the entire circulation, propelling the blood through the arterial walls, and thus producing a force sufficient to keep the blood in active circulation during diastole, as well as systole. Thus we conclude: 1st of all, the speed of the blood is in inverse proportion to the calibre of the vessels measured in sectional areas. 2nd. At each systole the rapidity of the blood flow is increased in the large arteries close to the heart. 3d. The rapidity is constant in the small arteries, capillaries and small veins. 4th. The speed is increased in the veins toward the heart. In the large arteries the influences of the inspiration retard the speed while expiration increases it. 5th. In the large veins the influence of respiration and the suction force of the heart causes an increase of the velocity of the blood.

Time Occupied by the Entire Circulation. - The width of the blood path by which we have said, determines the rapidity, thus regulating the movement where the blood requires longer time to perform its functions in the tissues, and the more rapid movement where the blood simply passes along. In this way the red corpuscles are found to spend a large portion of time in the capillaries where these corpuscles are brought into active connection with the tissues.
VELOCITY OF THE BLOOD CIRCULATION.

The velocity of the blood circulation depends upon the blood supply to the various organs, and changes with each heartbeat. In the muscular tissue, the blood is driven out of the capillaries at each heartbeat, and the velocity is diminished when the muscular contraction occurs. In the thoracic cavity, the blood flow is confined to the smaller vessels. Each organ receives the necessary supply according to its requirements.

The activity of the myocardium, that is, the beating of the heart, determines the blood flow into these organs. There are, however, some organs whose continuous activity determines a constant supply of blood to these organs; for example, the heart, which is kept alive by its own blood supply. These organs have a constant supply of blood, and the compensation leads to a more uniform distribution of the blood through the body.

Changes in quantity are compensated for by changes in the diameter of the blood vessels. The volume of blood in the blood vessels is slightly increased or decreased by the change in the blood pressure due to the muscular contraction, and this is compensated for by the constriction of the blood vessels. This is accomplished by the adjustment of the pulmonary resistance.

The thoracic cavity is divided into the left and right sides, and the pulmonary resistance is increased on both sides. The thoracic cavity is also divided into the left and right sides, and the pulmonary resistance is increased on both sides. The thoracic cavity is also divided into the left and right sides, and the pulmonary resistance is increased on both sides.

The movement of the lymph is a very important process, as it aids in the absorption of the fluids from the capillaries and the lymphatic vessels. The lymphatic vessels are not only important in the absorption of the fluids, but also in the transport of the nutrients and oxygen to the tissues.

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The movements of the lymph.

The lymphatic vessels are the means by which the body expels its waste products and the lymphatic system provides a method of dilution of the blood. They are also important in the absorption of fats and the nutrients from the digestive tract. The lymphatic system consists of a network of vessels, lymph nodes, and lymphoid organs.

Lymphocytes are the white blood cells that form in the lymph nodes and are responsible for the body's immune response. They circulate through the lymphatic system and fight off infections and diseases.

The lymphatic system helps to maintain the balance of fluids in the body. It is important for the proper functioning of the cardiovascular system and the immune system. The lymphatic system is also involved in the absorption of fats and the nutrients from the digestive tract.

The lymphatic system is a network of vessels that return fluid from the tissues to the bloodstream. It is a closed system that helps to maintain the balance of fluids in the body. The lymphatic system is important for the proper functioning of the cardiovascular system and the immune system. It is also involved in the absorption of fats and the nutrients from the digestive tract.
THE MOVEMENTS OF THE LYMPH.

freely in one direction from the lymphatic system into the venous circulation system, and the blood cannot flow from the venous system into the lymphatic system. The pressure of the blood in the capillaries and the smaller vessels is very much larger than in the larger vessels. In the lymph spaces the lymph also is subject to considerable pressure, along the lymph path, also, the lymph flow in effect of the valves, as we have seen, which keep it up in one direction to the venous system the pressure always varies from a slight the estimated about one half of the pressure in the capillaries. is also, a resistance continuously met with, causing the lymph influence of resistance being balanced normally by the muscular activation of the lymph vessels. On account of the difference in the pressure between the blood and the lymph, the lymphatic system, exudation takes place from the blood to the lymph spaces.

This pressure which causes the transudation of blood from the blood into the lymph spaces marks the highest point in the lymph pressure, determine lymph spaces that are found in the tissues toward a lower pressure, which is found at the junction of the lymphatic and the venous systems. This differentiates the lymph flow in the one direction toward the venous in the large veins near to the heart becomes negative, causing as we suction action that we see in the venous system, we find the suction acuity in the right lymphatic duct into the venous system. The thoracic becomes somewhat expanded, setting up in this way, a suction thoracic cavity, and always tending during systole this great duct, and then from the great duct into the venous circulation. Upon which Physiologists, however, are not agreed. These two influences, which cause the muscular contractions of the lymphatic walls, the lymph spaces, thus originating, at least, lymph in the capillaries. The increase of blood pressure increases at the same time the pressure of the fluid in the capillaries. The influence on the origin in the pressure of the fluid in the capillaries. The venous regions. These dilated regions are said to contrast after the same the lymph always flows from the lymph spaces to the larger lymph vessels. These movements, however, in the human subject, are only ideals, because so far, no experiments have been made to indicate that there are such movements.

These lymph hearts, as we said before, do exist in the frog, but whether they exist in the human subject or not is simply a matter of theory. From the standpoint of the heart, the pulsation of these lymph hearts seems to present a possible explanation of certain amount of pressure brought to bear upon the lymph in its onward movement.

The combination of these influences tends to produce a steady lymph flow toward the larger duct, even against the force of gravity, this flow is steadily maintained from the lower limbs: especially by the valvular arrangement, preventing reflux. This is also supposed by some Physiologists that from the analogy of the blood circulation that in the nervous system the circulation through the lymph vessels, this nerve system exerts an immediate influence on the distribution of the lymph and in circulation through the lymph vessels. It is also supposed by some Physiologists that from the analogy of the blood circulation that in the nervous system exercise an immediate influence on the distribution of the lymph and in circulation through the lymph vessels. This, however, has not yet been demonstrated by physiological experiment. In the passage of the lymph to the lymph there are two characteristic stages. (1st) The passage from the blood to the lymph spaces and (2nd) The passage from the lymph spaces to the lymph vessels. These lymph vessels are not closely connected with the blood vessels. Hence, this has raised a difficulty in Physiology to explain the flow of the lymph out of the spaces into the lymph capillaries. Attempts have been made by some Physiologists to apply the principles of diffusion and filtration of the passage of the lymph from the lymph spaces into the lymph vessels. This passage, however, although the vessel wall cannot be explained either by principle of diffusion or by the principle of filtration. The explanation becomes more difficult when we consider that a double passage takes place between the blood and the lymph spaces and between the lymph spaces and between the lymph vessels. And blood, indicating that in addition to a purely physical principle of diffusion or filtration we must always take account of the Physiological condition of the vessel walls. According to some Physiologists the passage takes place in the lymph vessels. According to some Physiologists the passage takes place in the lymph capillaries. According to some Physiologists the passage takes place in the lymph capillaries. This, however, is incorrect, because so that there are openings at these points along the lymph capillaries into the lymph spaces forming a direct passage between the blood and the lymphatic vessels. As we saw before, when the fluid and sometimes the white corpuscles pass through the walls, they change the red corpuscles press their way through between the margins of the cells which line the walls, how they are. The quantity of lymph varies, the tissues demanding in certain circumstances. Although it never normally exceeds a certain definite quantity. This limit may be exceeded in pathological conditions resulting in oedema. Oedema may be produced in one of two ways: an excessive amount the lymph vessels due to some obstruction to the lymph spaces or by some obstruction to the lymph spaces. In the latter case an obstruction does not materially affect the lymph flow as the lymph vessels lose their anastomosis openings up a natural passage for the lymph in its onward movement. In the real cause of oedematous condition is excessive transudation. These, belong to the field of pathology. The importance of the lymph circulation is evident from the circulation it bears to the blood circulation, from the amount of fluid that daily passes through the lymph circulation, and
THE MOVEMENTS OF THE LYMPH.

From the dangerous effects resulting from the excessive accumulation of lymph.

The blood circulation depends upon certain factors, all of which vary more or less, the heart-beat, the peripheral resistance, the length of the vessels, their calibre, the elasticity of the walls and the valvular mechanism. These under the force of muscular contraction and relaxation control the influence of the nervous system keep the blood in proportional distribution and normal circulation in the body. The quantity and quality of the blood, also exercise an influence upon the circulation. It seems remarkable that the heart should go on continuously resisting temporary irregularities and overcoming temporary obstructions, and at last without almost any notice cease to beat and suspend life. Each heart-beat, however, involves an effort, and the effort is one to sustain life against the odds presented by all the resisting forces of the system. Thus the maintenance of life through the circulation of the blood with the analogous circulation of the lymph represents the most important factor in life. When we add to this the fact that the lymph system upon the circulation keeping up the constant condition of the vessels, and maintaining the distribution and circulation of the blood, we have the foundation factors of the life in the human being. Along the entire circuit, or as in the case of the fish, by the admission of water containing in this case, the gases. In the still higher forms of life, for example—In the frog, there is a process of swallowing the air, by which the air is forced into the air sacs, while in the case of man we have a complex automatic action of muscles and nerves, playing such a very important part in the process of respiration. The object of respiration is two-fold. 1st of all, to take in a fresh supply of oxygen, such as is found necessary for the process of oxidation in the human body, and 2nd, to expel the carbon dioxide formed within the body. In the complex organism, such as the human body, the phenomena of respiration may be divided into two parts. 1st. There is an interchange of gases which takes place between the blood and the tissues. This is sometimes spoken of as internal or inner respiration. 2nd. In order that this process may go on successfully, there must also be an interchange between the gases in the blood and the tissues of the surrounding atmosphere. In this way external air is introduced into the air cells of the respiratory organs. This interchange is called the external, or the outer respiratory process between the blood and the external atmosphere. In the human subject this process is carried on almost entirely in connection with the lungs, hence, this process of respiration is sometimes called pulmonary respiration. 3rd. In addition to these there is a subsidiary respiration carried on in connection with the blood. This is called cutaneous respiration. There is also a respiration carried on in connection with the intestines called intestinal respiration. There are also some changes that take place in connection with some other organs, but these are of minor importance. Both of these inter-changes are, in the main, physical processes rather than physiological, because they are due to the mutual diffusion of the gases and depend but little upon the state of the surfaces through which the exchange of these gases takes place. The respiratory apparatus, therefore, in the human subject, consists of the following mechanisms: 1st. The lungs with a large number of air vesicles and air cells connected together and in close connection with a denseplexus of blood vessels. 

CHAPTER IV. RESPIRATION.

SECTION I.—The General Statement in Regard to Respiration.

Respiration is essentially an interchange between the gases of the organism and the gases of the medium in which the organism lives. Oxygen is essential to the life of every tissue, whereas carbon-dioxide is non-essential. The simplest organism, such as the amoeba and the infusoria, deprived of oxygen or placed under such circumstances that oxygen is not available, dies. The amoeba is able to live in carbon-dioxide, but is more sluggish than when deprived of oxygen or placed under such circumstances that oxygen is not available. The infusoria are able to live in carbon-dioxide, but are more sluggish than when deprived of oxygen or placed under such circumstances that oxygen is not available. The carbon-dioxide is removed from the body by the exhalation of the organism, but the oxygen is not removed from the body by the exhalation of the organism. The blood contains a small amount of carbon-dioxide, but it is not removed from the body by the exhalation of the organism. The blood contains a small amount of carbon-dioxide, but it is removed from the body by the exhalation of the organism. The blood contains a small amount of carbon-dioxide, but it is removed from the body by the exhalation of the organism.
and 4th. The nervous mechanism of respiration, 5th, and last, the subsidiary function discharged by the skin and by the intestines in the respiratory process.

SECTION II. The Respiratory Apparatus.

The larynx is made up of several parts, forming a cartilaginous framework, the different parts of which are movible upon each other by means of certain muscles. There are three single cartilages: the thyroid, the cricoïd and the epiglottis. There are three pairs of cartilages: the arytenoid and the cartilages of Santorini and of Wrissberg. The thyroid consists of two lateral plates which meet one another at an angle anteriorly forming the promontory, known as Adam's apple and from posteriorly a wide open space. The cricoïd plate formed between the thyroid and trachea is shaped like a signet ring, the deep part being behind, the seal projecting upward. Its cartilage is somewhat smooth but on its lateral part and over the true vocal cords, where the mucous membrane forms a narrow aperture in the middle line, the trachea opens upward. On the lateral part of the upper border of this aperture the trachea is higher, wider and more nearly horizontal than the left bronchus. The bronchi enter into the lungs branch again and again forming finer and more delicate bronchioles, each of which ends in a dilatation called the infundibulum. Changes take place in the structure of the air tubes, as by this repeated process of branching they become narrower until they terminate in the infundibulum. The fibrous coating of these branches becomes thinner and thinner as the branch becomes smaller, and very distinct bundles of longitudinal yellow elastic fibers are found developing. The cartilage is found in small plates so arranged that together they completely surround the tube, making it quite cylindrical in shape. These plates of cartilage gradually become more delicate and in the minute capillary bronchioles they have entirely disappeared. The bronchi divide into smaller and smaller air tubes all around about the inside of the tube inside of the cartilage, in the trachea, as it ascends, the cartilage is entirely disappeared. The mucous membrane also gradually becomes thinner and more delicate as the branch become smaller, but it still retains its columnar ciliated epithelium until the tube expands into the infundibulum, where we have patches of squamous epithelium. Each of these bronchioles presents near its termination, small recesses leading out from it, called the infundibulum. Changes take place in the structure of the air tubes, as by this repeated process of branching they become narrower until they terminate in the infundibulum. The fibrous coating of these branches becomes thinner and thinner as the branch becomes smaller, and very distinct bundles of longitudinal yellow elastic fibers are found developing. The cartilage is found in small plates so arranged that together they completely surround the tube, making it quite cylindrical in shape. These plates of cartilage gradually become more delicate and in the minute capillary bronchioles they have entirely disappeared. The bronchi divide into smaller and smaller air tubes all around about the inside of the tube inside of the cartilage, in the trachea, as it ascends, the cartilage is entirely disappeared. The mucous membrane also gradually becomes thinner and more delicate as the branch become smaller, but it still retains its columnar ciliated epithelium until the tube expands into the infundibulum, where we have patches of squamous epithelium. Each of these bronchioles presents near its termination, small recesses leading out from it, called the infundibulum.
between the lobules is continuous, with a thin layer of connective tissue, containing numbers of elastic fibers immediately below the pulmonary tissue, pleura. The interlobular connective tissue is highly developed in the case of the two. The right lung is the larger, the broader, and the shorter of lung by the bronchial artery, and is returned by the blood to the heart by the Venous return from this bronchial artery, we find minute vessels extending along the intercostal vessels, the minute veins descend along the sides of the anterior, in the pulmonary veins. Each lung is completely invested by the pericardium. The outer surface of the pleura, the pleural cavity. It is lined by the endothelial layer of the pleura, the outer surface of the pericardium, and the upper surface of the diaphragm. Hereon this coat there is a rich plexus of lymphatic vessels lying in the substance of the small lobules.

From these lymphatics there arise vessels which run along with the bronchi and convey the lymph to the bronchial glands. Nineteen large lymphatics, collected together in numerous grooves, collect the distributed to the muscle tissues of the minute blood vessels and to the walls of bronchi and the bronchial glands. These large lymphatics are the ones of the proper and sympathetic area and are scattered over the surface.

SECTION III—Mechanism of Respiration.

The movements in respiration consist of certain rhythmic changes, through contraction and relaxation of the muscles of the chest and partly dependent upon the elastic forces of the lungs themselves. The lungs are a large elastic bag with an outer surface of the thorax. The lung is a large elastic bag, lined with a thin layer of connective tissue, containing numbers of elastic fibers immediately below the pulmonary tissue, pleura. The interlobular connective tissue is highly developed in the case of the two. The right lung is the larger, the broader, and the shorter of lung by the bronchial artery, and is returned by the blood to the heart by the Venous return from this bronchial artery, we find minute vessels extending along the intercostal vessels, the minute veins descend along the sides of the anterior, in the pulmonary veins. Each lung is completely invested by the pericardium. The outer surface of the pleura, the pleural cavity. It is lined by the endothelial layer of the pleura, the outer surface of the pericardium, and the upper surface of the diaphragm. Hereon this coat there is a rich plexus of lymphatic vessels lying in the substance of the small lobules.

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there is no air in the lungs, the lungs being in a condition that we speak of as atelectasis, airless. The air cells in this condition have not expanded; those air cells walls are lined with nucleated cells and well rounded cell substance, those cells being adhesive, so that the tissues remain within the lungs, being not filled, but with fluid, that is, in the fluid life. The lungs in the child are in close proximity to the chest wall, being separated only by the pleural membranes. At the birth of the child the first volume of air is admitted to the trachea and the larger bronchi passing with considerable force into the bronchioles and the air cells of the lungs, thus setting the inspired air into motion. The newborn child remains within the course of the fluid life. This condition has only lasted until those air cells, the alveoli, are able to form a distinct gas-filled cavity. The first inspiration is the largest, and has been measured by a number of Physiologists. In the dead subject, for example, the manometer can be connected with the trachea. When the collapse takes place in the lungs, then the mercury in the manometer will be found to rise. Donders, a Physiologist, who has devoted considerable time to this subject, found the pressure under these circumstances to be from two to three mm. of mercury. During life this pressure is much greater and it is estimated that during that time it is about 7.5 mm. of mercury, 6 mm. at the close of a quiet expiration, and 9 mm. at the close of a quiet inspiration; that is, this pressure represents about 100-part of the atmospheric pressure. In the case of complete forcible distension of the chest the pressure was found to be much greater, estimated to be about 1.35 times the pressure of the atmosphere or about 30 mm. of mercury.

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MECHANISMOF RESPIRATION.

The diaphragm, being a sheet of muscle attached to the lower ribs, and the other muscles of the chest, including the sternum, the ribs, and the intercostals, work in unison to produce the respiratory movements. The diaphragm is the most important muscle in respiration, as its contraction causes a downward movement of the diaphragm, creating a negative pressure in the thoracic cavity and drawing air into the lungs. The肋间肌 further aid in respiration by contracting and expanding the rib cage. The serratus posterior superior and serratus posterior inferior muscles help in the movement of the ribs. The intercostal muscles, both external and internal, act in opposition to each other, with the external muscles contracting to expand the chest and the internal muscles contracting to compress it. The accessory muscles of respiration, such as the scalene muscles and the pectoralis major, also play a role in respiration, especially during heavy breathing or exercise.

In deep inspiration the diaphragm (through its action on the 5th, 6th, 7th, and 8th ribs) is the most important muscle, while the external intercostals and the scalenes contribute to the inspiratory movement. In expiration, the diaphragm relaxes and the external intercostals and scalenes contract to help expel the air from the lungs. The process of respiration is controlled by the respiratory center in the brainstem, which responds to changes in oxygen levels and carbon dioxide concentration in the blood.

The muscular actions of respiration are not limited to the muscles of the chest. The abdominal muscles, such as the transversus abdominis, play a role in respiration by stabilizing the trunk and assisting in the movement of the diaphragm. The glottis, the junction of the epiglottis and the vocal cords, opens and closes to allow air to enter and exit the lungs.

In summary, respiration is a complex process involving multiple muscles and organs, with the diaphragm playing a central role in the inspiratory phase. The intercostal muscles and scalenes also contribute to inspiration, expanding the rib cage, while the diaphragm and external intercostals contract to compress the rib cage during expiration. The respiratory center in the brainstem coordinates these muscular activities to maintain the proper exchange of gases in the lungs.
MECHANISM OF RESPIRATION.

The diaphragm, the principal inspiratory muscle, is the sheet that forms the floor of the thoracic cavity. Its contraction brings about expansion of the thoracic cavity. The thoracic cavity is the space between the thoracic walls and the diaphragm. The thoracic walls consist of the ribs, the sternum, and the vertebral column.

During inspiration, the diaphragm contracts and flattens, increasing the size of the thoracic cavity. This causes the ribs to move upward and outward, expanding the lungs. The intercostal muscles also contract, pulling the ribs upward and outward.

During expiration, the diaphragm relaxes and flattens, decreasing the size of the thoracic cavity. This causes the lungs to collapse slightly, and the diaphragm and intercostal muscles relax.

Other muscles that aid in respiration include the sternocleidomastoid muscles, which help to rotate the head, and the pectoralis major muscles, which assist in Inspiration. The external intercostal muscles also contract during inspiration, pulling the ribs upward and outward.

The accessory muscles of respiration include the serratus anterior, which aids in pulling the ribs upward, and the intercostal muscles, which help to maintain the pressure in the thoracic cavity.

The abdominal muscles, including the rectus abdominis and external oblique muscles, also play a role in respiration by contracting during expiration to help expel air from the lungs.
the thoracic base and aiding in the expulsion of air from the lungs. These muscles also assist in pulling down the ribs and contracting the diaphragm, the lower intercostal nerves.

13. The triangularis sterni draw downward the attached costal cartilages in expiration, these muscles being supplied with nervous connection by means of the intercostal nerves.

SECTION IV—Respiratory Movements.

From what has been said it will be evident that each respiration consists of, 1st, the period of inspiration; 2d, the period of expiration, and normal breathing, the respiratory movements follow each other in regular succession. As for example, in the case of the excitation of the vagi inspiratory action is caused by the vagi and in some other cases the expiration action is caused by the vagi.

In certain cases the inspiration becomes longer than expiration due to irritation. This, however, is still continued in length of the period of expiration, which may be either long or short.

In quiet breathing the duration of the period of expiration occupies about one fourth of the total time and being increased during sleep, unconsciousness and mental position, species, temperature, that is, internal temperature, the seasons of the year, the activity of the body and the digestive process.

In the normal adult there are 15 or 17 respiratory movements per minute. Respiratory movements are more frequent in the child and are influenced by age. Respiratory movements cannot be found in normal adults if they are between the ages of ten or eleven per minute, while in children the number of respiratory movements is greater.

In the adult, in children and in inspirations due to irritation the expiration action is longer than inspiration, the diaphragm and the breathing is abdominal. In the chest, expiration is increased transversely and antero-posteriorly, the breathing being principally thoracic or costal.

When the inspirations are very deep, the distinction between the costal and the diaphragmatic breathing disappears altogether. During sleep, the breathing is entirely thoracic. By the use of the movements of the body, exercise, etc. in old people the average number of respiratory movements per minute is often found to be higher than in normal adults.

The amount of air passing into and issuing from the lungs may be measured by means of instruments, these instruments being called spirometers. The Hutchinson spirometer is the best of them. This instrument is made on the principle of the gasometer for the purpose of storing gas. Cavella has invented an instrument called spirometer. A spirometer forms one side of a rectangular box. It is connected by means of a tube with the mouth attached to the axis of this plate, leaving a light lever with the point which writes upon the blackened paper surface moved by clockwork. The air passes through the tube and comes into contact with this valvular plate, the pressure changes being transmitted to the valve and being recorded on blackened paper surface.

By blowing through the mouth, the air is forced into the box and the paper is written. This instrument can be taken which represent not only the air pressure but also the amount of air that is inspired and expired and the velocity of the air current. The elastic lungs, even after a forced expiration, still contain a quantity of air, this quantity of air being generally estimated about 100 cubic inches. This volume of air is called the residual air. At the end of an ordinary expiration the emptying of the lungs is not nearly so complete, an additional 100 cubic inches still remaining in the lungs. This second 100 cubic inches is called the supplemental air, so that a normal expiration reduced to ten or eleven per minute.

The amount of air that is taken in at each ordinary inspiration measures about 30 cubic inches. The total maximum capacity of the lungs may be estimated at 330 cubic inches, of this volume of air—330 cubic inches—only 230 cubic inches can be expelled by the most forcible expiration, following a very deep inspiration.

The term, vital capacity is applied to this maximum amount of air that can be contained within the lungs. As a rule the vital capacity is greater in the male than in the female, increasing up to 35 years of age and after that period of life diminishing. It also increases normally with the height and the internal capacity of the chest. Each centimeter added to the height of the body representing about 2 cubic centimeters in the male and 1.5 cubic centimeters in the female. In the normal male adult of about 5 ft in height the vital capacity would be about 2,350 cubic centimeters and in a female of the same height, about 2,000 cubic centimeters.

Various instruments have been invented for the purpose of recording the respiratory movements. Marey's stethograph is, perhaps, the one that is most commonly used. The movements of inspiration and expiration are, 1st of all, communicated by a system of levers to a tambour passed through rubber tubing to a second tambour, which has a lever to record the tracing on the kymograph. In the case of the costal movements, the stethograph is always used. In the case of diaphragmatic movements, a long instrument is passed through the walls of the abdomen, between the liver and the diaphragm, so that the one end which is flat or sound through the bronchial tubes, no audible vocal sound being heard in connection with the lungs. By fluid effusion into the pleural cavities, a peculiar vocal sound is heard over the middle and posterior part of the thorax. This sound is of a short tremulous and a sharp character, also peculiarly metallic in its character, called egophony.

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spoon shaped, rests between the abdomen and the liver, the other end which is pointed, rests upon the recording lever, while the walls of the abdomen may be followed and traced out just as we found the diaphragm with its peripheral pulse and the heart pulsations. It has been found by study

The inspiratory movements are sudden and abrupt as compared with the expiratory movements. 4th. There is an inspiratory pause brief. These represent the four main points that now are settled in Physiology by the use of these instruments. In certain diseased conditions there is a return of abnormal breathing, irregular, then the pause is increased, this applies to the heart. The pause must be measured by a tube with what is called the "T" junction connected that we have mentioned indicating the rapid movements of inspiration and expiration is about 1 to 2 or 1. In the adult this becomes about 3 to 0 normally. Inspiration is more abrupt and sudden than expiration. The changes of respiration are as follows:

The normal pause varies in abnormal conditions, representing either an inspiratory pause or an expiratory pause. During sleep the normal rhythm of the periods, both of inspiration and expiration is broken, particularly in the case of children and aged people. In the latter case the pause becomes sometimes characteristic of inspiration. This disturbance of the respiratory rhythm is characteristic of what is called the Cheyne-Stokes breathing, in which we find respiratory movements in a series, each series being characterized by inspiration and expiration. The first respiration of each succeeding series by a marked pause. The second respiration of each succeeding series is by a marked pause. The expiration is always shorter than the inspiration. In the case of the newborn child the ratio of inspiration to expiration is about 1 to 2.

There is a marked variation in inspiration and expiration in sleep and in certain pathological conditions. In sleep the expiratory pause becomes longer, the inspiratory pause becomes shorter, and the inspiratory movement becomes greater, and vice versa. In certain pathological conditions, for instance, in certain stages of asphyxia and in cases of poisoning by chloral or curare, and in certain stages of fever caused by the absorption of septic substances. There is a marked variation in respiratory period both in inspiration and expiration.

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The normal pause varies in abnormal conditions, representing either an inspiratory pause or an expiratory pause. During sleep the normal rhythm of the periods, both of inspiration and expiration is broken, particularly in the case of children and aged people. In the latter case the pause becomes sometimes characteristic of inspiration. This disturbance of the respiratory rhythm is characteristic of what is called the Cheyne-Stokes breathing, in which we find respiratory movements in a series, each series being characterized by inspiration and expiration. The first respiration of each succeeding series by a marked pause. The second respiration of each succeeding series is by a marked pause. The expiration is always shorter than the inspiration. In the case of the newborn child the ratio of inspiration to expiration is about 1 to 2.

There is a marked variation in inspiration and expiration in sleep and in certain pathological conditions. In sleep the expiratory pause becomes longer, the inspiratory pause becomes shorter, and the inspiratory movement becomes greater, and vice versa. In certain pathological conditions, for instance, in certain stages of asphyxia and in cases of poisoning by chloral or curare, and in certain stages of fever caused by the absorption of septic substances. There is a marked variation in respiratory period both in inspiration and expiration.
The movements of respiration are accompanied by very characteristic changes in the circulation. If the blood pressure is recorded in the carotid artery, a tracing is obtained showing systolic and diastolic pulsations. These pulsations are due to the movements of the heart, and it is noticed that the systolic pressure is greater during inspiration than during expiration. If the heart is a strong muscular substance, whereas, the vessels are soft and yielding. In the large vessels themselves this influence is felt more upon the veins than upon the arteries, on account of the softer walls of the veins and the thicker, more unyielding walls of the arteries. During inspiration the pressure upon the aortic surface is less, the aorta being distended and the blood flow through the aorta is lessened, producing a fall in the blood pressure. The thick aortic walls will give way less to the distension than the thinner vein walls, so that inspiration does not materially affect the aorta and this effect is always counterbalanced by the distension of the large veins, and by the rapid blood flow out of the veins into the heart. This flow of blood from the lungs throws more blood into the heart, which passes through the heart and is thrown into the aorta. Thus the greatest respiratory influence felt, in the increased distension of the large veins. The lungs, the heart, and the large vessels being suspended in the expanding thoracic cavity, the blood vessels outside the thoracic cavity. Circulation being noticeable in these circumstances, hence it is said the maximum influences of tracheal respiration or assisted breathing during inspiration, the thoracic cavities are filled with air which is a hollow elastic muscle, is also affected by this pressure. The effect however, are very different, being more favorable to the venous blood flow, and retarding the arterial blood flow. The chief influence, however, is upon the relaxed and yielding veins that lie close to the heart. If the chest cavity is the inspiratory action ceases to expand the lungs, and there is no tension of the heart or the large blood vessels.

If the thoracic cavity is compressed, the inspiratory action becomes greatest upon the heart, the greatest influence upon the thoracic circulation being noticeable in these circumstances, hence it is said the maximum influences of tracheal respiration or assisted breathing during inspiration, the thoracic cavities are filled with air which is a hollow elastic muscle, is also affected by this pressure. The effect however, are very different, being more favorable to the venous blood flow, and retarding the arterial blood flow. The chief influence, however, is upon the relaxed and yielding veins that lie close to the heart. If the chest cavity is the inspiratory action ceases to expand the lungs, and there is no tension of the heart or the large blood vessels.

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the general blood pressure to rise during inspiration while it is lessened during expiration. In deep inspiration the elastic action of the lungs and the intra thoracic pressure become greatly increased; consequently the pressure upon the organs inside the chest is much less than the pressure of the atmospheric. Forced expiration, on the other hand, produces a pressure amounting to 100 mm which added to the atmospheric pressure would represent about 800 mm; the intra thoracic pressure being less we must subtract it, leaving 840 as representing the pressure on the organs of the chest. In case the veins are very much enlarged and the blood is prevented from flowing into the heart, the veins presenting a characteristic venous pulsation during forced inspiration and forced expiration, the action of the diaphragm and of the abdominal walls, transmitted to the abdominal vessel. Arterial pressure tends to force the blood downward into the body to restrain the blood flow from the heart, while the flow toward the heart is checked by the diaphragm and the abdominal pressure. The arterial walls are so thick and rigid that this pressure very little affects the arterial blood flow, whereas, the venous walls do not resist so well, being so thin and yielding, it tends to facilitate the flow of blood toward the heart. The result of this would be seen in the case of the section of the phrenic nerves, producing diaphragmatic paralysis, the blood pressure curves in this case being very much lessened. This is due to the diminished respiratory actions which are confined to the ribs and to the sternum, and also to the loss of the pressure communicated from the diaphragm to the veins.

The general effect, therefore, of inspiration, is to increase the blood pressure and the general effect of expiration is to decrease the blood pressure in the thoracic cavity found during inspiration and expiration, a diminution of inspiration resulting from an intra-thoracic pressure below zero. The flow of the blood is also lessened because a smaller volume of blood passes through the large veins, and the intrathoracic pressure being greater than zero, and as the arteries are now more turgid, more blood is being returned with the blood and as the lungs contract, the vessels enlarge, and the flow from the right side of the heart through the pulmonary circulation is also diminished.

Hering has devised an instrument to illustrate the influence of the respiratory movements on the circulation. There is a large conical chamber representing the thorax, at the bottom of which there is a rubber represented the diaphragm. At the top of the vessel there is a tube entering into the side. At each side is a vessel, one being filled with water, representing the venous blood and the other empty, these two communicating by a tube with a long being at each end of the bag representing the venous blood, the tubes being connected with the heart by tubes representing the phrenic nerves. In the cavity there are suspended from the tube representing the trachea, two sacks representing the lungs. If the diaphragm is pulled down from the center the air is driven out of the lung vessels, and in the same time the blood pressure increases, the vessels being filled with blood, and the heart is greatly distended. The diaphragm when released is pulled up partly by the negative pressure in the cavity and partly by the elasticity of the diaphragm. Then the rubber bags are emptied by their own elastic reaction. The heart sac contracts, forcing the fluid into the vessel on the other side, the blood pressure increases, and the heart sounds and pulse may disappear.
THE INFLUENCE OF RESPIRATION ON THE CIRCULATION

Respiratory action is aided by cardiac activity, and hence, the two go hand in hand in preventing that collapse which is sometimes represented as want of breath and at other times as heart failure. Hence, muscular activity depends not upon respiration only nor upon the blood circulation only, but upon the concerted action of both of these. The proper distribution of air implies the proper circulation of the blood. It may seem that respiration is more important for muscular activity, but circulation is as important. This abnormality is represented in the common expression, breathless applied to an exhausted person, the real cause and condition being more probably want of heart action. The great difference between the endurance of persons is found to be due not so much to want of air represented by a panting, breathless condition, as to the incapacity of the heart to keep up with the quickened rate of respiration. As we said before, there is a normal ratio between respiration and heart pulsation. Wherever this ratio is broken down, energy is impaired by reason of the impairment of one of the two actions, lung action or heart action, most commonly the heart action.

There are therefore, two main elements in respiration, i.e., respiration proper and 2d, the circulation of the blood, the former bringing the air to the blood and the latter the blood to the air. Of course, there is implied in this, thenormal condition of the blood, its richness in haemoglobin, that is, in red corpuscles, for upon this depends the volume of oxygen that is taken from the lungs into the blood. That this is so is evident from the fact that anaemic persons are very easily made breathless because of the lack of blood supply, and hence, oxygenation through the blood. The force of the mechanism of respiration can only deliver to the blood and to the tissues the oxygen, the blood itself must take in and utilize it in order that it may be of value to the system.

Certain changes taking place in the circulatory system affect the respiratory system. The supply of blood furnished to the respiratory center may, and does, materially affect respiration. If the blood flow is suddenly taken away from the medulla we find respiration attended with difficulty and sometimes accompanied by spasms. The supply of blood to the medulla through the basilar artery and its branches, if interfered with in any way either by increase or diminution of the blood flow, may effect the respiration, similarly the supply of blood to the lungs if abnormal interferes with respiration. The arterialization of the blood is accomplished by the blood flow through the lung capillaries by being brought into close connection with the air in the alveoli. If the pulmonary arteries become obstructed or if the valves of the heart fail to act properly or if the cardiac beat be weakened, the circulation of the blood from the pulmonary vessels to the heart is interfered with, and hence, the amount of oxygen carried by the blood to the different tissues of the body is lessened on account of the decreased blood flow. In this way the blood circulating is less than normal and it is less arterial than normal, then nerves and muscular tissues being thus deprived of a chief part of their nutriment, the oxygen. This deficiency of oxygen manifests itself in connection with the medullary dyspneic conditions, the difficulty of respiration associated with this condition, sometimes leading to the more normal pulmonary circulation. The blood circulation and consequently the tissue nutrition thus depend to a large extent upon the normal respiratory action.
THE INFLUENCE OF RESPIRATION ON THE CIRCULATION.

MODIFICATIONS OF THE NORMAL RESPIRATORY MOVEMENTS.—The chief function of the thoracic expansion and contraction is to secure adequate aeration of the lungs. There are subsidiary functions however, due to accessory respiratory actions. Some of these actions are present in all and some of the feeblest conditions. The volume of air expired from the chest is also provided for a clearing of these air passages so as to aid the normal respiratory functions, although they assist in the general economy of nature. These actions are called coughing. Coughing consists of a deep inspiration followed by glottis opening forcibly and a volume of air is forced through the upper respiratory tract represents not only an abnormal state of the upper respiratory tract, it may also indicate the presence of a foreign body in this tract. These are sometimes called sympathetic coughs. Coughing carried by the larynx, as for example, in the case of an irritant with the vagus branches to the bronchial tubes and to the stomach. The case of cold drafts of air. Sneezing represents a deep inspiration followed through the nasal cavity, the opening from the pharynx into the mouth, of the soft palate. Sneezing generally is a reflex action, resulting from the narrowness of the case of sneezing produced by a brilliant light the optical nerve be by premonitory signs, it may be stopped by the fingers coming on, manifested as it may by contraction of the upper lip, or by the close pressure of the lower lip against the spasmic and interrupted inspirations, the glottis being opened and the in the case of laughter are less forceful than they are in the case of coughing.

The mouth is opened and the muscles of expression give rise to the face

In the case of crying the movements of inspiration are somewhat simi

larly modified, in the case of crying, the mouth is open, the nose is overbreathing, the glottis is forced open. The subnasal branch of the facial nerve is activated by the phrenic nerve. The same muscles are also involved in the expression of fear. The emotional disturbance is transmitted to the respiratory muscles through the vagus nerve. The respiratory movements are inhibited due to the increase in vagal activity. The inspiratory phase is shortened and the expiratory phase is prolonged.

Changes in the Air During Respiration.

It is only in comparatively recent times that the necessity of fresh air has been recognised as one of the necessities of life. Other writers did not recognise the importance of respiration until the 3rd century. In addition, the idea of通气 or air into the body to ensure life. In the other cases where the air is taken into the lungs for the purpose of nourishment, the air is withdrawn from the lungs and replaced by air from the atmosphere. The air is then passed through the body to nourish the tissues. The air is then passed through the heart to nourish the tissues. The air is then passed through the blood vessels to nourish the tissues.

SECTION VI.—Changes in the Air During Respiration.

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inspirations. In the expired air the first portions expelled are atmospheric air while the portions of CO₂ and aqueous vapor gradually increase in the expired air varies but it is usually slightly above that of the inspired air.

When the atmosphere is about 20°C the temperature of air is about 34°C and in the nose 35.3°C if the temperature of the air sinks low, expired air falls slightly, for example, at 5°C if the expired air is the inspired air, for example, at 40°C the expired air is 37°C. The expired air usually follows the blood temperature depending on the relation of the tissues to the blood in the lungs but in the upper respiratory areas.

The average composition of the air is as follows:

In 100 volumes we have oxygen 20.90, nitrogen 78.80, CO₂ 0.50, but, of course, there is a percentage of vapor H₂O about 8.5. There are also organic and inorganic minute substances. The aqueous vapor is higher on the like the heat, is impaired not in the upper respiratory areas.

Breath, therefore, is influenced by the air temperature and also by the breath.

When the temperature is high an air containing less oxygen becomes deeper and also more numerous. The difference between the inspired and the expired air is an important element in connection with the respiration.

1st. The air contains 20.81 per cent; in the expired air that amount of oxygen is decreased to about 16.03. 2nd. The nitrogen is about 79.00 per cent in the inspired air, increased to about 83.97 in the expired air, the nitrogen is decreased to 4.38 sometimes to 5. 3rd. The CO₂ varies in the inspired air from 0.04 to 25 per cent in the expired air, also in the expired air with the temperature.

In the inspired air the H₂O of the inspired air varies with the temperature and also according to the pressure and with certain substances containing a quantity of organic matters which give the odor to the breath and some of which are poisonous. (5) In the inspired air we find N₂, the organic proportion of the gases in the atmosphere containing one per cent of CO₂ is far less as a result of respiration of the living organisms in the atmosphere. In one volume, the air has more CO₂ and less oxygen at the clothe than time, that is, if we have a pause between inspiration and expiration the air that is held for a long aeration in the CO₂ is greater in the expired air. In the case of expired air we four or five different points. First of it contains times more of the CO₂ 3d. It contains about 3½ per cent of nitrogen. 4th. The expired air is almost five per cent less of oxygen. 2d. There is also the volatile gases. The volume of air expired at one respiration is the same normally as the volume that is inspired.

The volume of expired air however is more than the volume of inspired air, but this is due to the expansion of the expired air resulting from an increased temperature. If both volumes, the volume of inspired and expired air are measured at the same temperature, and at the same pressure, the volume of the expired air is slightly less than the volume of the inspired air, the difference being that of 1 or 3% of the whole volume. This diminution is due to the fact that a large portion of oxygen does not appear in the expired air as CO₂. Some of it being retained and acting, for example, at 37°C, the volume of other combinations within the body. It is estimated by the Physiologists that from 800 to 3,000 grams of H₂O are given off by the expired process in 24 hours. It is believed by Physiologists that the larger proportion of this comes from the moist walls of the upper respiratory air. This conclusion is based on the fact that dry air is not expired, becomes quickly moistened in passing through the respiratory apparatus of the body. This gives us the results: 1st that the air is saturated with vapor, the amount of water which the higher the temperature, the smaller the amount of CO₂ being vaporized.

The expired air is then saturated with this aqueous vapor, the amount of gas can take up as aqueous vapor, depending on the temperature. The higher the temperature, the smaller the amount of CO₂ being vaporized.

This amount of CO₂ represents 244 grams of carbon, and 565 grams of oxygen, so if we subtract this from the 700 grams absorbed, we have left 44 grams of oxygen disappearing through the body. We must conclude, accordingly this fact that CO₂ is not only eliminated from the body by the lungs, but also to a slight extent through the skin, the estimate being that about 1-140 of the entire volume of CO₂ eliminated is about 19.50 in the expired air of the same volume.

The volume of CO₂ eliminated in the lungs but in the upper respiratory areas of the breath.

Foster states that in his own observation the CO₂ has varied from 686 to 792. The amount of CO₂ in the air varies from 594 to 1072 grams, those variations depending on the age and the condition of the body. The amount of CO₂ eliminated is increased by rapid and deep breathing. An atmosphere is poorer in oxygen and richer in the CO₂ the breath is held for a long time there is a pause between the inspiration and expiration at the volume in which the CO₂ is increased in the air that is expired. The relative proportions of oxygen taken in and the CO₂ eliminated vary in the proportions of 6:1.

This respiratory quotient is found by dividing the variation in the CO₂ by the volume of oxygen, that is 6:1 - 0.9. Hence when a volume of oxygen is lost we find an increase of 6 parts of CO₂. The volume of the CO₂ gained. This variation is less during sleep. It is greater in middle aged persons and in persons with muscular activity. An increased amount of carbon in the diet will increase the amount of CO₂ eliminated. The principles of ventilation demand a proportion of oxygen and CO₂ in the air of 0°C to 6:1. The reason why the Physiologists have estimated this respiratory quotient so as to have an adequate foundation for the principles of ventilation. When a number of persons placed in a limited space with little or no ventilation the oxygen is diminished and the CO₂ is increased also the aqueous vapor and the organic substances are increased. If an animal is placed in a limited space without any air renewal the air gradually loses its oxygen and becomes more fully charged with CO₂. If the proportion of oxygen does
not fall below 15 per cent the respiration remains normal. From 15 to 7 per cent the respiration is liable to become labored, inspiration and expiration under four per cent it is liable to result in asphyxia. When the blood contains oxygen and this oxygen is absorbed into the tissues of the body. It is generally fatal when the animal, for example, placed in a confined space the animal accommodates itself to the limited amount of oxygen and it will live in an atmosphere so saturated with CO₂ as to cause the immediate death of another animal put in the same chamber. Claude Bernard, for example, placed a bird under a glass globe and a few hours later he put into the same globe another bird; the second animal died in a few minutes in convulsions while the first animal survived for several hours and continued to respire. In addition to the absence of oxygen we must remember the presence of CO₂ percent of CO₂. Other gases are given out from the body which give to the air a gusty character arising from the causing the oxygen to be consumed and also filling the air with many the differences of opinion exist as to the nature and action of the toxic substances in vitiated air, depending on the extent upon the place, the persons and their circumstances, which are in direct relation to the CO₂ expired air contains, we have said, other substances which render the air impure. Small quantities of ammonia have been found and this air is taken directly from the air passages. By condensing the oxygen and organic substances which by the presence of micro-organisms gives rise to organic decomposition. These substances in this condition are poisonous, either on account of some poisonous substance directly soluble in water or on account of the decomposition of organic matter. These poisonous substances make the air very injurious to the system. This poisonous matter accompanying the expired air is sometimes found to contain carbon monoxide. The presence of these poisonous substances does not affect the blood directly. The mixture of these substances than to the presence of CO₂ these substances accompanying themetics according to the proportion of CO₂ found. Hence, the problem of lung ventilation is not only not the gas containing oxygen or that it be comparatively pure, but also the passing air comparatively free from CO₂ and accompanying organic substances which constitute the impurities of the air for breathing purposes. The object of ventilation is not only the introduction of fresh air, but to introduce the CO₂ so as to restore it to its normal condition. If it is estimated and size of the room and then the estimated size of the person, supposing that an individual gives off 900 grams of C O₂ daily and that CO₂ is inhaled in the atmosphere at the rate of 0.7 cubic volumes per cent, 2,000 cubic feet of fresh air should be supplied per hour. If it contains one volume per thousand it is impure and gives off an odor. In cases of muscular activity more than this would be required on the increased elimination of CO₂. When persons are limited to certain apartments every person should have a thousand cubic feet of space, and the floor-room should be at least 1-10 of this and fresh air should be introduced hourly. In the case of large rooms where a number of persons meet, for example, lecture rooms, this renewal of air should be very frequent. The lung capacity represents the total amount of air that can be forced out of the lungs by inspiration. The bronchial capacity is the capacity of the bronchi and trachea, estimated about 8½ cubic inches. Alveolar capacity represents the amount of air that can be accommodated in the small air passages, the alveoli being smaller during expiration than during inspiration. During normal expiration it is about 120 cubic inches, and during normal inspiration about 150 cubic inches. These are distinguished from the vital capacity which represents the quantity of air that can be expired by the most powerful expiration. The exhaled air is called negative ventilation and the two processes alternated compound ventilation. In the human subject these methods are very dangerous as the continual action of positive ventilation causes cerebrovascular accident, loss of blood pressure and body heat. Hall and Sylvester have described the most commonly adopted methods. Hall's method is to put the patient on his face, supporting the chest upon a pillow, then turning the body gently a little beyond the side position then quickly turning the body on the face, repeating this process about fifteen times per minute. Rain's method is to put the patient on his face, supporting the chest upon a pillow, then turning the body gently a little beyond the side position then quickly turning the body on the face, repeating this process about fifteen times per minute. Rain's method is to put the patient on his face, supporting the chest upon a pillow, then turning the body gently a little beyond the side position then quickly turning the body on the face, repeating this process about fifteen times per minute. Rain's method is to put the patient on his face, supporting the chest upon a pillow, then turning the body gently a little beyond the side position then quickly turning the body on the face, repeating this process about fifteen times per minute.
Changes in the Blood during Respiration.

Lavoisier, found that respiration consisted of the combustion of carbon and of hydrogen, the blood furnishing the combustion materials and air furnishing the oxygen. He admitted, however, that $CO_2$ is formed directly in the lungs, wherever the oxygen can come in contact with the carbon found in the blood. His successor, Pfluger, believed that oxygen is dissolved in the blood combining with carbon and hydrogen to form $CO_2$ and $H_2O$. These are liberated, the $CO_2$ and $H_2O$ in the lungs, but the $CO_2$ production does not depend upon the oxygen, that is, the oxygen that is supplied by or in the lungs. If an animal, for example, is placed in water, some of the nitrogen or hydrogen in the lung atmosphere is produced to the same extent as in the normal atmosphere. The $CO_2$ also is found in the body, this $CO_2$ being supposed by some Physiologists to be stored in the capillaries, and from these capillaries to be passed into the lungs.

Two theories of respiration have been advanced by Physiologists in recent years, and in the changes between the blood and the air. 1st, the combustion theory. This theory ascribes a process of combustion to the production of the $CO_2$ and $H_2O$ aqueous vapor, and the secretory theory. This theory denies that there is any combustion process in respiration, whereas, the oxygen becomes absorbed in the lungs and then becomes diffused through the other tissues of the body, the $CO_2$ being secreted in these, absorbed into the blood and then carried to the lungs and given off in the expired air. Recent investigations in connection with the gases of the blood and the temperature of the blood as found in the right and left sides of the heart have given predominance to the last theory which now prevails in the field of Physiology. The older Physiologists rejected the secretory theory on account of the fact that no proof exists of free $CO_2$ being extracted from the blood. The same objection met those who defended the secretory theory because if the process of interchanges places take place in the blood then certain free gases must be found in the blood. For example, the $CO_2$ has a greater solubility than the $O_2$, and in the case of an animal the $CO_2$ is always in excess. The $CO_2$ enters the blood and becomes absorbed into the blood vessels. The amount of each gas may be easily measured. The total amount of gas being found is called the volume of blood. The percentage of the gases obtained from the two long barometric tubes is measured at $0°C$ and $760$ mm. of mercury barometric pressure are found to be as follows:

In 150 volumes of blood. — In the arterial blood we find 20 per cent of oxygen and 10 per cent of $CO_2$, and 12 per cent of nitrogen. In the venous blood, 40 per cent of oxygen, 40 per cent of $CO_2$, and 2 per cent of nitrogen. That is, the variation between the two is very marked. If, however, $CO_2$ is raised and the oxygen lowered, this means that arterial blood as compared with venous blood contains from Physical laws, $8$ per cent less of $O_2$ and $8$ per cent more of $CO_2$. In the case of arterial blood there also is a much greater difference according to the location of the blood vessels. For example, venous blood from an active secretory gland is almost identical with arterial blood, while, if the gland is inactive the blood is characteristically venous.

Changes in the Blood during Respiration.
CHANGES IN THE BLOOD DURING RESPIRATION.

of the gas, and when the fluid reaches boiling point no gas is absorbed. The case of this being that the fluid becomes gas. The density of absorption does not depend upon the pressure but the weight of the gas absorbed rises in proportion to the pressure. If an atmosphere above a fluid consists of two or more gases, absorption will take place in proportion to the pressure of each gas. If the atmosphere be one gas, the density of absorption does not depend upon the pressure at a point where the fluid becomes gas. According to Rumens, the partial pressure of CO₂ in the blood is in the amount of 0.3 and CO₂ in arterial and venous blood is respiration is simply a process of diffusion. Three important elements enter into the process of respiration and respiratory movements, providing a partial pressure change in the air, by causing the CO₂ to be absorbed in the blood, and by causing the CO₂ to be absorbed in the blood in the same manner that it adsorbed. The CO₂ in the blood is reduced. Thus the CO₂ is reduced in the tissues. The blood which assists or causes the absorption of oxygen is therefore something that is an important part of respiration. The CO₂ in the blood is reduced. Thus the CO₂ is reduced in the tissues. The blood which assists or causes the absorption of oxygen is therefore something that is an important part of respiration. The CO₂ in the blood is reduced. Thus the CO₂ is reduced in the tissues. The blood which assists or causes the absorption of oxygen is therefore something that is an important part of respiration.
CHANGES IN THE BLOOD DURING RESPIRATION.

Porous membrane. The oxygen, as we have said, is loosely bound to the haemoglobin of the corpuscles; hence, the law of diffusion applies only in so far as it may pass into the plasma of the blood so as to reach the corpuscles. The corpuscles of the venous blood returning from the tissues with reduced haemoglobin. Oxygen enters the plasma from the air to once take up a fresh supply of this oxygen. If the oxygen were not loosely combined with the haemoglobin, the oxygen alone would be absorbed, and the amount that is absorbed would depend upon barometric pressure at the time, varying at different times with the variation in the pressure, and only with the variation of the pressure. If this is true, such variation would would, materially, interfere with the conditions of health. This is the fact that in high altitudes as well as in deep mines, the fall of the oxygen in the air is compensated for the law of partial pressure. In the case of CO, it is reduced to a small part of the CO being absorbed, and a large part chemically bound with the acid of sodium carbonate and sodium phosphate. In the air, CO, is found only in small amount. The air of the lungs is never wholly expelled, some of the air that is rich in the CO, always remaining in the lungs. Hence, the mixture of the inspired air with the air of the air vesicles makes the latter air rich in oxygen and poor in the CO, although there is more CO than in atmospheric air. The pressure of CO in the venous blood is found to be almost 50 per cent more than that of the air cells. CO then passes from the blood into the air cells till equilibrium is attained. Before this is attained, however, the pressure of the CO again becomes less than that of the blood. Elation follows; in fact, all the air is not being expired and the CO, just being formed, then no diffusion could take place out of the lungs for if it was so then diffusion could only be possible during inspiration. The separation of the CO from this case of the pulmonary blood would be incomplete, the respiratory changes being found only in the rapidity of the process which is naturally interfere with the respiratory changes in connection with the blood necessary to carry on the normal process of respiration.

Having discussed these changes that take place in connection with the gases of the blood it is necessary now to inquire what are the causes of the changes that we have observed. The absorption by oxygen of the blood, as we have said, does not follow the physical law of simple "absorption" on the basis of pressure. It is suggested, as we have said, that oxygen is in equi- pressure is lowered until a certain point is reached when no appreciable dissociation taking place. At this point, there is seen that the substance with which the oxygen is closely associated is the haemoglobin of the red corpuscles. Haemoglobin when dissociated from other substances is an amorphous powder or a crystal in solution. The peculiar relation between the haemoglobin and the stroma in the normal blood prevents the haemoglobin from being dissolved in the serum. In order to get the haemoglobin this relation between the stroma and haemoglobin must be broken. By the addition of dilute water or ether, or chloroform, the blood will be rendered lacy. By the removal of the alkaline serum the haemoglobin is given up in the solution. If dilute acetic acid be then added the alkaline reaction is reduced, and if alcohol is then added to the solution to revising the pH of the solution and the solution be at pH the haemoglobin in the solution will be crystallized. These crystals being separated by the process of filtration. These crystals vary in the case of the blood of different animals. These haemoglobin crystals are said to contain, for example, in the case of the dog’s blood of C 5.85, O 21.84, N 16.17, H 7.32, S 30, and iron 43. Iron is found in small quantities and it is a characteristic element of the haemoglobin. If these crystals are examined microscopically they are found to possess the bright scarlet hue of arterial blood, in masses they are much darker. If these crystals are placed upon a slide two or three drops of distilled water the same arterial color may still be light. This solution placed in front of the microscope absorbs some rays of light, two very marked absorption bands being observable. These absorption bands are characteristic marks in the identification of blood. The intensity of the bands depends upon the solution of the crystalline substance. The blood of the micro-spectroscope the same marked appearance is represented by the crystals of haemoglobin. If these haemoglobin crystals are placed in the mercurial pump vacuum there is a change in color, and the oxygen is driven off. This indicates that there are two volumes of O in the haemoglobin, (1) the oxygen found in the molecular composition of haemoglobin, and (2) a quantity loosely combined with haemoglobin and therefore easily dissociated under the influence of pressure. If this second quantity of O is dissociated the change of color takes place, the crystals being dark purple in the thick parts and greenish in the thinner parts at the marginal edges. In the case of a solution of haemoglobin we find the same quantities of O which may be liberated by the low pressure of the air pump or by passing through the solution a stream of hydrogen, releasing the change of color from the bright scarlet to dark purple. When this reduced solution of haemoglobin is examined spectroscopically the two absorption bands (formerly seen in the unreduced solution) one is found on the single absorption band wider and more faint in color, the single band lying about midway between the two bands of the unreduced solution. If this haemoglobin solution which has been deprived of all the loosely bound O is exposed to athermodynamically, O is at once absorbed. The amount of O absorbed, if there is an atmosphere filled with O amounts to the full combina- tion in the haemoglobin as low in the blood, each gram of haemoglobin absorbing 1.59 of O. If the full complement is taken up the haemoglobin changes to the dark purple color to the bright scarlet hue. In these changes we have from the point of the physiological physical action in part at least of the changes taking place in the blood in connection with respiration and an explanation of these changes of color in venous and arterial blood. When the venous blood leaves the right ventricle it is too small a proportion of the haemoglobin for the red corpuscles. Hence the dark color of the blood. In ordinary venous blood when examined after dilution under the spectroscope two characteristic absorption bands are observed. The haemoglobin is only partly reduced in this condition, there being a quantity of loosely combined O. The venous blood only loses this O after death resulting from asphyxia when the venous blood becomes characteristically venous, the haemoglobin being reduced and exhibiting the characteristic absorption band instead of the two. When the venous blood goes through the lung capillaries it takes up O from the air, the red corpuscles being oxyhemoglobinized, that is, almost completely saturated with the
The changes in the blood during respiration.

Oxygen and changing to the bright scarlet color. When the blood goes out from the heart into the capillaries, the haemoglobin being the oxygen carrier. Hence, the oxygen in the venous blood is the presence in the former and the absence in the latter of oxygen in combination with haemoglobin.

In addition to this there are subsidiary changes that enter into the power of reduction: hence the presence of water or CO₂ tends to reduce the capacity of the combination of O₂ and haemoglobin: this is, the readiness with which the haemoglobin is reduced by destroying the integrity of the haemoglobin. The CO₂ takes the place of the oxygen in the combination and is carried to the tissues.

The haemoglobin is separated from the air by the plasma and the membrane of the capillary and alveolar walls, corpuscles being separated from each other, hence the haemoglobin causing diffusion, that is, the CO₂ is carried in each corpuscle it surrounds the oxygen. Hence the presence of CO₂ causes the blood to pass through the membranous pump, a large proportion of CO₂ is given off. This is called the loose CO₂. If an acid is used, an additional quantity of CO₂ will be given off from the solution called fixed CO₂. If a volume of blood is passed through the membranous pump all the CO₂ will be given off, indicating that all the CO₂ in the blood normally is in loose combination, being associated with some substance in the blood plasma, the substance itself being unknown.

In the case of O₂ we find not only the haemoglobin in individual molecules, but also in masses and bound in the capillaries. The haemoglobin is separated from the air by the plasma and the membrane of the capillary and alveolar walls, corpuscles being separated from each other, hence the haemoglobin causing diffusion, that is, the CO₂ is carried in each corpuscle it surrounds the oxygen. Hence the presence of CO₂ causes the blood to pass through the membranous pump, a large proportion of CO₂ is given off. This is called the loose CO₂. If an acid is used, an additional quantity of CO₂ will be given off from the solution called fixed CO₂. If a volume of blood is passed through the membranous pump all the CO₂ will be given off, indicating that all the CO₂ in the blood normally is in loose combination, being associated with some substance in the blood plasma, the substance itself being unknown.

In the case of CO₂ it would seem that there is a diffusion from the blood in the minute capillaries surrounding the alveoli into the air in the alveolus. In order to do this the pressure in the pulmonary artery must be always greater than the pressure in the pulmonary vein. The alveolar pressure of CO₂ is very difficult to estimate because the CO₂ comes from the blood into the alveoli. The experiments seem to indicate that the passage of the CO₂ from the blood into the alveoli takes place by diffusion. If a catheter surrounded by a small bag is injected into the bronchi of a dog so that the air inflated the sac the bronchus can be occluded, in this way the air in this portion of the lung can be collected and analyzed to discover the amount of CO₂ in the air. In this way it is found that the physical loss of diffusion explains the passage of CO₂ from the pulmonary capillaries into the pulmonary alveoli. In the mixing of air in the lung, the first force brought into play is the principle of diffusion depending upon the partial pressure at the different points on the respiratory system. The differences in the partial pressure depend
CHANGES IN THE BLOOD DURING RESPIRATION.

As the process of inspiration advances, more of the vitiated air comes from the lower respirators, and less of the inspired air enters into the combination, the last of the inspired air being almost wholly air from the lung alveoli. O₂ is constantly being diffused from the upper respirators to the smaller air passages and the alveoli; in other words from greater pressure of inspired air to lesser pressure. Equilibriums cannot exist, for the inspired air is constantly entering and after entering the lungs is constantly being brought into the lungs. The CO₂ is also constantly being diffused under the influence of pressure, the CO₂ passing from the blood to the smaller air passages and the alveoli in increasing proportion of inspired air and a small amount of air found in the respiratory passages preceding inspiration.

The respiratory changes in connection with the tissues depend upon the nature of the diet, upon the amount of the CO₂ that is produced, and upon the amount of O₂ that is absorbed. This is not true of all tissues equally, for some, as the lungs, require a greater portion of O₂, but in general the tissues that require most O₂ also require most CO₂. In the case of animals that are deprived of food, the respiratory quotient is represented as 75, indicating that the combustion takes place at the expense of the carbohydrate substance found in the tissue.

The respiratory activity varies in the different animals, the general rule being that the smaller the animal, the higher the degree of its respiration. This, however, is only true to a limited extent. For example, a small singing canary requires 12 to 13 times as much O₂ as a common fowl. In the case of a frog, the respiratory quotient is represented as 75, indicating that the combustion takes place at the expense of the carbohydrate substance found in the tissue.
THE RESPIRATORY CHANGES IN CONNECTION WITH THE TISSUES.

The importance of tissue respiration is evident from the fact that the chief chemical changes of the body take place in connection with those tissues. The same is true of the decomposition changes which result in the formation of CO₂. The tissues have a strong affinity for oxygen, and a very low pressure is sufficient for the absorption of a large proportion of the oxygen. The tissues of the body can represent an aggregation of cells, each cell absorbing O₂ and excreting CO₂. The cell activity depends upon the amount of O₂ that is absorbed and the degree of oxidation in connection with the O₂ absorption. Experiments have been made by Physiologists in connection with the different tissues of the body. For example, it is found that 100 grams at a temperature of 38°C give the following results in connection with them.

In connection with all the ordinary muscles 23 C. C. in the heart muscles 21 C. C., in the brain 12 C. C., in the liver and kidney 10 C. C., in the spleen 8 C. C. and in the lungs 75 C. C. In the case of all these tissues, CO₂ is formed directly in proportion to the volume of O₂ absorbed. The blood as it circulates, carries the CO₂ to the lungs and there it also discharges the function of disintegration and oxidation. 100 grams of blood for example, at 38°C absorb 8-10 of one cubic centimeter of O₂ and produce the same volume of CO₂. In addition to this the blood absorbs partially oxidized substances from the tissues to the lungs. In the case of the muscles, when resting at normal temperature, the O₂ absorbed is larger than the CO₂ eliminated, while, during the activity of muscles, more CO₂ is produced than the amount of O₂ that is absorbed. This, however, is not fully tested as yet. The question now arises, "How do these processes take place and where does this process take place, in the blood, or does it take place in the tissues?" There are certain oxidizable substances in the blood and the blood has a value of oxidation but when the blood is taken from the body this power of oxidation is found to be very small. We must take into account this fact, that this may be due to a certain extent to the fact of the removal of the blood from the body. In the case of the muscle of the frog, for example, extirpated from the body no free O₂ is found by submitting the muscle to the mechanical pump; while resting muscle produces O₂ and also CO₂ even when no O₂ can be obtained from the outside of the muscles. O₂ is necessary for the maintenance of life and also for the maintenance of muscle irritability, although it is not necessary for the manifestation of that irritability. As we find, muscles will continue to exhibit irritability in an atmosphere charged with H₂ or with N₂. We must take into account this fact, that the O₂ thus stored can be used by the body.

At the same time there is a constant oxidation process. As we know, we can observe the normal conditions and O₂ absorbed daily by an adult is estimated about 700 grams varying up to 1100. Of the CO₂ it is estimated that in 24 hours an adult exhales 360 grams, the rate of respiration depending upon the number of circumstances. It depends upon the number of the respirations. The amount of oxygen is increased by the number of respirations and the amount of CO₂ eliminated depends upon the number of circumstances. 1st. It depends upon the number of circumstances. 2nd. It depends upon the number of circumstances. 3rd. It depends upon the number of circumstances. 4th. It depends upon the number of circumstances. 5th. It depends upon the number of circumstances. 6th. It depends upon the number of circumstances. 7th. It depends upon the number of circumstances. 8th. It depends upon the number of circumstances. 9th. It depends upon the number of circumstances.
ABNORMAL RESPIRATION.

The kind of food taken also affects the amount an increase, for example, in the carbon from the use of carbohydrates and vegetables increasing the production of CO₂. During sleep, for example, CO₂ is lessened 10 fold as a result of physical and emotional conditions, to a lesser extent. The deprivation of food has also a similar effect, the diminution reaching a minimum.

The body mechanism is designed to work under a normal pressure, varying from 700 mm. B. or 90 ft. above the sea level. If there is any great change either of increase or decrease in the pressure it affects the process of the body, both chemical and physical. If an animal is placed in an air in which the pressure is greatly exhausted, convulsions follow the gas free from the blood. The slightest obstruction to the circulation and also interfering with the cardiac movement. In any sudden lowering of pressure, pressure which unbalances the entire vascular and respiratory systems. This unbalancing causes the feeling of distress that is associated with sudden change of pressure. This produces, in the case of the sudden lowering of pressure, the conditions which differ from asphyxia, namely muscular debility and paralysis due to the lack where the increase is above a certain point the signs are a sleepy condition or an unconscious feeling similar to that which is produced in the case of the narcotic poisoning due to the depression of the system. When the pressure rises to 15 atmospheres of air in which we have 3 atmospheres of O₂, we will find convulsions and asphyxia taking place together with the effects of the reduced pressure.

Expired air always contains slightly more N than inspired air; the amount varying according to the character of the air inspired, the depth of the respiration and also the duration of the respiratory period.

The respiratory mechanism can adapt itself to abnormal conditions within certain limits. Certain gases modify the respiratory action, gases, such as 10 per cent of CO₂, produce a feeble respiratory action, hydrogen or nitrogen may be breathed without any dangerous results. Pure nitrogen or hydrogen when breathed quickly, produce fatal results 10 to 12 or 13 percent of O₂. Such gases as hydrochloric acid, sulphonated nitric acid and ammonia gas cannot be inspired because they result in spasmodic contractions of the respiratory system. Other gases like carbonic acid, carbonic oxide, oxygen, hydrogen, etc., enter into the lungs and produces dangerous results from irritation of the blood of the tissues. Inspiration of pure CO₂ gas is very short effective time but 25 to 30 per cent in the air does not prove fatal if not continued for more than a few minutes. Carbon monoxide is a very dangerous and poisonous gas quickly destroying life when found to the extent of 1 per cent. It combines with haemoglobin so that the haemoglobin is prevented from performing its function in connection with the carrying of oxygen. The blood under its influence turns into a very bright cherry red and 70 per cent of the air will affect the breathing and it is found that if 60 per cent of the haemoglobin is combined with carbon monoxide the heart's action is effectuated, respiration is weakened and death gradually caused. Nitrogen dioxide intoxication. This is called the laughing gas. If breathed in its direct action of 1 per cent of 4 per cent causes the blood to become greenish and results fatal.

Certain expressions are used to denote peculiarities associated with respiration. When the respiration is normal and easy, the amount of O₂ and CO₂ being normal it is called eutphoria. Variations from this normal are ex- pressed as follows:

Apnoea represents a state of temporary respiratory arrest. It may result from quick repeated inspiration of a great quantity of air in which case the suspension takes place for a few minutes. In the case of artificial respiration, especially in infants subjected to tracheotomy, stopped, apnoea follows. After a short rest the respiration begins very feebly, and gradually return to the normal. The cause was formerly supposed to be found in the excessive amount of O₂ in the blood and the lack of CO₂. If the blood becomes saturated with O₂ the respiratory actions will cease between the successive infusions, the respiration becomes slower and gradually is arrested together without arresting the cardiac movements. This is due undoubtedly to the large amount of O₂ in the blood, but this only represents one apnoic condition. There is a connection between the amount of O₂ in the blood, the apnoea being more characteristic after breathing pure O₂ than after breathing a mixture complement of CO₂ if O₂ is not present in its full oxygenated. From this it is concluded that the blood is connected with the apnoea produced sufficient to cause respiratory activity. That there is something more shown in the fact that by respiring pure O₂ it is less than in respiring the pure air. To answer this it has been shown that in the apnoea, apnoea may be produced but not of such a marked character, the apnoic pause being entirely absent. This difference in the apnoic pause has led to the conclusion that the new oxygen storage of O₂ in the air cells, thus rendering inspiration unnecessary.

The hydrogen produces apnoea, although the hydrogen drives out the O₂ from the lung and produces that the O₂ does not furnish a full explanation. Apnoea, although hydrogen resulting from inflation of the lungs, produces a condition in which enough O₂ is found in the lungs to supply the blood. The fact that if the vagus nerves along which impulsive violent violets and apnoea, whereas inflation of the lungs with air produces no result at all, seems to suggest that the repeated respirations stimulate the pulmonary peripheries of the vagus nerves, producing impulses which...
ABNORMAL RESPIRATION.

Apnea may result from inflation of the lungs with air, pure O or similar substance; these causes may be cut and the lungs be inflated with N or CO, hence, the respiratory center is strongly stimulated and violent inspirations, followed by violent expirations, take place. This dyspneic breathing is quicker and deeper, the viscosity of the blood arousing the respiratory centers so that respiration becomes violent, resulting in the activity of all the muscles of respiration almost immediately.

There is a form of dyspnea due to the existence of certain substances in the blood, which may be derived from the muscles during muscular operation. Dyspnea may result either from a deficiency of O or an excess of CO. In the case of a person forced to breathe an air containing a large quantity of CO, although more than the regular quantity of O is present and even although the blood contains less than the normal quantity of CO, dyspnea results although there is sufficient O present and in the air. If an animal breathes pure N the result is, that the respiration becomes frequent and the inspirations become very strong. In the case of an animal breathing an air laden with CO the respirations become slower and the expirations marked by strong expirations. This marked increase in the depth of respiration is due, not only to direct action upon the respiratory center but also and especially to the reflex actions upon the center conveyed through the sensory fibers of the parasympathetic system. Hence, the depth of respiration in connection with the inhalation of excessive CO arises from the stimulation of the sensory fibers of the bronchial mucous membrane. In the case of the inhalation of air deficient in O the exhalation of CO is not affected at all.

It is marked, however, by increased pressure. This increased blood pressure continues for a considerable time before death takes place; death being preceded in this case by certain disturbances in the respiratory centers. It is also marked by a rise in the temperature of the brain, which is not always associated with the fatty degeneration of the heart. In hypoxia we find increased activity in the respiratory center, with an increase in the external temperature. When the body becomes abnormally heated by the presence, for example, of the body in a medium of hot air, the respiration becomes faster. This hypopneic condition is peculiarly characteristic of heat dyspnea, even when the blood becomes hyperoxyanated. No apnoea results. This forms an additional proof of the fact that the apnea is not produced by an excessive supply of CO.
ABNORMAL RESPIRATION.

If the blood of the carotid artery is heated artificially above the normal temperature, this will produce dyspnea. In fact, anything that weakens the circulation, or diminishes the amount of haemoglobin found in the blood will cause dyspnea.

Asphyxia. This literally means without pulse, but Physiologically it is a state of asphyxia to which the respiratory centers are exposed by the deprivation of air, or to which the brain is subjected. Anything that prevents the normal passage of air to and from the lungs, as for example, in the case of the closed glottis, causes this asphyxia.

1st Stage: During this period general exhaustion follows, resulting in collapse. The inspiratory muscles at first act weakly and only intermittently, while the expiratory muscles give occasionalspasmodic contractions, resulting in convulsions. In the same way the muscles of the extremities become spasmodically convulsive in their movements, chiefly the extensor muscles; gasping being associated with short respirations.

The pupils of the eye then become dilated, the lids of the eye do not close when the eye balls are touched, consciousness disappears and the reflex actions cease. The muscles, particularly the muscles of respiration, become soft and the convulsions give place to a quiet comatose condition. Afterwards the body becomes steeched backwards, especially the head and the body trunk. The lower extremities become stiff and extended, the lungs being expanded and the heart paralyzed. The right auricle and the right ventricle are dilated, while the cardiac musculature becomes feeble, loose and flaccid. Finally the heart ceases to beat, the pulse cannot be felt and the respiratory movements become completely paralyzed. This period normally lasts 4 or 5 minutes. The heart, however, continues to beat, very slowly and at some time after its ceasations, as an example, by placing an animal in a limited supply of O2 (oxygen). Asphyxia may take place suddenly, as, for example, in the case of the complete blocking of the lungs, or in the case where you have only the partial blocking of the lungs, divided into three stages.

Asphyxia and Hypoasphyxia. These latter stages are characterized by the respiratory movements...
forcing of the blood into the venous circulation by the elasticity of the large arterial vessels. During the 1st and 2d periods the pressure of the blood increases, the smaller vessels contracting, this contraction being due to the stimulation of the efferent fibers of the cardiac center. The heart's action becomes stronger for a short time, although the heart beats become less numerous and more rapid in the cardio-inhibitory center, which has become excited. The heart beat at this point becomes more forcible, on account of the large quantity of the venous blood in the heart, the left ventricle being unable to force the blood out of the heart against its lowest, marking the beginning of the 3d stage. This takes place on the venous blood. The venous blood, as we have said, gorges the right side of the heart when the blood flows into the veins and then the left ventricle, diminishing the peripheral resistance which results in a large fall in the arterial pressure and in the complete collapse of the system. These changes result mainly from the deficiency of O in the blood. With an increase in the velocity of the blood, the respiration becomes more frequent and greater in force, the expiratory action predominating over the inspiratory action, under body in this case being brought into active operation. These expiratory movements of the cardio-inhibitory centers due to the excitation of the cardio-inhibitory centers do not appear. If the brain above the medulla is removed, these convulsions do not appear. If the brain above the medulla is later—that the respiratory center is in the medulla. This center is sometimes independent existence is a matter of dispute. The question of an independent respiratory center with the expiratory part of the respiratory movements depending on the main expiratory supply of the brain is still in question. The respiratory center causes the respiratory movements and the convulsive reaction. It is at this time that the brain is ligatured and the convulsions will continue to act. If the convulsions are not lost until the whole body is thrown into convulsions. This does not take place however in the male of dispute. Some have identified this is an independent convulsive center in the medulla. The centers of nervous activity in the medulla are subjected through lack of blood to the deficiency of blood containing O. If there is a large loss of blood by hemorrhage, the deficiency of blood from the deficiency of blood. These inspiratory movements are called the beginning of the 3d stage. These inspiratory movements give place after the exhaustion of the nervous system to inspiratory movements. These inspiratory movements also represent the generation of the inspiratory movements by the inspiratory center, until the center becomes entirely exhausted and all activity ceases in death.

SECTION X.—The Innervation of Respiration.

Pulmonary respiration we have said is carried on by means of the action of the various muscles, some of which are in positions widely separated from each other, but all of which are coördinated. Whether the intercostal muscles were to contract before the scaleni muscles, there would not be any difference in the inspiratory action. The intercostal muscles are more coördinated in the inspiratory action of the various muscles and a forced respiration implies a quiet action of the various muscles and a forced respiration implies a normal inspiration.

The nervous system, which has been excited, becomes more quiet, the abnormally excited respiratory center becoming more quiet. The heart is no longer excited, the peripheral resistance becoming more quiet, the peripheral resistance becoming more quiet.

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THE INNERVATION OF RESPIRATION.

Without locating or attempting to locate exactly the center of respiration, most recent Physiologists have concluded that there is a center of respiration located in the lower part of the medulla. This center consists of two parts, one on each side of the median line, the two parts being closely connected together by means of commissures. The two parts of the respiratory center act simultaneously and yet their action is independent, having connections with the respiratory muscles on the two sides. If the median line is divided the two parts will continue to act simultaneously, whereas if the part on the one side of the median line is destroyed, suspension follows in the action of the muscles of respiration on that side of the median line. If, on the other hand, impulses reach the center on that side from the lungs, producing the slowing of respiration, the action of the muscles of respiration is increased. If stimulation is applied to one of the vagi afferent impulses reach the center on that side from the lungs, producing the slowing of respiration, the action of the muscles of respiration is increased.

Essential has proved that if the medulla is cut off from all afferent connection by cutting it below the corpora quadrigemina and also by driving the posterior roots of the spinal nerves, the pneumogastric respiratory centers will assume the function of the respiratory center in the brain. The consequent impulses, therefore, influence not the normal respiration.

Some writers claim that there is a respiratory center, or centers in the spinal cord, acting automatically and also by reflex action on the peripheral. Other Physiologists have claimed that higher centers exist in the upper part of the brain. One has been located, for instance, in the prominence of the grey matter of the brain between the optic tracts and the corpora quadrigemina and has been called a polyneuropic center. This has been shown to become very rapid. If a rabbit, for example, is placed in a high external carotid cistern with continuous afferent impulses reach the central end of one of the vagi, high energetic respiration may occur.

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It has been shown that the respiratory center is sensitive to afferent impulses, therefore influence not the normal respiration.
THE INNERVATION OF RESPIRATION.

can produce spasmatic actions. Normally, however, it is subject to different impressions so that normal respiration depends upon reflex action. The nerve fibers of the center of respiration are communicates by means of impulses to the respiratory movements. An afferent fiber causes the center to discharge impulses. This power of producing the rhythmic actions is inherent in the center, and the center is subject to afferent impressions so that normal respiration depends upon reflex action. The activity of the respiratory center is manifested in certain chemical changes that take place in the nerve cells constituting the center and this activity of the nerve cells is sustained by its respiratory movements, the center discharging as many impulses as the respiratory movements, depending upon, not a single influence but a complexity of influences which may and do continuously affect the center; for example, the will and the emotional, and it is not so in relation to the balance of the body, particularly the blood supply to the brain. If both the vagus nerves are divided we find that respiration continues but only in a modified form. If the spinal cord is cut below the medulla the respiratory movements still continue, at least in the face and in the larynx, indicating that the activity of the respiratory center continues, even though the vagus influences are entirely cut off and even when the movements of the chest are not entirely executed. The cranial nerves, except the vagus, are not especially brought there to play in respiration, although the cranial nerves are considerably modified by the afferent impulses. This indicates that the center of respiration is automatic in its action. Respiration is a double action so that nerve impulses may affect either part of the center or both parts of the center. In this way affecting either part of the respiratory movement or both parts of the respiratory movements. Nerve impulses may diminish or increase the depth of the volume of respiration. They may also increase or diminish, the respiration rhythm, and this seems to be the center's natural function. Thus, the respiratory center is subject to the following influences:

1. The influences of the higher centers.
2. The influence of the afferent nerves.
3. The influence of the blood.

1. THE INFLUENCES OF THE HIGHER CENTERS.

All Physiologists admit that there is an influence exerted upon the respiratory center by the higher centers. For example, the strong excitation of the special senses in the case of sneezing, results in inspiratory movements. All the sensory nerves of the head act in a similar way creating impulses to the brain producing inspiratory and expiratory impulses which are sent down to the respiratory center in the medulla. If the medulla is divided high up on the 4th ventricle so as to divide it, the breathing stops for a few minutes and then may resume again, the breathing going on almost normally as before, the difference being in the extent of the movement of inspiration, the variation being almost the same as in inspiration and expiration. If a transverse division is made lower down the respiration becomes forced, and if the incision takes place at the point of the cranium, the respirations become periodic with long pauses, the respirations gradually diminishing in force and frequency. If this condition by the stimulation of the sensory cutaneous nerves this periodicity will be removed and the normal respiration will be restored. The simple pressure upon the medulla cannot produce this periodicity of respiration.
There must be an inhibition of some of the normal stimuli that come down to the respiratory center in order to interfere with periodicity. This throws some light upon the abnormal condition of respiration that we find in certain diseased conditions of the heart and of the lungs in which, as we have before, breathing becomes periodic with long intervals. The excitement of the vagus is not always of the same intensity. The vagus becomes suppressed, and the inspiratory muscles may be thrown into a tetanic condition. In activity according to the period of the respiratory rhythm at which the stimulation is applied. Hence we conclude that the vagus contains both the inspiratory and the expiratory fibers. The impulses arise along the vagus so stimulated the respiratory center that there is rhythmic inhibition of certain tracts which arise in inspiratory and expiratory movements.

Marckwald says the respiratory cyclical either inactivating the higher centers and also by the section of the vagus. In the last section of the vagus causes these periodic breathings to go to place because the interruption of the higher centers are in a condition of lethargy, either inactive on account of inability to perform their function, or failing on account of inhibition of some kind to send down impressions from the higher part of the brain to the lower centers along which we find the respiratory center. Thus the Cheyne-Stokes breathing occurs when higher centers send down no impulses to the respiratory center. This indicates an important point in connection with the innervation of respiration, namely, that the normal condition of the respiration at all or it diminished gradually, thus resulting in the production of slower respiratory movements and in longer and deeper inspirations and shorter expirations. The effects quickly pass away. If both the vagi, however, are divided, the respiratory rhythm is diminished sometimes at once and at other times later.

This is followed by slow and deep inspirations. The inspirations then become gradually more forcible, accompanied by strong expirations, and a pause between each inspiration and expiration, a pause representing the abnormal pause. If the divided ends of the vagi are left alone because of this, no inspiratory impulses pass to the vagus, the inspiratory parasympathetic fibers, the glosso-pharyngeal, the trigeminal and the cutaneous nerves. Impulses passing along the pneumogastri, the vagus and the glosso-pharyngeal, the trigeminal and the cutaneous nerves. Impulses passing along the pneumogastric have an important influence on the respiratory center. If the divided ends of the vagi are left alone because of this, no inspiratory impulses pass to the vagus, the inspiratory parasympathetic fibers, the glosso-pharyngeal, the trigeminal and the cutaneous nerves. Impulses passing along the pneumogastric have an important influence on the respiratory center.

2D. THE INFLUENCE OF THE AFFERENT NERVES.

These afferent nerves are the vagus, the glosso-pharyngeal, the trigeminal and the cutaneous nerves. Impulses passing along the pneumogastric have an important influence. The afferent nerves are the vagus, the glosso-pharyngeal, the trigeminal and the cutaneous nerves. Impulses passing along the pneumogastric have an important influence on the respiratory center. Hence the action of the vagus is the most important in connection with respiration. These influences of the vagus nerves can best be brought out in connection with the section of these nerves and the effects that are produced by stimulation of various kinds applied to the vagus nerves when divided. When the median nerve has been separated from the higher centers, if the vagus are divided, there is a loss of inspiration followed by spasmodic inspiration and expiration, resulting in a short pause to become more powerful. If the vagi, on the other hand, are cut off before the separation of the medulla from the vagus centers the respiration will continue for a time normally and after a few moments the respiration will become deeper and slower followed in a few moments more by respiratory spasms. The absence of impulses passing through the vagi can be made up for by certain impulses arising in the brain and passing along the higher portion of the brain to the respiratory center. If the impulses are also from the one side the rhythm of inspiration is not affected, but if the impulses from both sides are suspended the center acts without any rhythm at all. This indicates that the rhythm of respiration depends upon the afferent impulses that are borne to the respiratory center by the vagus nerves. The vagus and the upper parts of the brain are therefore the media through which the impulses that influence the respiratory center act and the respiratory action.

In the case of the vagus nerves are constant; whereas in the case of the upper parts of the brain the impulses are only occasional and intermittent. It is through this latter channel that the volitional and the emotional and the mental impulses pass to the respiratory center as well as those impulses that come from the special organs of sense. These impulses send their impulses along the vagus, these impulses affect the vagus nerve in the neck produces strong inspirations and if this excitation becomes strong the inspiratory fibers may be thrown into a tetanic condition. In activity according to the period of the respiratory rhythm at which the stimulation is applied. Hence we conclude that the vagus contains both the inspiratory and the expiratory fibers. The impulses arise along the vagus so stimulated the respiratory center that there is rhythmic inhibition of certain tracts which arise in inspiratory and expiratory movements.
The different fibers are differently affected under the different degrees of stimulation. Both kinds of fibers carry impressions originating in the vagi peripheral to the lungs. The inspiratory fibers respond more readily to weak stimulation, and they are not so easily exhausted. If the stimulation is strong, on the other hand, medium or strong, the inspiratory fibers are more easily affected so that expiration action prevails. The expiratory impulses, however, may arise in the laryngeal nerves, especially in the superior laryngeal.

The superior laryngeal nerves are sensory branches of the vagus nerve terminating in the larynx. The excitation of these produces expirations and as the nerve fibers are very sensitive strong stimulation produces a stoppage of the expiration with a tetanic condition of the muscles of expiration. For the reason that the presence of irritant substances in the larynx can produce an immediate stoppage of respiration. Impulses which arise in the larynx originate from the mechanical stimulation of the larynx. Some Physiologists think that the stimulation arises from the gases that are contained in the air vesicles. According to this, during expiration the increased CO₂ contained in the vesicles stimulates the inspiratory fibers, terminating in the lungs, the impulses being carried to the inspiratory center. On the other hand, the dilatation of the lungs during the act of inspiration stimulates the expiratory fibers terminating in the lungs arousing impulses carried to the expiratory center. The mechanical lung movements, however, are stronger and originate the impulses which affect both inspiration and expiration. In the case of the glosso-pharyngeal nerves their division does not affect respiratory reactions whether the vagi are divided or not. Their stimulation is followed by an arrest of respiration for a period equal to the entire duration of respirations. After that breathing commences with inspiration just from the moment before the diaphragm was arrested. The glosso-pharyngeal nerve, therefore, is a nerve of inhibition coming into active operation only in the commencement of deglutition. During the process of deglutition respiration is stopped, there is first a stimulation and afterwards an inhibition of the stimulation taking place through the sensory nerves of the tongue and the pharynx and the inhibition through the glosso-pharyngeal nerves. The inhibition makes it possible to swallow either food or drink without drawing them into the larynx. The stimulation that passes through the sensory nerves to the center excite the mylo-hyoid muscles used in swallowing and then the inhibition takes place so arresting the breathing as to prevent the food from passing into the lungs. Thus, the deglutition process the breathing is temporarily arrested. Nervous impulses seem to pass from the deglutition center to the respiratory one producing a tetanic condition of the muscles of expiration. As soon as the food is swallowed the deglutition center by impulses conveyed along the cutaneous nerves of the body or face with cold water, plunging into a cold bath or drinking a stimulating fluid may during an arrest in expiration. These actions, however, are only temporary and affect respiration only during the period of arrest.

36. THE INNERVATION OF RESPIRATION.

The respiratory center is also affected by the condition of the blood through the influence which the blood exerts on the peripheral extremities of the vagus nerves distributed to the lungs. The activity of the center is directly affected by the state of the blood. Various theories have been pronounced historically as to the nature and the cause of this influence. It was first suggested by all that excess of CO₂ in the venous blood brought to the lungs stimulated the pulmonary branches of the vagi producing inspiration.

Later it was supposed that the same cause of stimulation applied to the sensory nerves. Rosenthal then suggested that inspiration resulted from the deficiency of O₂ in the medulla, his idea being that the respiratory center depended for its stimulation to activity, upon the oxygenated blood, passing through it. The vagi impulses went up according to this view to the center, lessening the pressure existing in the center, the superior laryngeals increasing the pressure and thus respectively assisting inspiration and expiration. For the reason that the latter have all been based on the idea that the deficiency of oxygen in the medulla is the cause of respiratory movements is found in the gases of the blood in its circulation through the brain, both deficient oxygenation and excessive carbonization, affecting the respiratory center. The former produces inspirations and the latter expirations. In opposition to this theory we find Hering defending the idea that the mechanical expansion of the lungs during inspiration, ares the vagi nerves which convey impulses to the center, gives rise to inspiration. On the other hand, the action of the lungs resulting in contraction, stimulates other nerves, arousing the center to inspiratory action. This is negated by the fact that respiration may continue after the removal of the lungs. The theory of Rosenthal based upon the deficiency of O₂ as the cause of inspiration, is disproved by the fact that the blood of amputated limbs is deficient in O₂. The most reasonable assumption is that defended by Marekwald, who says that the normal stimulation of the center of respiration is not due to deficient oxygenation of the blood or its excessive carbonization, but to some other cause, such as the presence of irritants, as the hyperventilation of the blood in the substance itself, or by the changing of the different centers. When the anaesthetic process advances to a certain point the substance itself yields to dissolusion during the anaesthetic process, thereby setting free energy that produces of breathing in expiration. Odors may in the same way affect respiration through the olfactory nerves. Respiration is also influenced through the center by impulses conveyed along the cutaneous nerves. If the stimulation of a sensory nerve has not any decided effect but if the exaltation is strong there is an increase in respiratory movements followed by a number of deep inspirations and the cessation of expiration. For example, the shrinking of the body or the face with cold water, plunging into a cold bath or drinking a stimulating fluid may during an arrest in expiration. These are reflex impulses and they are more decidedly marked if the higher centers have been severed from the medulla, becoming distinctly spatial after the deglutition center which is excited by sensation from the cutaneous nerves is stimulated. The splancnics are stimulated strong expirations result and may even result in an arrest in expiration. These actions, however, are only temporary and affect respiration only during the period of arrest.
The innervation of respiration.

Spasmodic respiration. After this, a still further process of anabolism follows, resulting in the same change and so on successively.

During katabolism the branches of the vagi terminating in the lungs are also producing by impulses sent to the center a discharge which maintains the respiratory rhythm and prevents spasmodic activity. If the katabolism is stopped astronaut results, so that the vagi are the direct producers of the katabolic changes which result in respiratory action and rhythm. If the blood is more highly oxygenated than it is normally from any cause, for example, by breathing an atmosphere too rich in O2, the respirations are slowed and may even be suspended, the person passes rapidly into a state of unconsciousness, indicating that excesses of carbonic acid in the lungs, from breathing an atmosphere containing too much CO2, or from respiratory movements become more rapid and more violent. In this variety of other muscular movements, such as convulsions will occur, due to stimuli being sent from the respiratory center to various other motor centers. This state of dyspnea continues until the energy of the respiratory center is exhausted unless fresh O2 is introduced into the blood.

After this exhaustion the respiratory movements gradually cease and a state of asphyxia follows. From this it is evident that the increase of O2 with the diminution of CO2 in the blood lessens while the opposite condition increases the activity of the respiratory center. A rise or fall in the temperature of the blood produces similar changes in respiration.

Any impulses that affect the center have an influence upon this metabolism. Cessation of katabolism and anabolism. In the case of diffuse总经理s rendered the structure of the center more unstable and in the case of excessive carbonization increasing its explosive character.

The double a blood so changed in character as to affect the center, either unusually in the case of great muscular activity, being more venous than normal. This venosity of the blood does not account for the changes in the center, because the blood that leaves the left side of the heart in cases of great muscular activity is not less oxygenated, but more oxygenated than usual. This suggests that it is due to the presence in the blood of an acid, like sarcolic acid. Whatever the substance may be, the respiratory center is affected through the blood. Thus, the respiratory center is not so much influenced by impressions sent along the afferent nerves by the character of the blood that circulates through the brain as to modify its metabolism. All of these influences affect the breathing and assist in the character of the blood that circulates through the brain as to modify the respiratory mechanism.

Adaptation. In respiration in aereation a particular instance may be found in deficiencies of O2 or excess of CO2. If an animal breathes an air containing 11%, N, 7%, CO2, the blood is normal, but the blood has its normal amount of CO2. If an animal be asphyxiated, if the animal becomes dyspneic and asphyxiated, if the N is breathed for a time. This is due to the want of O2. If an animal breathe an air laden with C02, the respirations become deeper and more rapid, inducing unconsciousness, indicating that the anabolism process is operated upon, so that the vagi are the direct producers of the katabolic changes which result in respiratory action and rhythm. If the blood is more highly oxygenated than it is normally from any cause, for example, by breathing an atmosphere too rich in O2, the respirations are slowed and may even be suspended, the person passes rapidly into a state of unconsciousness, indicating that excesses of carbonic acid in the lungs, from breathing an atmosphere containing too much CO2, or from respiratory movements become more rapid and more violent. In this variety of other muscular movements, such as convulsions will occur, due to stimuli being sent from the respiratory center to various other motor centers. This state of dyspnea continues until the energy of the respiratory center is exhausted unless fresh O2 is introduced into the blood.

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found, for example, that by excitation of one pneumogastric the bronchi of the lungs become constricted. On the section of one pneumogastric the bronchi on that side are dilated. The stimulation of the peripheral and also of the central ends of the divided end of the vagus produces a contraction of the bronchi on both sides. The contraction, however, is less marked when the central end is stimulated. In the case of the administration of ether or chloral, this stimulation of the cut peripheral or central end of the vagus produces dilatation of the bronchi. This seems to indicate, first of all, the existence of constrictor and dilator bronchi fibers in connection with the pneumogastric. 2d. That both of these fibers, constrictor and dilator fibers, pass through the pneumogastric representing the afferent constrictor and dilator fibers, these being found by the stimulation of the peripheral end of the pneumogastric affect both lungs so that each pneumogastric sends both constrictors and dilators to both lungs. When sensory nerves are stimulated, there is in fact only a slight effect by way of contraction. Various experiments have shown the existence of pressor fibers, the excitation of which produces a contraction of the air vessels of the lungs. These pressor fibers are found in the vagus while the pressor fibers pass through the sympathetic to the lungs. There are these fibers in connection with the vagus and also with the sympathetic. By dividing one vagus for example, there are found to be certain changes taking place in the lungs. For example, the intensification that is present in the lungs due to the severance of the respiratory fibers is accounted for by the fact that nutrition is cut off from the lung substance. 5th. There are also sensory fibers in the vagus reaching the trachea, the larynx and the lungs. This is proved by the fact that these sections destroys sensibility. 6th. In addition to these the sympathetic nerves furnish vasomotor fibers, these vasomotor fibers arising from the spinal cord in the autonomic nerve centers of the 2d, 3d, 4th, 5th and 6th dorsal nerves, passing to the sympathetic and plexuses to the thoracic ganglion and thence to the lungs. These represent the chief nerves that we call the effector fibers that reach the lungs.

THE RESPIRATORY CENTER IN THE FETAL LIFE.

In the foetal life the fetus receives O from and gives CO into the maternal blood. The respiratory center is in a condition of apnea resulting from the large quantity of O in the blood and also from the absence of irritability. In the foetal blood there is a large percentage of hemoglobin and also a large capacity for oxygenation. Normally however the child does not breathe in the uterus. In abnormal conditions, however, where the foetus supply is interfered with there may be respiratory movements even when the child remains intact in the foetal sac. If the blood should become very venous this excitement would produce respiratory action. This respiratory action, however, would be abnormal. So long, therefore, as a child remains within the umbilical membrane the respiratory normally is impossible even if the activity of the center of respiration is aroused, because if such respiratory movements take place then the nasol cavity would be filled with fluid. This fluid acts as an irritant, stimulating different nerves, setting up impulses which inhibit the center of respiration so that in the fetal life the respiratory system is intact and complete but there is a constant inhibition by the action of the fibers of the nasal cavity. This forms the reason why sometimes after birth, it is necessary to remove the mucus from the nasal cavity in order to produce respiration. The mucous so long as it remains in

the nasal cavity produces the inhibition of the respiration activity. The fetal lungs have no air although they occupy the entire space of the chest. Newborn child a very small amount of air takes place in at the beginning of life. The expansion of the lungs and the air channels and the respiratory passages take place. This accounts for the fact that respiration is not present in the until expansion of the lungs, air cells and air passages takes place when we find the normal respirations consisting of inspiration and expiration.

CHAPTER V.—ALIMENTATION.

SECTION I.—Introduction.

Alimentation includes those processes through which matter taken in to the body becomes assimilated to the tissues and the fluids of the body and solid and fluid substances necessary for the body nutrition of the body. The different materials that the body nutrition of the body. Alimentation, therefore, supplies the matter for the between the matter introduced into the system and the system itself, energy assimilation is a process consisting of a great variety of stages. All these stages represent certain actions that are necessary in the maintenance of the tissues and also in the maintenance of the body organs as the body the osteopathic standpoint the lack of nutrition or the failure to perform the functions of metabolism is one of the causes of the abnormal and diseased conditions of the body. In fact it forms the main cause of the formation of the blood. A food that the body receive their nutritive, whose formation and circulation in the body is its assimilation is a process by which it passes, represent the different processes of nutrition. Each of these processes may be said include subsidiary processes but they are all united together, in the dis-
tion or circulation. In other cases the secretory and excretory systems do their work imperfectly, thus permitting the presence of waste substances in the body that are dangerous to the system.

The physiology of alimentation is most important, therefore, in order to reach an ideal conception of food in its purity and its adaptability to the system and in relation to the processes through which the food must pass in order to be made ready for assimilation to the body. Alimentary disarrangements must be remedied, therefore, along two lines either on the basis of proper diet, or on the basis of proper alimentary actions. How does nutrition of the tissues take place? All the tissues of the body receive their nutriment from the blood that circulates freely in all tissues. To this we must add the oxygen brought into the system in respiration. The proper food elements in connection with the blood depend upon the principles of dietetics. Food, whatever the food may be, is different very materially from the blood and its elements. Hence, certain substances, either in solid or fluid form enter the body to be subjected to certain physical and chemical changes which constitute the digestive process.

In order to the carrying on of digestion, certain actions and processes are necessary for the breaking up of the food, and for its passage to the various glands which secrete fluids, into contact with which food must be brought in order to prepare it for absorption. When it has been acted upon by the various juices, it appears in the soluble form of chyme so that it can pass into the blood or into the lacteals. The chyle passes through the mesenteric lymph, from whence it passes along the thoracic duct to the blood. In this way the blood receives by absorption new nutritive supplies to which is added the oxygen from the respiratory process. For the process of blood formation, blood corpuscles are introduced from the blood glands, these blood corpuscles being held in the fluid. Under the mechanism of the circulation the body is being thrown into the blood. The proper food elements to the different tissues of the body. The blood is receiving new supplies of nutriment, and also collecting the waste matters from the tissues. These waste elements cause the blood to become impure, so that these impurities have to be given off in the form of excretion. The organic functions of the different organs, although distinct, are not independently so. The blood, for example, is a bearer of oxygen and the nutrient matters, at the same time being the bearer of the waste matters.

Similarly the liver is the organ in connection with whose cells the formation of the bile takes place, and also the metabolism which is connected with secretion. In the discharge of all these functions there is the setting free of energy in the form of heat and mechanical work, all the organs of the body being concerned in this liberation of energy and heat. In this way nutritive processes lie at the basis of all the activities of the body mechanism and are therefore of great importance.

**SECTION II. Diet.**

As the body is made up of various proximate principles it is evident that the food which is to nourish the body, must contain or yield similar proximate principles.

The parts of the food which are digested and used by the body are called alimentary principles. An adult, in order to maintain life and health, must use a certain quantity of food daily. The waste is constantly going on in connection with the physical and psychic changes depending upon activity. In a person who is growing a larger amount of food is necessary in order to furnish matter for the new forming tissues of the body. As the food stuffs version requires to take place in order to fit them for nourishing the year to year, but when all which we have been analyzed they are found to consist of certain specific substances which have been reduced to classes, to find the constitutives contained in it. In order to understand the digestive processes certain actions and processes are necessary for the breaking up of the food, and for its passage to the various glands which secrete fluids, into contact with which food must be brought in order to prepare it for absorption. When it has been acted upon by the various juices, it appears in the soluble form of chyme so that it can pass into the blood or into the lacteals. The chyle passes through the mesenteric lymph, from whence it passes along the thoracic duct to the blood. In this way the blood receives by absorption new nutritive supplies to which is added the oxygen from the respiratory process. The blood is receiving new supplies of nutriment, and also collecting the waste matters from the tissues. These waste elements cause the blood to become impure, so that these impurities have to be given off in the form of excretion. The organic functions of the different organs, although distinct, are not independently so. The blood, for example, is a bearer of oxygen and the nutrient matters, at the same time being the bearer of the waste matters.

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much for the chemical changes which they are subject as in connection with metabolism of the body.

3d. Carbo-hydrates. Among these are starch found in potatoes, arrowroot, cereals and in the leguminous vegetables. It is found in small oval granules possessing different degrees of resistance to water penetration. Cane sugar is found in connection with the cane and the beet, and in some vegetables such as carrots, turnips and watermelons. Grape sugar is found in fruits, in honey, in wine and beer. In addition to these, there is milk sugar, muscle sugar and cellulose. All the carbo-hydrates become absorbed as sugar in digestion. If the diet is rich in carbo-hydrates, the urine excretes less, because the carbo-hydrates are easily oxidized. In wine and beer they are used up first by the body. They have no nitrogen and they are destroyed in the body, and from them is set free which we find in heat and work. They form the bulk of all diet.

4th. Fats. The fat in animal food consists of three substances, stearin, palmitin and olein; the latter representing the fluid fat, such as oil and the nature taken in the solid fat such as butter and lard. If an animal is fed on fat alone, the excretion of urea is less than if the animal receives no food at all, indicating that if much fat is present the proteids substances are less likely to be changed in metabolism. There is no nitrogen in fat and hence the fats have greater value as a source of heat and energy than the carbo-hydrates for they are less easily digested and less easily subjected to destruction in the body. Their chief physiological value is, that the fat can be stored up in the body.

5th Proteids. There are two kinds of albuminous substances. (a) Animal substances such as casein (milk) myoin (muscle) and albumin (egg and blood) (b) Vegetable, such as the albumin in wheat and legumin in peas and beans. Albuminous matter is not found so largely in vegetables as in animals. These albuminous substances form the chief substance in the metabolism of nutrition because there is a large amount of proteid in the blood and in the tissues. The proteids whether animal or vegetable are practically the same. Physiologically they furnish the matter for the formation of new tissues for the repair of old tissue and also as a source of body energy. Because the proteids consist of nitrogenous substances, since the fats and carbon hydrates do not contain nitrogen. Hence protein is necessary to the maintenance of the tissues. If the food contains no proteid the tissues would soon waste, hence the proteids and water are the most essential for existence and the other foods are accessories to these. Among the proteids are classed also the albuminoids. One of the chief albuminoids is gelatin. It is not found in the raw foods but we find it in such cooked foods as soup. Like the proteids the albuminoids contain nitrogen. They cannot, however, take the place of the proteids, their value being that they are nitrogenous, although differing considerably from the pure nitrogenous foods.

6th. Gases. Oxygen may be regarded as a food. Its passage into the body and the tissues takes place in respiration.

7th. In addition to these certain condiments and beverages are used as food accessories. These stimulate the appetite and promote digestion. They are nutritive, the indigestible substances being not only lacking in nutritive value but also hurting the digestive organs. They also contain other substances which are of Physiological value. For example, coffee has a large quantity of aromatic substances, tea a large quantity of tannin and cocoa a large quantity of fat and albumin. Tea also contains iron, copper and sodium and ethereal oil. Coffee contains pure tannin salts. Tea and coffee act as stimulants to the nervous system and have no after effects of depression like alcohol, relieving feelings of fatigue. This is especially true of coffee which is a digestive of which enables persons to undertake long and fatiguing journeys.

A healthy diet must first contain all the proximate principles found in the body, or in other words, all the necessary substances for the maintenance of life. Experience and usage have led people to adopt certain diets, and the results of their experience furnish the only means of selecting a proper food diet on a correct basis. Food includes those liquid or solid substances necessary for the nutrition of the body. In the body tissues certain processes of metabolism are necessary to sustain vitality. Chemical changes take place and certain substances are formed which are thrown off as waste matters. This daily
loss takes place in connection with the lungs, the kidneys, the skin and the other excretions. Food is necessary to make up for this loss. In the case of an adult working moderately, there is a daily loss by the lungs of about 100 grams of CO₂ or 245 grams of C; by the skin of about 91 grams of CO₂ or 2.4 grams of C ; by the kidneys about 36 to 36 grams of CO₂ or 9 to 2.3 grams of C ; and by the faeces a total of from 370 to 280 grams of C excreted from the body daily. In the urine there is about 30 grams of urea excreted daily or 14 grams of N.

In the other nitrogenous matters excreted from the body there are about 5 grams of N excreted daily, making a total of about 19 grams of N excreted daily. There are also excretions of O and H and various salts, but the chief interest are the N and C. It is because food from a dietetic standpoint depends largely upon these elements. This represents a total loss of about 1,000 grams of matter aside from the water that is thrown off. In addition to this energy is being expended, this energy assuming the forms of motion and heat. This energy is estimated as amounting to over five million foot pounds. The energy represented by the heart action daily is about 50,000 kilogram meters; by the activity of the muscles of respiration, 12,000 kilogram meters; by the activity of the ordinary muscles 125,000 kilogram meters; by the body heat 650,000 kilogram meters; representing the total of about 807,000 kilogram meters of energy exhausted daily. This energy must be compensated for by the food supply and by the O of respiration. The changes taking place in the body result in the setting free of energy in the form of heat and mechanical work. The larger amount of the energy takes the form of heat. Even during the inactivity of the muscles, these chemical changes are constantly taking place. In the contraction of muscle more than 3/4 of the energy assumes the form of heat, the remaining 1/4 taking the form of work, even a part of this latter being in the case of work also converted into heat. This heat supply arises in connection with the oxidation of the food materials, this oxidation taking place in connection with the O absorbed, combining with the CO₂ and the H₂O.

The energy of the body thus converted takes the form of potential energy, these foods being derived originally from plant life in connection with the energy of heat-producing bodies, such as the sun. This potential energy under the influence of active body metabolism becomes kinetic energy. The combustion of foods outside the body gives an approximate estimate of the amount of energy available in the case of certain food. In connection with any substance, it is necessary to determine the energy that goes into the body, and also the elimination of CO₂ from the body. This must be replaced by metabolism between the food and the O of respiration. The food supplied to the body during the process of digestion, when not used, is a greatest activity of the digestive process in digesting proteid alone and on account of the greater increase of activity in the excretory system. Hence, the chief consideration of hygiene is that there must be a mixed diet consisting of proteids, fats and carbo-hydrates. The ratio between these three chief food elements depends upon the experimental values obtained. In the cases about 15 to 20 grams of C is on this basis that the iso-dynamic equivalents made use of by Moleschott are estimated. Various experiments show the ratio of nitrogenous to non-nitrogenous foods as from 1 to 2, this calculation being based on the amount of food in the dry condition. In addition to this the food may be digestible or indigestible. Some foods digest easily and others with difficulty. This can only be determined by experiments in the test tube. It is true that meat food great nutritive value because only a small per cent is lost, whereas, in vegetable food, it is lost in a large part escapes digestion and absorption. Various attempts have been made to fix an ideal diet that would meet all possible needs of the bodily system. Moleschott taking as his basis the daily loss of all food as we have found it already amounting to about 19 grams of N and 280 grams of proteids, fats, and carbo-hydrates, making in all about 49 parts of solid food. According to the estimates of energy on the basis of the colorimetric method, this would produce by oxidation normally a little over one million kilogram meters (one kilogram meter equals 7.233 foot pounds) yielding more than sufficient energy to sustain life, on the basis of the energy expended as given before, considering that complete oxidation does not take place in the body. Experience has shown that dietary variations are necessary for different people, according to their employments or manners of life. Those actively employed in occupations calling for muscular exertion require more food than those engaged in the lighter occupations. This has brought out chiefly in connection with prisons and reformatories, much larger diets than the active work is performed in any one of these cases. An ordinary diet of solid food should contain proteid 120 to 130 grams, fats 80 to 90 grams, carbo-hydrates 350 to 450 grams, and salts 30 grams. This is a meal with very little over 20 to 25 ozs. of solid food. In addition to this about 20 to 25 ozs. of water is necessary in connection with the food for cooking purposes, as ordinary food contains about one-half of its weight fluid and as much as 30 ozs. of water in addition as a third daily 18 ozs. of bread, 20 ozs. of meat and 16 ozs. of vegetables in addition to 70 ozs. of water, and this also is a meal with less than one pound of solid food. According to the scientific estimate, a soldier is fed exactly the same as an ordinary man, and in the composition of various food stuffs indicates that bread, oat meal, peas, rice, arrowroot, potatoes, cheese, beef, including mutton and veal, fish and eggs are rich in proteid. Rice, arrowroot, potatoes, cheese and pork are rich in fats, these being arranged so far as the composition concerned so that deficiency in one can be made up by others. There are sold in the greatest count the proportions of the body or food diet. 1st. To find out the per centage composition of the articles made use of, estimating baryta mounted to be required to yield the necessary proximate principles. 20 To make this last we must first estimate the proportion of C to N and various articles of food. The food is not taken in the form of the proximate principles but in combined articles of diet like bread. In order to estimate the ideal diet it is necessary, therefore, to estimate the
proximate principles as found in the various composite foods. In order to have an adequate measure of the vital necessities it is also necessary to estimate the dynamic value of the different foods, which can be done by the calorimetric method in which an estimate can be formed of the amount of heat generated from a given weight of a certain substance or substances, taking into account the fact that complete oxidation does not take place in the system in connection with most of the substances, the amount of energy furnished being less than its estimated amount theoretically. Experiments in regard to the use of certain diets have confirmed these ideas in regard to the distribution of the food elements and their nutritive value. A normal diet therefore, consists of the three great food elements, protein, fat and carbohydrates, the latter being always in excess of the other two. The body may be sustained on the proteins alone, but this is at the expense of the body mechanism because more labor is necessary and the foods are more costly. The fats and the carbohydrates are nearly akin to each other, the fats being converted to sugar and the carbohydrates furnishing the fats necessary for the body when the fat is absent from the food.

In making an estimate of the amount of food necessary in a normal diet three additional circumstances must be taken account of: 1st. Age. 2d. Climate. 3d. The kind of employment. 1st. Young persons and those growing rapidly need more food in proportion to their size than adults, in order to assist the metabolism of the rapid bodily growth. Old people need less food than middle aged and active people, and females less than males:

<table>
<thead>
<tr>
<th>Age</th>
<th>Protein</th>
<th>Fat</th>
<th>Carbohydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children of one year</td>
<td>90</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Children of fourteen years</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Adult (man)</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Adult (woman)</td>
<td>70</td>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>Old people</td>
<td>60</td>
<td>30</td>
<td>70</td>
</tr>
</tbody>
</table>

Some think that the size of the body to a large extent determines the amount of food necessary. In general it is said a small body requires less food, but this is subject to the same exceptions as in the case of the weight of the body, namely: That the metabolism is greater in the smaller body, the surface being relatively larger, demanding more food for body metabolism. 2d. Climate. The chief element in climate is that of the temperature. When the body is exposed to a cold bracing atmosphere, the body metabolism increases on account of nervous stimulation producing an increased appetite.

Greater amounts of food are therefore required in cold climates. As the metabolism of the body uses up more carbonaceous matter the food rich in fat elements is the most suitable. This leads to the use of large proportions of fatty substances which by the oxidation process becomes converted into heat. If the bodily system is subjected to a high temperature the metabolism is lessened, although the results are less noticeable in this direction than in the case of cold, chiefly because the temperature of the body tends to maintain its normal heat level by an increase of the amount of heat lost. This leads to the conclusion that more food is required in the last instance than in a moderate climate, chiefly fluid in character, in order to compensate for the continuous loss by perspiration. Differences in climate to a large extent, however, are compensated for by artificial arrangements, such as clothing, and the supply of heat by air as in the heating apparatus of the house. This, however does not wholly compensate for the metabolic changes and hence in hot regions as compared with the cold the normal diet will be maintained about the same, except that in the hotter regions an increased amount of fat and carbohydrates in the colder regions an increase in the fatty substances taken as food is required. 3d. The amount of food modifies the amount of food required in the case of those engaged in the lighter avocations. Experiments with those in active employment. One who is engaged in hard active muscularly, particularly as the amount expended in energy is not taken accompanied usually by an increase in the heat set free. Muscular metabolism labor requires a larger and more varied supply than one who is not from the amount of heat liberated, the increased energy in this case being not does not necessarily require an increase in the food intake. In muscular available energy, must be considered, but the capacity for work depends upon the metabolism of the brain. The brain requires more energy than the body, therefore, whatever diet would be suitable for the greatest advantage during muscular activity it is increased in such proportion as to meet the general expenditure of energy in this case is minimal except in so far as it bears of all parts of the body is brought out very clearly in the effect which severe mental work has as it draws upon the metabolism of alimentation. Hence the brain because this work is not one that would stimulate or nourish the keep active the juices of the body in connection with digestion and secretion, may be yielded by the materials. This represents certain protein, fats and to be present in such form as this digestive process must be such as to interfere with metabolism of the alimentary system. But a substance really valuable in alimentary digestion is one that can be easily discovered what per cent of the food used remains undigested and hence unabsorbed. This percentage, of course, depends upon the nature of the meal of which it forms a part. For example, in rice and mutton 97 per cent; eggs, 95 per cent; in milk and peas, 95 per cent; in bread, 15 per cent remains undigested. This would represent the amount of these foods inorganic material or food require in the body. In addition to this the process of digestion may vary in the case of a diet of fats. The same substances found in the different articles of food may even in the alimentary canal through changes in the processes of food matter may be broken up into leucin or changed into peptone. These changes means not only the change in the alimentary process, but the nature of the changes that take place during the alimentary process. Hence the chemical composition of food, such as clothing, does not furnish all the nutritive elements. Food substance may be either animal or vegetable. The proteins and the vegetable source seem to pass through the same or most of the
fats and extractives. Hence, from a physiological standpoint all that can be said as to the relative merits of vegetarian and animal diet bears upon the question of the quantity of the proximate principles and the proper proportion of these principles in animal and vegetable diet. Various experiments have been made in the use of a strictly vegetarian diet. As a result it is found first, that a much larger proportion of the vegetarian diet is to same amount of protein referred to as a normal diet, namely, 120 to 130 grams. However, it has not yet been definitely settled how much protein matter is absolutely necessary in order to sustain life. 2d. In vegetarian diet there is a marked increase of the carbohydrates and a diminution of the amount of fats. This seems to be a disadvantage to the system, kept up continuously for a length of time. 3d. In the vegetarian diet a large proportion of the food is indisputable and hence is lost to the system, being given off as waste matter. The most important factor in the vegetarian diet than in the animal diet. As excretion is necessary in order to sustain the normal function and activity of the metabolic system it does not seem to be compensated, for however in the case of vegetarian diet since a larger demand is made upon the alimentary system it is the system is opened to more foreign substances which may materially affect its vitality. For these reasons vegetarian diet would seem to be less satisfactory than the mixed diet that includes animal food.

In the case of the human subject there is not needed any special dieting for the purpose of increasing the amount of adipose tissue. The nature of the food has less effect in this case than the general characteristics of the individual animal organism. The same dieting in the case of two persons may produce opposite results; one person becomes fat and the other lean. The chief fat producing is the carbohydrate. In the case of animals fattening is the result of feeding on the fat producing carbohydrates. Therefore, it is very important to consider the dietary habits of the individual animal organism.

The reason of this is found in the fact that the body metabolism is stimulated by the food. More quickly destroying the protein matter and hastening the oxidation process. It is possible to combine this with an increase of the protein diet to such an extent as to exclude all or almost all fat and carbohydrates from the body. If this is not done excessive tissue changes may occur in the body metabolism. More quickly destroying the protein matter and hastening the oxidation process.

This, however, unsatisfactory and even perilous to the functional life decrease and get rid of excessive protein that there is danger of collapse. To diminish the fat and carbohydrates only at the same time diet it is necessary to increase the amount of protein with an increase in the bodily exertions and activity. In this case the metabolic processes is the most satisfactory method. Daily exercise digestion and promote the metabolic processes, will materially help this by producing large metabolism. In body metabolism a number of conditions circumstances require to be considered. Supposing that these substances are of the individual organism. In the case of a healthy person normally active the regulation of diet depends upon Physiological and Pathological conditions.

Diet.
amount of chloride of potassium, sodium chloride and iron. Milk is a good diet for growing persons but is not sufficient for adults, because the balance of the nitrogenous elements cannot be sustained on such a pure diet. Cream butter yields about 87 percent of fat, 8 to 9 percent of water and 75 or 70 percent of albuminuous substances. When combined with foods that yield proteins and carbohydrates it is very valuable as a diet. Butter milk is milk deprived of its fats, but contains sugar, casein and salts. Cheese contains fat and casein, from 10 to 20 percent of the former and 25 to 30 percent of protein. It is valuable as an addition to other foods poor in proteins and fats. Animal meat of average leanness contains about 75 percent of water (fowl about 70 percent and pork 72 percent); of protein 20 percent (fowl 22 per cent and pork 19 percent); of fat 5 percent (fowl 4 percent and pork 6 percent); of carbohydrate, 7 percent (fowl 1.3 percent and pork 6 percent). Then, the flesh of fowls and birds is richest in protein. Raw flesh finely grated is almost wholly digested but its value for nutrition may be counteracted by the introduction into the body of foreign living bodies endangering life as in the case of trichinosis. Meat may be prepared in various ways by roasting, stewing and boiling. Meat should be cooked to a temperature which leaves within the meat itself ranging from 56° to 70° C. Salted meat loses a small percent of its protein and of the extractives and of phosphoric acid passing into the salt brine. The amount lost, however, is small unless where the meat is kept in brine for a long time when the potassium salts are lost to a large extent. The flesh of young animals is richer in gelatin, the variation being according to Liebig in veal 50 parts in a thousand and in beef 6 in a thousand. Meat roasted openly before a fire develops a layer on the surface keeping the juices inside. In the process of roasting, about 25 percent of the weight is lost. If meat is placed in cold water there will be dissolved out of it a small percent of protein and extractives and most of the saline matter. If beef is boiled then the salt and the extractives with gelatine are found in the fusion. Even after long boiling there remains about the meat about 20 percent of the salts and about 13 percent of protein. To prepare what is called beef tea, the meat should be placed in cold water and generally boiled. By placing the meat suddenly in hot water there is a starch layer formed around the meat, thus preventing the juice from being dissolved out of the meat. Beef tea is nutritious because it contains salts, gelatin extractives and a small quantity of protein. Its chief value is that of stimulation upon the extractives; its nourishing quality being found in the gelatin, fat and albumin.

In Liebig's meat extract there is about 20 percent of water and 80 percent of solids, its action being rather stimulating than nourishing, due to the presence of phosphate of potassium. Eggs are found to contain much nutritious matter, about 27 percent of solid and 73 percent of fluid. The chief constituents of the solids are albumin, vitellin to the extent of 3 percent and palmolin, olein, cholesterol and lecithin about 11 percent together with, about 1 percent of the salts of potassium and chloride and a very small proportion of iron. As found in the egg, the substances are very easily digested. When hard boiled they should be boiled for at least 20 minutes slowly. They should be finely grated so as to come readily into contact with the digestive juices. They are more easily digested if soft boiled, poached or raw. Vegetable feeds are less easily subjected to the digestive juices on account of the fact that the nutritious elements are bound up with cellulose and combined with large quantities of indigestible matters. The protein in vegetables does not differ much from animal protein. The salts, however, are different, being chiefly those of potassium and magnesium phosphates. When the cereals are broken so as to divide the cellulose it is found that the flour contains about 12 or 13 percent of albumen, 65 to 67 percent of crude fibrous substance, 8 to 9 percent of fine fibrous substance, 75 to 76 percent of water, 36 to 37 percent of carbohydrates and 1 percent of salts. Indian corn bread is rich in carbohydrates and poor in albumin. Barley and oat meal flour are nutritious on account of the combination of albumin and carbohydrate. Bread consists of a mixture of flour with water under the action of a ferment. By fermentation the starch is changed into sugar and is converted into alcohol. The formation of gas the bread becomes softer and lighter in formation. The flour is baked in a high temperature fermentation is arrested and the bread becomes very digestible. From these facts it follows that bread with albumen is necessary for the proper digestion. Among the leguminous or pulse and beans are said to contain over 23 percent of albumin, 50 percent of water, only 2 percent of albumin and 20 percent of carbohydrates. Rice being very deficient in protein, large quantities are required to be added to it. Rice is often taken to be of much value in nutrition, 2 kilog. of rice and 2 to 3 kilog. of potatoes as the proportion of carbohydrates is large, the excessive use of these is dangerous. When used in this way the rice should be boiled for a long time. The vegetables, cabbage, cauliflowers and turnips are rich in the potassium salts, although not very nutritious as foods and hence form a good combination with corn meal which are deficient in protein and rich in potassium and salt. These elementary foods are not suitable easily digestible, and the fat is valuable in the vegetable kingdom. All the vegetables are not suitable for food and many of them are injurious. Even in the same plant all the different parts are not equally useful, hence man requires a knowledge of the plants and their adaptability for human use. Some portions of the vegetable kingdom are received adapted for the food of animals, and thus in the economy of nature, the lower serves the higher, the edible parts of the vegetable kingdom are fed upon rough materials unfit for human use, converting the food into issues, food is thus made available for man. In this way the inorganic becomes adapted to man's necessities. The animals could not live without vegetables, each being indispensable to the life of the other. The vegetable is nourished upon the soil and the air, carbon being extracted out of the air and stored up in its substance so that it becomes the animal food. In this way the vegetable lives and grows upon the waste of the animal kingdom, the decomposition of animal bones, the CO₂ exhaled from the animal breath furnishing the food matter of the vegetable life. The food substances
represent a moderate principle in the nourishment of both mind and body. Dr. Richardson, of London, says that animal food should not be taken oftener than twice daily and the amount of animal and vegetable food combined should not exceed 1.24 parts of the body weight in the form of food. In general, the use of various foods but also by variety in cooking. The constitution of others results in failure because the body is imperfectly nourished and health thereby shortened. Dogs have been fed exclusively on a single food and have soon died of starvation. A monkey fed on rice alone died in 14 days. Dr. Hammond fed himself on 1 1/2 lbs. of gum and on another occasion on 1 1/2 lbs. of starch with water daily with the result that the fever increased to such an extent that in a few days he had to abandon this diet. Later he fed himself on 1 1/2 lbs. of albumin and found that diarrhoeic conditions and the amount of albumin in the urine became so dangerous that he had to give it up on the ninth day.

2d. The absence of necessary elements of diet results in diseased conditions. It has been found that where persons have been deprived of vegetables for 1-24 part of the body weight in the form of food. In general, the use of various foods but also by variety in cooking. The constitution of others results in failure because the body is imperfectly nourished and health thereby shortened. Dogs have been fed exclusively on a single food and have soon died of starvation. A monkey fed on rice alone died in 14 days. Dr. Hammond fed himself on 1 1/2 lbs. of gum and on another occasion on 1 1/2 lbs. of starch with water daily with the result that the fever increased to such an extent that in a few days he had to abandon this diet. Later he fed himself on 1 1/2 lbs. of albumin and found that diarrhoeic conditions and the amount of albumin in the urine became so dangerous that he had to give it up on the ninth day.

3d. The absence of necessary elements of diet results in diseased conditions. It has been found that where persons have been deprived of vegetables for a long time, skin diseases like scurvy become prevalent. Where the food is poor it has a depressing effect rendering persons liable to all kinds of diseases.

There is no condition that favors the spread of a plague so efficiently as a poor and unvaried diet. This is evident from the accounts we have of the poor and their scanty diet during the great European plagues. A diet to be healthy ought to be varied. The same diet from day to day becomes, not only monotonous to the sense of taste, but develops unhealthful conditions. While we do not think that a diet should be purely vegetable no diet should be without vegetables. Variety may be secured not only by the use of various foods but also by variety in cooking. The constitution is often undermined by the lack of variety.

By one of the most promising of English Physiologists in the 19th century, became a victim in this way to experiments upon himself. For 44 days he lived on bread and water; for 29 days he took only bread, sugar and water. For 44 days he lived on bread, olive oil and water, the result being that he died on account of the damage done to his constitution by limiting his diet to these simple foods. A sufficient variety in food and a sufficient quantity of food thus represent the two great essentials of a healthy diet. For an average adult there should be from 88 to 112 ozs. of food and water distributed as follows:

20 days. Children and those rapidly growing succumb sooner than adult persons. With a supply of water life may be prolonged with a small quantity of food or even with no food at all, an animal surviving longer upon water than upon food. Hunger and Thirst. Hunger is a sensation that is usually referred particularly to the stomach. Physiologically, however, it is due rather to a general want of the whole system. It is usually referred to the stomach because by supplying the stomach with food there is a feeling of relief. It would appear to depend upon the stimulation of the gastronomical centers in connection with the parasympathetic nerves of the stomach. Hunger arises not from the stomach alone, but also from the other organs and tissues which demand nutrition. It is intimately connected also with the central nervous system. The division of the gastronomical centers does not produce any change in the feeling of hunger by way of relief. The use of stimulants like tobacco or alcohol lessens or at least reduces the feeling of hunger.

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FERMENTATION.

in certain stages of fevers, especially during the convalescent period. The minimum of food necessary to sustain life, cannot be stated because this depends very largely upon the individual characteristics and upon the activity of life. Even the activity of life does not depend upon the amount of food, as individuals have lived actively upon a very small proportion of the food. It is generally stated that most persons take food in excess, this being one of the common causes of gastric disorders and dyspeptic conditions. Hence the advice of hygiene is to modify and regulate the diet in its quantity, as well as in the proper selection of food. During the starvation of the animal there is a constant body loss due to the using up of the tissues. When the body ceases to receive nutrition it lives upon its own substance, the active organs losing rapidly. The fat stored up in the body is first exhausted, next the blood, its albumin being used up in the tissues. This is followed by diminution in the digestive ferments and in the amount of CO₂ given off is diminished. The tissues then lose their power, become weaker in activity, the central nervous system is depressed and especially the activity of the kidneys resulting in death very soon. Hence water must be taken in sufficient quantities. The same is true of salts. If albuminous matter is cut off from the food supply there is a great diminution in the excretion of urea. This becomes more marked if the food is rich in carbohydrates. In this case the body metabolism, especially of the albuminous tissue is lessened in activity, less urea being excreted than if no food is taken at all. The carbohydrates in this case use the O of the body in the oxidation process, leaving but little of the O for the albuminous matter. If the carbohydrates are cut off and only proteins are given with plenty of water life may be sustained for a considerable period. If fat is given alone with the albumin there is a large quantity of fat given with a large quantity of albumin most of the albumin is lost in bodily metabolism. If a large quantity of fat is given and a small quantity of albumin, the fat is stored in the body. These facts indicate that a mixed diet is the preferable one. Being more suitable to the bodily system, the proper combination of the different foods yielding most satisfactory results.

SECTION III. Fermentation.

Digestion consists largely of chemical changes taking place in the food in its passage along the alimentary canal. These changes are peculiar inasmuch as they are not limited to the substance of the food itself. Besides the existence, development and reproduction of ferments, are intimately associated with certain diseased conditions. In the fermentation of fluid it becomes either clear or more muddy, throwing off gas and seething with the froth, these representing physical changes. Associated with these changes are certain chemical changes represented by the alcoholic and other substances such as CO₂ found in the fluid and given off from it. There is also a deposit at the bottom consisting of small organisms, called fermenting juice. These processes, including the physical, chemical, and biological, were all associated together as phenomena in connection with the ferment which is so called, from the fact that the surface presents the frothing appearance.

These processes must have been known from very early times. The first fact noticed was the frothing or the physical change caused by the alcoholic fermentation, when warm, for fermentation was separated from the water by alcohol. It was found that the gas thrown off was the same as that given off by the human body. Hence the idea of fermentation was produced. Difference of opinion arose as to the substances formed from the fermentation of sugar, Pasteur being the first to differentiate the substances in connection with sugar including alcohol, CO₂ succinic acid and glycerin. It was early discovered that the phenomena of fermentation were not until comparatively recent times that fermentation was shown to be caused by the action of the microorganisms which are found to grow and increase rapidly in sugar solutions. Many theories have been proposed to explain this phenomenon.

The chemical theory was that it was due to catalysis or to the simple fact of the presence of the ferment in the fluid. LIEBIG theory was that there existed no necessary relation between the fermentation and the existence of living cells. The living cells produce some substance which, as it acts upon the substances to be fermented, produces a motion among the atoms of the substances, giving rise to the boiling or frothing condition. This is simply an extension by the ferment resulting in vibratory movements. LIEBIG says that "physiological action would be necessary for the production of these substances" in other words, the living organism undergoes a certain chemical change associated with physiological metabolism resulting in the formation of these substances. For a long time it was thus supposed that fermentation was purely a chemical process. More recent times the question has been discussed largely from a biological and physiological point of view. The ferment of Liebig was caused by the presence of minute organisms. This has been accomplished, especially through the investigations of LEFEBVRE, who spent considerable time in the attempt to cultivate these minute organisms. Thus, we have been led to the vital theory of fermentation according to which these organisms represent germs of life, a particular germ of which Pasteur, who spent considerable time in the attempt to cultivate these minute organisms, succeeded in this work. We have been led to the vital theory of fermentation according to which these organisms represent germs of life, a particular germ of which Pasteur, who spent considerable time in the attempt to cultivate these minute organisms, succeeded in this work. We have been led to the vital theory of fermentation according to which these organisms represent germs of life, a particular germ of which Pasteur, who spent considerable time in the attempt to cultivate these minute organisms, succeeded in this work. 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cause being unable to pass through the wall of the bladder. From this and similar experiments it is evident that the organisms in the air are the cause both of fermentation and putrefaction. At this point Pasteur began his studies which have immortalized his name and produced a revolution in the scientific world. He found that certain organisms are produced by a different ferment. The alcoholic by the yeast cell, lactic fermentation by lactic acid, etc. He then began to cultivate these organisms in certain fluids which seemed germane to their life so that he could localize certain organisms with certain fluids. He found that the ferment producing the butyric fermentation could live and grow in a fluid mixture of certain minerals with sugar, the presence of free air intercepting the fermentation. He found that this applied to some of the other fermentations. It was that he led him to the conclusion that most of the ferment organisms may be aerob or anaerobic, that is, live in the presence or absence of air. It is while it is anaerobic that it does the fermentation work. When it receives free air it grows and develops as in the case of molds found on the surface of exposed foods, but when free air is excluded it forms the substances in which it exists and in this way produces fermentation. This does not mean that these organisms produce fermentation, but that they can produce that air necessary for their life inside the substances in which they are found. They can live without free air as Pasteur has said, extracting sufficient oxygen from the substances such as sugar.

Engleman has pointed out that some of these organisms gather close to an air bubble while others move away from the air bubble. There are some, however, that require O2, as the bacteria aceti. Pasteur's final theory is that some O2 is necessary at the beginning of fermentation, but that when fermentation begins O2 is not necessary. By these experiments the biological theory of fermentation has been established.

Some organisms have been identified in connection with lactic fermentation, the acetic mannate and urine as well as putrefaction and fermentation. These fermentations are different and also the ferments, some of the productions of fermentation are different, for example alcohol; some claim that the increase in the minute organisms is the substances in which the fermentation takes place but the product of fermentation. It has been noted that these fermentations do not pass into the fluid, fermentation may be prevented, so that it is possible to completely sterilize certain fluids and substances and so anything that could cause fermentation, and that these minute organisms produce a kind of ferment which acts on the take place, although the fermenting ferments is the product of fermentation. It has been noted that these fermentations are produced by the action of the enzymes which are secreted by the microorganisms and which cause the fermentation to take place.

These digestive changes are effected by means of these enzymes whose action is peculiar. These are substances produced inside animals and plants although not actively endowed with life. When obtained in free solution from organic matter, they are colorless and form of fermentation can be destroyed in water and precipitated by alcohol. They are like the albumin derivatives, but do not contain sulfur. These are distinct from the living germs found in bacteria and are really dead, although they are generated in living substances. Their chemical composition is not known, although they are complex compounds. Some think that this ferment belongs to the albumin derivatives, the solutions of these ferments give the proteid reactions, but this may be due to impurity in the solution. These are usually classified according to their reactions, most of these changing protein into soluble peptones, proteoses or triptones. In connection with digestion we find the pepsin of the gastric juice and the tripsin of the pancreatic and intestinal juices, the former and develops as the case of protease line. 2d. Amylotytic; act ing on starch and changing it into a solution of sugar, or sugar and dextrin.

In animal digestion we find the ptyalin of saliva, amylopsin of the pancreatic and liver the organisms can live without air, fructose, fructolytic or fat separating ferments, acting on the neutral fats and separating them into fatty acids and glycerine by the action of the pancreatic ferment called steapsin. 4th. Inversive ferments, transforming the double into the single saccharides. For example, converting the cane sugar into the dextrine, laevulose and glucose by the action of invertin in the intestinal juice, and possibly to a small extent in the salivary juice. 5th. Coagulating ferments, as the fibrin ferment of blood, acting upon the proteins and producing an insoluble clot similar to this, and of the same nature as the rennin ferment of gastric juice which produces coagulation. Some organisms have been found to belong to the class of albuminoids and this has led Physiologist to propose that all ferments belong to the same class.

This, however, is incorrect. 6th. Urea ferment, splitting up urea and converting it into carbonates of ammonia. These are found in connection with the rejection of urine and the not the cause of the urea ferment. The chief agents in the food changes that take place during the process of digestion and hence are most important element in considering the digestive secretions. A ferment is a substance that causes a kind of ferment which acts on the substance under the process of fermentation. This action is not directly supposed to change O2 would be characterized by reduction. In this case, of course, the absence of O2 would be characterized by oxidation. If O2 is present it is supposed to be due to the process is one simply of oxidation. If this latter statement is true this is true not only in the case of the results at least of oxidation taking place in the living tissues, these may be partially oxidation changes but where sufficient O2 is set free O2 is also liberated in the substances which may result from fermentation. When this change is not accompanied by the partial oxidation of the living tissues, these may be partially oxidation changes but where sufficient O2 is set free O2 is also liberated in the substances among the molecular ferments, there are the unorganized ferments or enzymes or the unorganized ferments that belong produce by the field of Physiology. Digestion consists largely of certain processes of chemical changes through which food passes in its passage through the alimentary system.
SECTION IV.—1. Digestive Processes in the Mouth and Passages to the Stomach.

Digestion includes all those processes and changes through which the food passes in the alimentary canal, in order to prepare it for entering into the blood by the process of absorption. These changes are the result of mutual action on the part of the mouth, stomach and the intestines. These processes to which the food is subjected are various. In connection with the mouth there are two, mastication and insalivation and there is deglutition in the passage to the stomach, as the food is not introduced into the mouth by means of the hand or some other artificial means devised for the assistance of hands. After the introduction of the food into the mouth it is subjected to a series of changes. First of all the food is introduced into the mouth, passing into the pharynx and from thence to the stomach. It is by inspiration that fluids are sucked into the mouth. If the lips are immersed in the fluid in drinking, inspiration pulls out the air from the mouth, the fluid passing in under the pressure of the atmosphere. If the lips are not immersed in the fluid there is some air that passes in along with the fluid.

The movements in connection with alimentation are dependent upon the action of plain muscles. It is of importance to consider the character of the muscles as these movements depend upon the muscle. Plain muscle size of the whole. There is no cross striation, the cells being united to form fibers, all running in a longitudinal direction corresponding with the cell axis. These cell pleaxes form sheets of muscle which constitute the external coats being either longitudinal or circular. These cells are bound together by a cement substance, the cells being continuous in their protoplasm and thus affording a continuous path for the waves of contraction, the close connection between the muscle tissue and the nerve fibers. The chief Physiological point in connection with this plain muscle is the location of the contraction. It is subject to any kind of stimulation but the latter period is longer than usual. A slow contraction being followed by a slow relaxation. This lengthening of the periods depends on the fifth pair of nerves and the glans-pharyngeal in connection with the tongue. Motor influences are conveyed to the muscles 5th in its inferior maxillary branch to the buccinator, the anterior belly of the genio-hyoid and the mylo-hyoid pulling down the lower jaw; the temporal, maseter and inter-mandibular muscles closing it. The external pterygoids in alternating tension of the base of the tongue, being the palate muscles and the genio-hyoid and the mylo-hyoid muscles which fix the hyoid bone, open the mouth of the tongue, the genio-hyoid and the mylo-hyoid muscles closing it. The external pterygoids in alternating tension of the base of the tongue, being the palate muscles and the genio-hyoid and the mylo-hyoid muscles closing it.
glands and the small glands of the buccal mucous membrane. The saliva is a thickish, transparent, glairy and somewhat turbid fluid with a slight albuminous odor. In this sediment are found that epithelial cells from the mucous of the mouth, mucous corpuscles probably leucocytes, which are few and have escaped into the secretion and spheroidal cells from the salivary glands known as the salivary corpuscles, together with protoplasmic masses with ameboid movements. The specific gravity averages about 1.001 to 1.009.

The saliva is alkaline in reaction, due to the presence of alkaline sodium phosphate, its alkalinity being about 0.5 per cent. It consists of water with about 0.5 per cent of solid matter. The solids consist of salts including lime carbonate, alkaline chlorides and the phosphates of lime and magnesia with sulpho- and sulpho-cyanides of sodium and CaO in combination with carbonates. Small quantities of Na and N, mucin, albumin and globulin and albuminoids which may be known as ptyalin of the amylolytic class which has the power of converting the starch into various forms of sugar, of being of sugar, dextrin and maltose. Ptyalin when pure by precipitation is a whitish grey powder very soluble in water. The saliva is found in the gland by combination of the protein and carbohydrate. Ptyalin is an important element, producing the viscous character of the saliva. It is found in the gland by combination of the protein and carbohydrate. Ptyalin constitutes the main portion of the products of proteid metabolism. This effect is produced more quickly in the starch granules. There are other conditions favoring the ferment power of the saliva including a moderate temperature 70°F and the fluid in which the action is taking place being either alkaline or neutral. The various salivary secretions have been secured by the use of tubes in connection with the glands. The parotid saliva is clear and limpid, not viscous, somewhat alkaline although the first flow is acid, and it yields but little ptyalin. The submaxillary saliva contains ptyalin and sulpho-cyanide of potassium. It is clear, is alkaline and contains ptyalin and sulpho-cyanide of potassium. The action of saliva upon starch is hindered by the product of saliva sugar. Hence, the process is not so efficient as if the starch was allowed to remain in the mouth. If it is taken out as it is formed, the process becomes incomplete. In the infant and children the saliva contains very little ptyalin and the very proportion of mucin with more salts and is very markedly alkaline. The parotid saliva is clear and limpid, not viscous, but is highly alkaline although the first flow is acid, and it yields but little ptyalin. The submaxillary saliva is found in the gland by combination of the protein and carbohydrate. Ptyalin constitutes the main portion of the products of proteid metabolism. This effect is produced more quickly in the starch granules. There are other conditions favoring the ferment power of the saliva including a moderate temperature 70°F and the fluid in which the action is taking place being either alkaline or neutral. The various salivary secretions have been secured by the use of tubes in connection with the glands. The parotid saliva is clear and limpid, not viscous, but is highly alkaline although the first flow is acid, and it yields but little ptyalin. The submaxillary saliva contains ptyalin and sulpho-cyanide of potassium. It is clear, is alkaline and contains ptyalin and sulpho-cyanide of potassium.

SECTION V. Inervation Of Insalivation.

The ordinary flow of saliva is a reflex action. The lingual nerve being the afferent path and the chorda tympani the efferent path for impulses. The food substance stimulates the glosso-pharyngeal and the lingual nerves which convey impulses to a center in the medulla from which efferent impulses pass to the salivary glands. The efferent nerve to the submaxillary is the chorda tympani. The sa-
INNERVATION OF INSALIVATION.

Insalivation is drawn from the blood under the influence of the activity of the cells, the amount of the fluid flow depending upon the necessity of the digestive system; hence, when the mouth has no food in it only sufficient saliva flows to keep it moist. When the food or any substances enter the mouth the salivary flow commences. The influence of the nerve fibers on salivary secretion and flow has been chiefly studied in connection with the submaxillary glands. There are connected with these glands in the human subject fibers from the facial through the chorda tympani and from the sympathetic. The chorda tympani springs from the facial nerves at the lower extremities of the Fallopian aqueduct passing through the small canal opening on the posterior wall of the tympanum, passing across the tympanum and then passing out of this canal by an opening in the inner ear close to the Glaserian fissure. It passes down along the internal surface of the internal lumen of the tympanum and the submaxillary glands. It is the lymphatic vessel connected with the chorda tympani. The nerve fibers run along the chorda and the gland, nerve cells arising especially after the entrance of the hilum into the gland. The salivary secretion is distributed in connection with the gland as yet unknown. The chorda fibers are medullated till they enter the gland, when denervation occurs. The sympathetic fibers also send fibers to join the ganglion, arising from the plexus of the facial artery. The blood vessels of the submaxillary gland are connected with the ganglion by means of a number of fine nerves, these being fibers reaching the gland along with the arteries of the gland. Several of these small fibers pass to the mucous membrane of the mouth. These fibers are non-medullated and may be traced to the superior cervical ganglion, thence, back to the cervical sympathetic and then to the lower extremities of the spinal cord. If a tube is applied to the sub-maxillary gland a whitish turbid fluid passes out of the tube if the stimulation occurs. If the tongue is stimulated by some food substances or if the lingual nerve is artificially stimulated. If chemical stimulation is produced the sub-maxillary fluid will continue, if there is sufficient afferent stimulation. If the tube is destroyed the saliva ceases. If direct stimulation is applied to the medulla the salivary flow will continue. The efferent stimulation of the peripheral end after its division into the sub-maxillary gland is caused by the chorda tympani or by the sympathetic. The saliva is produced by the chorda tympani or by the sympathetic. The saliva is produced by the chorda tympani or by the sympathetic. The saliva is produced by the chorda tympani or by the sympathetic. The saliva is produced by the chorda tympani or by the sympathetic. The saliva is produced by the chorda tympani or by the sympathetic.
INNERVATION OF INSALIVATION.

The latter vaso-constrictor. This center in the medulla may be stimulated not only by afferent impulses from below but also by impulses arising in the cerebrum, arising from a psychic influence connected with the thought of a savoury meal. The response may be either accelerator or inhibitory, in the former case producing a free watery secretion in the mouth, and in the latter case parching the mouth. Secretion in the submaxillary gland is not a process of filtration but takes place internally in the gland determining blood flow to the gland. Secretion is not arrested by the pressure becoming greater in the gland than in the arteries. Even after decapitation the secretion will continue in the gland indicating that the saliva not simply filtered through the gland from the blood but is produced in the gland cells. In confirmation of this it is claimed by some that the nerve terminals are found in the gland cell protoplasm or in the neuclei of the cells, at least they seem to be intimately connected in some way. This nervous connection with the cells has been traced in the case of the liver. In connection with the chorda tympani two different kinds of fibers exist, secretory or accelerator or inhibitory. The use of atropin produces paralysis of the accelerator without effecting the inhibitory. If the sympathization is applied to the chorda, no secretion takes place, though the blood vessels are dilated. Thus, the dilator fibers have not been effected at all, the secretory fibers have been affected. If the chorda is divided after the lapse of a day the Wharton duct begins to discharge the liquid secretion called the paralytic secretion which continues to flow for several days, after which it ceases, the gland beginning to waste. But if one chorda is cut, this watery secretion will flow from both glands. This is supposed to be due to the venousity of the blood stimulating a local center, this flow continuing during the vitality of the local ganglion. During the secretory process the gland temperature is raised from 1° to 2°C producing an increase in the flow of venous blood leaving the gland, as compared with the arterial blood received into it. The changes in the gland are due to certain electric influences, a change taking place between the normal gland and the gland under stimulation, resulting in a negative variation. During the resting of the gland the hilum of the gland is positive to the rest of the gland. If the chorda is stimulated the hilum becomes negative after a latent period. If the sympathetic is stimulated the hilum becomes positive to the rest of the gland. Secretion and flow are thus dependent upon three factors: (1.) Blood supply. The secretion increasing or diminishing according to the supply of the blood. (2.) Nervous impulses. There is an increase of the secretion by the nerve activity upon the gland cells. The blood supply is under the control of the nerve fibers, one set increasing, another set decreasing supply. This nerve impulse is under the control of the local reflex center or the centers in the central nervous system. (3.) The activity of the gland c. The gland c. This means that the gland becomes sensitive to atropin. This is shown by the fact already referred to in reference to the stimulation of the fibers of the chorda tympani in connection with the submaxillary gland when the system is under the influence of atropin. It can also be shown by ligaturing the duct of the gland when secretion is continued, although the pressure inside the gland is greater than that inside the blood vessels. The submaxillary gland appears to be a kind of secondary reflex center for the submaxillary gland. If the nerves that connect both with the central nervous system are divided, substances applied to the surface of the submaxillary gland prevents the flow of saliva. The nerve fibers to the sublingual gland come from the lingual division of the 5th and arise from the sympathetic complex as from the submaxillary gland. Nerve fibers passing to the parotid gland from the glossopharyngeal by the otic ganglion and the inferior superficial petrosal, the immediate connection with the gland being through the antero- lateral tympanic going through the petrous ganglion. Passing along the inferior wall of the tympanic, it passes out at the upper part becoming the division of the temporal bone, passing downward to the otic ganglion. The otic ganglion gets fibers from the inferior maxillary branch of the 7th, from the sympathetic and the glossopharyngeal through the small superficial petrosal. Thus, the nervous connection of the parotid is similar to that of the submaxillary gland.

Heidenhain has tried to explain the secretory process in the gland. In the cell we find the cell and also the secretion, each cell being a source of change in the cells and also of secretory fibers which are connected in the central nervous system. (3.) The activity of the gland. This means that the gland is under the control of the sympathetic nervous system and the sensation. (4.) Blood supply. This nerve impulse is under the control of the local reflex center or the centers in the central nervous system. This transmission of impulses takes place through the pharynx and the oesophagus. The pharynx is a muscular tube reaching up to the lower edge of the cricoid cartilage. The oesophagus below is continuous with it. The soft palate projects backward into it, and an envelope passing backward from the hard palate forming the connective tissue with the layer of the skull to the lower edge of the cricoid cartilage. The oesophagus below is continuous with it. The soft palate projects backward into it, and an envelope passing backward from the hard palate forming the connective tissue with the layer of the skull to the lower edge of the cricoid cartilage. The oesophagus below is continuous with it. The soft palate projects backward into it, and an envelope passing backward from the hard palate forming the connective tissue with the layer of the skull to the lower edge of the cricoid cartilage. The oesophagus below is continuous with it. The soft palate projects backward into it, and an envelope passing backward from the hard palate forming the connective tissue with the layer of the skull to the lower edge of the cricoid cartilage. The oesophagus below is continuous with it. The soft palate projects backward into it, and an envelope passing backward from the hard palate forming the connective tissue with the layer of the skull to the lower edge of the cricoid cartilage. The oesophagus below is continuous with it. The soft palate projects backward into it, and an envelope passing backward from the hard palate forming the connective tissue with the layer of the skull to the lower edge of the cricoid cartilage. The oesophagus below is continuous with it. The soft palate projects backward into it, and an envelope passing backward from the hard palate forming the connective tissue with the layer of the skull to the lower edge of the cricoid cartilage. The oesophagus below is continuous with it. The soft palate projects backward into it, and an envelope passing backward from the hard palate forming the connective tissue with the layer of the skull to the lower edge of the cricoid cartilage.
DEGLUTITION.

The oesophagus is striated muscle which gives rise to the quick movements of the third part of the oesophagus, whereas, the lower part is unstriated, the movements of the part being much slower.

Deglutition includes three periods, the passage of the bolus through the isthmus of the fauces, the passage through the pharynx and the passage through the oesophagus. After the bolus has passed there begins the involuntary and reflex movement. There is a backward movement of the tongue and an elevation of its central part by the contraction of the styloglossal muscles. The tongue at the same time changes its form, sending the bolus back to the soft palate. The bolus then goes through the isthmus and the anterior pillars, contracting, and thus preventing it from returning to the mouth. It then proceeds the passage of the food from the mouth to the stomach. It may be divided into three stages.

1. From the mouth to the isthmus of the fauces. This is the voluntary stage during which the bolus is by the tongue carried back to the fauces. When the bolus lies on the upper surface of the tongue it forces back to the soft palate. It is voluntary in the sense that the tongue can be freely used. However, a moistening of the food is necessary as soon as it passes within these fauces. This stage is then rapidly completed the 2d stage, through the pharynx. This stage is spasmodic and is of the nature of a reflex action. The tongue is jerked upward and backward by the stylo-glossal muscle and thus, the bolus is thrown into the lower part of the pharynx. The pharynx is the common tube for the food and air, and hence, more rapid movement of the food is necessary during this stage. At the same time other movements take place by which the earnings leading from the pharynx except that into the oesophagus are closed, and in this way the bolus is prevented from entering them. Various steps in this process are noticeable. (a.) The muscles of masseter, the lower jaw, pressing the arches of the teeth against each other. The pharynx is pulled upward forward by the palato-pharyngeal and the stylo-pharyngeal muscles, the constrictors and the muscles of the lower jaw to the tongue. The pharynx ascends, accompanied by the ascension of the larynx. The constrictors also contract from above downward, pressing the bolus against the soft edges of the palate and the tongue, carrying the bolus as to the soft palate as to the oesophagus as to prevent regurgitation of the food into the nose. The palato-glossal muscles contract and produce a narrowing of the anterior arch of the fauces, preventing the bolus from returning to the nose cavity. Having entered the pharynx certain movements are necessary in order to prevent its passage into the nasal cavity and to carry it into the oesophagus.

2. The soft palate is raised by the levator palati muscles, leaving between them a passage through the nasopharynx. The passage is filled up by uvula. In this way there is formed a sloping shelf which cuts off the bolus from the posterior nares and the eustachian tubes.

It is a matter of dispute whether the orifices of the eustachian tubes are open or closed during deglutition. The posterior surface of the soft palate I think, is directed back toward the wall of the pharynx occupying a horizontal position and almost closing the eustachian tube. The mylo-hyoid muscles contract rapidly thus lessening considerably the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity, the bolus being quickly sent from the mouth through the buccal cavity.

(b.) As the tongue is jerked upwards and backwards by the hyoid bone with the pharynx and larynx is carried upward and forward. Hence the base of the tongue reaches the isthmus of the oesophagus. The conclusion is completed by the contraction of the muscular fibers connected with the epiglottis. At the same time the rima glottidis is closed, the arytenoids are drawn together, the true vocal cords and the false being brought close together, the vocal cords being closed together. The production of the egressing fluid continues. The general view is that the epiglottis presses down on the laryngeal opening, closing it and protecting the respiratory passage if the epiglottis is carried out normal swallowing continues. According to some recent cases the epiglottis becomes erect in swallowing although this is not accepted as correct. By these means the orifices leading from the pharynx are closed with the exception of that into the oesophagus. The eustachian and the lower part of the pharynx are somewhat raised to meet the descending bolus by the contraction of the stylo-pharyngeal muscles forcing the food downward and thus preparing for the 3rd stage. During this stage, these orifices are closed, the lower part of the larynx is pulled up. In this way a clear and well marked passage is cleared for the food through the pharynx.

3. In the oesophagus, this is the involuntary stage. The constrictors of the pharynx close over the food which enters the oesophagus along which it is carried by peristaltic contraction. When the food enters the oesophagus the pharynx falls downward, the openings of the mouth, the nasal cavity and the glottis being opened and the fragments of food being carried down by the peristalsis of oesophageal contractions. The oesophageal movements are undulatory; and peristaltic contractions are called peristaltic. The circular contraction originating in the pharynx passes into the oesophagus, being first communicated to the transverse coats of the oesophagus and then assisted by the contraction of the longitudinal muscles of the oesophagus, the movements being always directed downward. The muscles of the oesophagus are found to contain striated fibers in the upper part and unstriated fibers in the lower part, peristaltic action being the same in both except that in the striated fibers it travels much more rapidly. These peristaltic movements may be carried out by the muscles without any assistance from the nerve fibers, terminating in the muscles and apart from any stimulation from the central nervous system, as these can be seen in the organs when removed from the body.

But in the living body the connections are so close with the nervous system as to make the contraction of nerves and muscles inseparable in the production of peristaltic action. The contractions do not originate above and are carried out by the walls of the tube alone and thus transmitted from segment to segment. The efferent impulses pass from the medulla to the different regions of the tract. Hence, if a part of the oesophagus is excited the constrictor will commence and go down the oesophagus to the cut portion and will proceed to go down the lower part, crossing the gap, indicating that nervous stimulation passes to the oesophagus in all its parts from the central nervous system. Peristaltic movements of the lower portion of the oesophagus can be aroused by irritating the pharynx. In the production of these peristaltic movements of the oesophagus we find the pharyngeal afferent nerves, the
superior laryngeal, the pharyngeal branches of the pneumogastric, the branches of the 5th and the hypoglossal, the 12th, and the glossopharyngeal. The center of peristaltic action is in the medulla being a portion of the deglutition center. The efferent impulses pass from the center along the pneumogastric, passing by the recurrent laryngeal to the upper part of the pharynx, from there they reach the opening into the stomach in 10 of a second. The action of the pharyngeal contractions and the esophageal peristalsis does not assist deglutition but takes place after the swallowing of the food, the object of which is to clear down the fragments, and if the food bolus is delayed to pass down more slowly through the pharynx and the esophagus. According to these Physiologists the food of the stomach or the food is immediately after the end of the esophagus which is the account of the tonic contraction of the sphincter until the peristalsis reaches that point so as to relax the sphincter and thereby permit the passage of the food into the stomach. The sensations that point about 6 seconds after the entrance of the food into the mouth. Instead of there being two regions in the esophagus as we find in the old theory, according to these investigations, there are three movements of the esophagus, upper, middle, and lower, but there are three contractions in the peristaltic movements. These three contractions together with the pharyngeal constrictors and the mylo-hyoid muscles are the five segmentary contractions producing deglutition in normal circumstances. This represents a new and simpler theory of the deglutition which has not been fully confirmed. If confirmed it will simplify very much the physiological of deglutition.

The Nervous Arrangement of Deglutition. Deglutition as a whole represents a reflex action complex in character. It is impossible without some stimulation of the mucous coat of the fauces. The first stage represents a voluntary action, the second stage is said to be partly voluntary and partly reflex. The movements, however, may take place voluntarily and during unconsciousness. In the last stage it is purely involuntary, the will having to do with the action and the movements of the alimentary canal in assisting the movements toward the act of deglutition, that many muscles, all these muscles co-operating to produce definitely results, the connections and the results being very definite. The nervous connections which are piled up with the stimulation arising from the food or liquid coming into contact with the tongue and fauces. These movements are aided by the insalivation of the food and the closure of the mouth, as it is very difficult to swallow any substance with the mouth open.

These movements originate from stimulation by the food or drink brought into contact with the posterior portions of the tongue and the anterior portions of the fauces. This is greatly asisted by insalivation of the food, as dry food is almost impossible to swallow. The same difficulty in swallowing is experienced when the mouth is kept open. By experiments it has been found that deglutition lasts about 6 seconds; 2 seconds representing the movements of the lower pharynx and esophagus and three seconds the upper pharynx. If the respiratory passages are not closed the food passes into the larynx, producing excitation, resulting in choking, this excitation produces expiratory movements, followed by a cough which drives out the foreign particles.

According to Kronecker and Meltzer soft food is forced through the mylo-hyoid muscles. When the food lies on the surface of the tongue, by the pressure of the tongue against the palate, it is forced back to the back part of the mouth, and prevented from coming forward. At this point under the contraction of the mylo- and the branches of the glossopharyngeal, the food is passed through the pharynx and esophagus. The movements of the hyo-glossal muscles move the tongue back and downward, pressing down the epiglottis over the larynx and pressing the food downward through the larynx to the upper part of the pharynx, reaching the opening into the stomach in 10 of a second.

The deglutition center is higher than the center of respiration, so that when the lower part of the larynx is injured the subject may go on unimpaired. Possibly this center like others, cannot be confined to a small local area but covers the region representing the muscles of the origin of efferent fibers to the muscles of deglutition. The different motor nerves carrying impulses to the muscles of deglutition are the hypo-glottis to the thyro-hyoid, genio-hyoid, hyo- and stylo-glossi muscles and the intrinsic muscles of the tongue, the glossopharyngeal and the
DIGESTIVE PROCESSES.

SECTION VII.—THE DIGESTIVE PROCESSES THAT TAKE PLACE IN THE STOMACH.

The stomach is a large muscular organ located in the upper abdomen, immediately below the diaphragm. Its primary function is the mechanical and chemical breakdown of food into smaller components that can be absorbed by the body. The stomach also produces and secretes gastric juices, which contain enzymes and hydrochloric acid that help in the digestion of food.

The stomach is divided into four anatomical regions: the cardiac, fundus, body, and pyloric regions. It is lined with a mucous membrane that secretes mucus, which protects the stomach from the acidic contents it holds.

The stomach is responsible for several processes:

1. Mechanical breakdown: Food is churned and mixed with gastric juices in a process called gastric motility. This mechanical action helps in the breakdown of food into smaller particles.

2. Chemical digestion: Gastric juices containing hydrochloric acid and pepsin (a digestive enzyme) begin the process of chemical digestion, breaking down proteins in the food.

3. Absorption: Some nutrients, such as water, electrolytes, and some vitamins, are absorbed in the stomach, although most absorption occurs in the small intestine.

4. Secretion: The stomach secretes various substances, including gastric juice, mucus, and hormones like gastrin, which regulates stomach motility.

When food is ingested, it enters the stomach through the esophagus. The stomach wall is composed of inner muscular layers that wrinkle and expand as the stomach fills. This expansion helps in the mechanical breakdown of food. The stomach is also equipped with a pyloric sphincter, which helps control the passage of partially digested food into the small intestine.

In summary, the stomach is a crucial organ in the digestive system, playing a vital role in the mechanical and chemical processes of food breakdown and nutrient absorption.
The action of the sphincter seems to depend on the contents of the bag, driving back into the stomach, the churning and propulsive action into the duodenum, the more solid parts remaining in the stomach for further action of the gastric juice. The food substance is generally converted into the duodenum, the indigestible elements being the last to pass from the stomach. Some indigestible elements do not leave the stomach, causing the disagreeable feeling in the stomach. The presence of the food does not always influence the movements by stimulating the stomach. The movements take place at intervals of 1 or 2 minutes after the food is digested and emptied into the small intestine. The nervous mechanism differs. Thus, the movements in the stomach walls are due to the influence of impulses sent out from the ganglionic centers. Impulses conveyed by them reach the fundus, another movement in the stomach is stimulated, and then the fundus is stimulated, and the stomach is dilated. If the stomach is subjected to a shock produced either by with circular fibers, the wave thus originated passing towards the pyloric end with increasing force. When the wave reaches the parietal region it comes to a stop. Following this there is a contraction of the entire pyloric end which drives the liquid part of the contents through the fundus, an anti-peristaltic wave, being originated that returns the larger solid elements of the stomach. These movements can be seen clearly in the pylorus, accompanied by a strong stimulation of the entire antrum, both circular and longitudinal. These combined phases of movements would keep up a constant motion of the contents of the stomach toward the pyloric end. From this it can be seen that the stomach is largely a reservoir for holding the contents, while the pylorus is the part of the stomach that through its muscles produces the stomach movements. The two parts of the stomach, therefore, have different and independent functions. This is of great advantage to the digestive process, as the large cavity represented by the fundus can hold the food, while gradually the food subjected to digestion is sent down to the intestine through the pylorus. It not only assists digestion but protects the intestines from congestion so that the digestive process is completed.

**Vomiting.** This is intimately connected with these digestive movements that we have just explained and hence, may conveniently be discussed in this part of Physiology. The act of vomiting is due to the direct or indirect stimulation of the center situated in the medulla. It may be produced, 1st. By the stimulation of afferent nerves of the gastric mucous membrane. For example, the introduction into the stomach of some irritant such as mustard, sulphate of copper and undigested food. These substances either act directly upon the mucosa of the stomach or after absorption into the blood by influencing the reflex centers connected with the peristalsis of the stomach. 2d. By substances introduced into the blood and acting upon it or else absorbed into the blood through the skin. For example, the injection of tarter emetic into the blood. 3d. Irritations of other organs affecting the stomach reflexly through the centers of reflex action. For example, tumors in the abdomen, certain conditions of pregnancy, gall stones, etc. 4th. Impressions reaching this center from the higher centers depending upon the psychic action, for example, arising from feelings, emotions, tastes, odors, etc. Sea sickness falls under this head, arising not from the food in the stomach but from a disturbance of the feeling of equilibrium in the bodily system, particularly in the stomach. 5th. Vomiting may arise from the reflex action produced by inflammations. For example, in acute meningitis. From the center in the medulla when it is stimulated a series of complicated efferent impulses pass. Some of these travel along the vagi and cause contraction of the walls of the stomach and the abdominal muscles. There are several characteristic stages of vomiting in the individual.

1st. Nausea. Vomiting is usually preceded by a nauseous feeling accompanied by a saliva flow and the swelling of some air which assists in the opening of the cardiac orifice to prepare for the discharge of the contents. 2d. Accompanying this is a deep inspiration by which the diaphragm is pushed down, the lungs being full of air, the diaphragm forming, thus, a solid base against which the stomach can be compressed. Accompanying this there is a contraction of the lower ribs, and the air does not enter the lungs as the glottis is closed, some air passing into the pharynx.
DIGESTIVE PROCESSES.

THE GASTRIC JUICE.

The gastric juice is easily obtainable for experimental purposes but it is difficult to determine the normal characteristics of the fluid in the stomach. By causing an animal to swallow a sponge the juice can be obtained. The juice is secreted by the pyloric orifice which is located opposite the cardiac orifice. The juice contains hydrochloric acid and pepsin.

When food reaches the stomach it is mixed with the gastric juice which begins as soon as the food enters the stomach. The gastric juice is a thin, clear, colorless fluid with a sour odor and taste, the reaction being distinctly acid, arising from free hydrochloric acid to the extent of about 1.0 to 2.10 percent. It has a specific gravity of about 1.001 to 1.003. On microscopic examination it does not present any well marked characteristics. In the human gastric juice the amount of solid matter is very small, about 0.5. Of this solid matter the greater proportion is found to be salts, especially the chlorides about 2.10 percent, and small quantities of phosphates with small traces of iron. There is always a free acid, hydrochloric acid, together with lactic acid and other acids which are secondary, the result of fermentation changes in the food. There is a small quantity of albumin, some mucin and a ferment pepsin which can be extracted from the gastric mucous membrane by glycine and hydrochloric acid. When dried it is a grayish white powder, slightly soluble in water, and in combination with hydrochloric acid it yields a purple-red color when added to an alkaline solution of hydrated capric acid. In dry powder form it contains 45 percent of water, 45 percent of alcohol, 4.03 percent of glycerin and 4.03 percent of hydrochloric acid. The pepsin is a proteolytic ferment.

The pepsin in the gastric juice contains another ferment which, as it has the power of converting ordinary protein substances into peptones which differ from the ordinary proteins as follows:

1st. The peptones are not coagulated by heat or by alcohol. When boiled no coagulation takes place but the digestive character is destroyed.

2d. They have the power of acting with considerable ease through animal membranes.

3d. They are easily dissolved in water.

4th. Such acids as tannic acid, corrosive sublimate, do not precipitate the solution.

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6th. In cold they yield a purple-red color when added to an alkaline solution of hydrated capric acid. In dry powder form it contains 45 percent of water, 45 percent of alcohol, 4.03 percent of glycerin and 4.03 percent of hydrochloric acid. The pepsin is a proteolytic ferment.

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Artificial digestion may be carried on at a temperature of 35° or 40°C. Be-
calcium chloride; 0.2 acid and 0.12 phosphate of lime, magnesia and iron
other organic matter; 1.46 sodium chloride; 0.55 potassium chloride; 0.6
into the blood to
SfdnS^S
inifoooparts, according to Schmidt 994. 4 parts of water; 3.19 of pepsin and
cholesterin and pepsin. By the use of ether the cholesterin is dissolved and
solution of cholesterin, alcohol and ether produces a precipitate of
nitrate more chlorinewould be found^coZVi^T^Ysilver with the gastric bases. The lactic acid is the
its action. Thenormal temperature is about 35° to 40°C. If the temperature is raised to 70° or 80°C it destroys the
pepsin. It may also be obtained by pouring a 5 percent solution of
of phosphoric acid and later some water on the mucous membrane. Phos-
the cell by a combination with some of the proteids of the secretion, the
the blood of the stomach is divided into small pieces and steeped in alcohol for a day, then
removed from the alcohol and put into a strong glycerine solution in which CO2 will destroy more pepsin than pepsin. If all the
pepsin found in the gastric juice varies according to the
of the digestive process, being smallest about the second hour and greatest
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proposals of this is stated that the para-peptone and the peptones very free-
ly combine with the acid. A more probable explanation is that it arises in
the molecular dissolution and of the chlorides accompanied by the protopla-
matic action of CO2. The liberated base in this case is excreted by
means of the kidneys, the urine acidity being inversely in proportion to that of
the stomach. In the principal cells there is found certain matter which,
under the influence of hydrochloric acid produces pepsin, the albumen being
converted into peptones. Thus the matter inside the cells contains sub-
stances which can produce pepsin, and hence this internal union is
called pepsinogen. This pepsinogenis supposed to be in union with a pro-
etid and it is supposed that the union is broken up by the use of
ether. If both pepsin and pepsinogen are found in the same fluid, a one percent
solution of sodium carbonate will destroy more pepsin than pepsinogen and
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mixed with fluid in connection with the pepsin and hydrochloric acid so as to produce the proper mixture and dilution of the food. 2d. When the peptones are formed during digestion they are absorbed in the blood through the blood vessels together with water, the remnants being eliminated as mucus. 3d. The stomach movements facilitate digestion by introducing the food contents into the different parts of the mucous membrane of the stomach and thus bringing them into contact with the gastric juice. 4th. Albumin will be readily transformed into peptone at 40°C, being stopped below 5°C and above 60°C. 5th. The peptone is quickly destroyed by the action of alkalies, its action being only until the close of the digestive process very slowly traced of the para-peptones are left with a large amount of the peptones. In the process of digestion a number of intermediate substances representing the different stages in the development of the para-peptones are formed, called by Halliburton, proteases, the different substances being albuminous in character. All these albumoses are precipitated by ammonium sulphate. Kühne says that the proteases divide up into anti-peptone and hemi-peptone bodies; the anti-peptone being divided in the pancreas of the pancreatic juice into leucin and tryosin.

To discover the presence of pepsin in a fluid, acetic acid must be first added, filtered. This is then treated with strong hydroxide and a very small quantity of cupric sulphate dilution. There will be a red colored reaction if there is pepson present and a blue colored reaction if there is no pepson present. When the protease is acted upon, according to Kühne it is converted into hydrochloric acid. The protease is thus hydrated under the influence of the hydrochloric acid. Each of these substances changes again under the influence of the second protease, these secondary proteases being the gastric juice ceases, although the peptones may be still further decreased in the presence of the mucus lining of the stomach. All of the stages after the digestion takes place of the peptones into smaller bodies, these representing the proteases and peptones. Formerly the production of is divided following the perimeters the peptones are taken to represent the final products of the process, whereas the influence of the stomach upon the absence of precipitation is supposed that they are formed by hydration an atom of albuminous or a drop of water. In this is proved by introducing acetic acid into the peptone and thus dehydrating the molecules by removing the water and thus converting the peptones into the albuminous. By the action of hydrochloric acid at a temperature of from 40° to 60°C peptones may be produced. If albuminous peptones will also be formed. This production of peptones is slow. Hydrochloric acid may be replaced by lactic acid, phosphoric acid, oxalic acid and succinic acid. The digestive process is influenced, first by gastric secretion which goes on during the entire digestive process, the food being
THE GASTRIC JUICE.

Lessening the amount of hydrogen in the stomach, there is found in the food or air generated in the intestinal organs. The O from the air becomes converted into CO₂ and rich in CO₂. The gastric juice acts differently on food substances. Milk becomes rapidly coagulated, the substances being freed from the milk cells and the casein changed into peptone. The coagulation of milk is produced by the rennin ferment, this ferment being easily destroyed by alkaline solutions. Milk may be coagulated by the addition of gastric juice. If the gastric juice is raised to 60°C or 80,000 parts of milk, it coagulates milk very rapidly. This is due to the presence of an enzyme rennin synzyme, the specific acid produced in the stomach, in the presence of milk, converts milk into casein. When the stomach is dried to 75°C, the product is coagulated protein. The casein is produced by the rennin acid, being converted into peptones. The milk curdles by excess of proteases and peptones. Gelatin is acted upon just as in the case of albumin. In the formation of peptones, the rennin acts upon the peptones and peptones by the rennin. When the gelatin is reached, the peptone is formed. The gastric juice does not act directly upon the carbohy-
digee of the stomach as the acid hydrolysis is very rapid. In this way the stomach becomes complete. This, however, is insufficient, as the acid becomes so great as to destroy the pyloric. Gastric juice does not act upon the invertin, ferments in the stomach, being transformed into dextrin and saccharine, a process that is complete in the intestinal digestion. The temperature is that unhealthy, where much mucus exists, or there is no free action upon the fats. There is no splitting or emulsification of the fats; however, are brought under the influence of a higher temperature, that is sufficient to melt them, so that until the 12th hour, when the digestive action is completed. When the food is digested, the food reaches the stomach, the stomachic movements become ceasing the flow. As digestion progresses, the acidity increases also. By the action of the gastric juice, there is a breaking up of the food so that the soluble proteins are digested into insoluble peptones, proteids, and globulins, which are acted upon by the rennin. This acid chyme consists of dissolved peptones, proteids, particles, fatty particles and small lumps of food substances. When the chyme is sufficiently digested, the food is removed from the stomach. The digestion process is much slower, and the food is not digested into an acid chyme, but is digested by the digestive juices in the small intestine.
pepsin, hydrochloric acid, sugar peptones and para-peptones, the last three varying in quantity. As digestion proceeds the chyme is ejected through the pyloric orifice into the duodenum, the length of time elapsing depending upon the nature of the food, whether solid or liquid, and also upon the nature of the solid food. The normal passage from the stomach to the duodenum in the human subject taking place from 1 to 5 hours after the food is taken, great variation being found in the nature of the change taking place and the length of time necessary for such a change. Some of the peptones formed becomes absorbed without passing into the intestines. In the passage of the food to the stomach considerable quantities of air pass into the stomach. Part of this is driven out in the form of gas, this gas consisting mainly of nitrogen and CO₂, the O₂ being absorbed in the lungs. Some of the CO₂ is diffused from the blood and some arises from the fermentation changes taking place in the stomach and in the intestines.

SECTION IX. Modifications of Digestion.

The question is asked in Physiology: "why does the stomach not digest itself?" The stomach of another animal will be readily digested. If the animal is killed, the stomach, itself, may be subjected, at least partially, to digestion. The stomach of another animal is freely digested in the stomach under the influence of the gastric juice. Some have suggested that the vital principle protects all the living organs, such as the stomach and the small intestines. In the passage of the food to the stomach considerable quantities of air pass into the stomach. Some of the peptones formed becomes absorbed without passing into the intestines. Some of the CO₂ is diffused from the blood and some arises from the fermentation changes taking place in the stomach and in the intestines.

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into the omasum, and another to the esophagus. The omasum has a fine wall with two openings into the reticulum and the true stomach. The mucous lining consists of leaves or flaps folding over into the sac, these being covered round papilae. The true stomach is like the stomach in higher animals with the fundus and pyloric glands. The food when roughly broken up passes down the esophagus into the rumen. Fluids may pass immediately into the omasum; if the amount of fluid is excessive, a part may pass to the reticulum, the free watery fluids thus passing to the reticulum into the omasum. The fluid is mixed with saliva passing into the rumen where the food is moved about and broken up and softened, fermentation taking place. After the complete mixing rumination begins. The action is almost identical with vomiting. The ruminal muscular wall of the rumen and diaphragm also contract with the muscles of the abdomen, retching in the driving of the food into the mouth, the nasal openings being closed. The food now becomes masticated and insalivated after passing down the esophagus, passing into the omasum, the more fluid matter passing most directly into the true stomach, while the rougher elements are passed through a process of filtration among the folds of the omasum. The fluid that is extracted passes into the true stomach, and the solid matters are also driven into the true stomach by the force of the contraction of the walls. In the true stomach digestion proceeds as in the human stomach.

SECTION X. Digestive Processes in the Small Intestine.

The chyme formed in the stomach is carried through the pyloric opening into the small intestine by peristaltic action. These peristaltic movements take place from above downward, the undulation beginning in the pylorus and extending down, although there are contractions originating also in the duodenum. These peristaltic movements take place successively with intervening periods of rest. These movements secure the passage of the chyme along the small intestine and its mixture with the three juices of the pancreas and the intestinal juices which act together in the digestion of the food. The small intestine is arranged in two layers, an inner circular and an outer longitudinal between which and the submucous coating the nerve plexuses. The muscular arrangement is the same as the stomach and therefore the peristalsis is similar. The small intestinal movements consist of regular and successive peristaltic contractions from above downward, the caliber of the intestine being lessened. There is also a contraction longitudinally in the tube so that lengthwise it becomes shorter. When the contractions become violent longitudinally, then the contraction takes place by loops. These contractions are due to the action of the circular fibers and the longitudinal fibers respectively, both acting simultaneously producing within movements. These represent the peristalsis moving about 10 to 12 mm. per second and the peristaltic movements. The peristalsis takes place of the contraction of the intestinal walls beginning at the upper part and extending downward section by section, the portions behind relaxing. This pushes forward, the contents of the intestine. The contraction takes place chiefly, if not altogether in the circular layer. Anti-peristalsis consists of a movement in the opposite direction away from the intestine toward the stomach and gener-
DIGESTIVE PROCESSES IN THE SMALL INTESTINE.

The blood supply of the liver is derived from two sources, the hepatic artery and the portal vein. The hepatic artery is a branch of the celiac artery, and the portal vein is formed by the union of the splenic and superior mesenteric veins. The liver receives a large supply of blood through the portal vein, which brings blood from the stomach, intestines, and spleen. The blood from the hepatic artery supplies the liver with oxygen and nutrients.

The liver is a large, complex organ located in the upper right quadrant of the abdomen. It is the largest gland in the body and is responsible for a wide range of functions, including the production of bile, the breakdown of carbohydrates and fats, and the detoxification of drugs and other substances.

The liver is divided into two main parts, the right and left lobes. The right lobe is the larger of the two and contains most of the liver's functions. The left lobe is smaller and contains some functions, including bile production.

The liver plays a crucial role in digestion by producing bile, which is necessary for the absorption of fats in the small intestine. Bile is produced by the liver and stored in the gallbladder, where it is concentrated and then released into the small intestine when needed.

The liver also plays a key role in the metabolism of carbohydrates, proteins, and fats. It helps regulate the levels of these nutrients in the blood and produces glucose from glycogen when necessary. The liver also produces urea, a waste product of protein metabolism, and helps to detoxify harmful substances.

In summary, the liver is a vital organ that plays a crucial role in the body's digestive and metabolic processes. It is essential for proper nutrition and health and must be protected from injury and disease.
injected into the portal vein the amount of bilirubin is increased in the liver. The form of haematoidin is the same as bilirubin. If solutions of haemoglobin are injected into the portal vein the amount of bilirubin is increased in the liver.

In connection with the blood clotting the bilirubin assumes the crystalline form of haematoidin. The secretion is also affected by the blood flow in the capillaries. If blood is injected into the veins it is increased, and if blood is taken from the arteries it is diminished. If the portal vein is ligatured the secretion will diminish until it ceases altogether. If the circulation is obstructed the secretion increases and then diminishes. While the blood pressure in the capillaries does not cause the secretion the velocity of the blood current through the capillaries has an effect upon the secretion, because the action of the hepatic cells depends upon the circulation of the blood through them. The bile is secreted by the hepatic cells and is not dependent upon the length of time the pressure of the portal vein is less than that of the bile in the ducts. The activity of the cells depends upon amount of blood received into them. If the blood pressure in connection with bile ducts increases beyond 15 mm. of mercury the secretion of bile continues, but its flow is arrested in the ducts, the bile flow taking place into the blood through the lymphatics, the bile pigment giving to the skin the peculiar jaundice color. The same result may follow, from a ligature at the bile duct, in which case the process requires three or four days. Associated with jaundice is a condition of constipation due to the cessation of the bile action, the faces being haggard and yellow colored with an offensive odor. An effect is noticeable upon the activity of the heart, which is much diminished, on account of the lessened activity of the intracardiac mechanisms. The bile enters the bile ducts, and when so formed uniting with the food they originate in the liver. The secretory process becomes slower. The blood corpuscles become dissolved under the action of the bile salts, the pigment being found in the blood and haemoglobin in the skin. The bile by the action of bile takes place in connection with the hepatic cells which are closely related to the blood and bile capillaries. The cells are polygonal in shape, the surfaces by juxtaposition, the spaces between them corresponds with the number of sides, at each of the pointed surfaces being found the blood capillaries. The bile capillaries are much smaller than the bile ducts, and the bile salts in these cells is evident from the fact, 1st, that if the liver is removed the bile acids and the bile pigments are not found in this duct, and 2nd, the bile acids and bile pigments are not found in connection with the body and if they are anywhere else they originate in the liver. The taurin, glycocin and cholalic acids are separated and when so formed unite to form the bile acid.

When the blood corpuscles are disintegrated the haemoglobin is taken to the liver and is converted to the bilirubin, the iron separated being retained in the liver. The iron is used in the formation of new haemoglobin when the bile pigments pass to the duodenum and are mixed with the food. Neither biliverdin nor bilirubin are found in the faces, but a hydro-bilirubin. The biliverdin is used in connection with the disintegration of the haemoglobin. In connection with the blood clotting bilirubin assumes the crystalline form of haematoidin the same as bilirubin. If solutions of haemoglobin are injected into the portal vein the amount of bilirubin is increased in the liver.
THE LIVER AND BILE.

The bile salts in solution have the same effect. This substance when hydrolyzed appears in the faces as stercobilin and in the urine as urobilin. The formation of bile acids takes place in the liver cells. In the bile duct they are secreted. It is difficult to determine from what substances the bilirubin in the taurin indication that some albuminous substance is broken up in which they are formed. Nitrogen found in the gallbladder and urobilin amount to sulfur production. These products, as we have said, are absorbed and again of these acids is possibly to form a stimulus for cell activity. It is supposed that in addition to this the act upon cholesterin, dissolving it for excretion. When the bile is formed in connection with the cells it is performed in a far greater extent. The bile acids and pigments become reabsorbed and hence are of further use in the metabolic process. Its chief digestive function is in connection with the fats. It helps in splitting up the neutral fats and then aids in their emulsification and lastly fat absorption.

SECTION XII. Pancreas and Pancreatic Juice.

The pancreas is an extended narrow gland lying across the abdomen on the back of the stomach and opposite the first lumbar vertebra. The head of it is in contact with the duodenum curve and the lower end is in connection with the spleen. The pancreatic duct extends along the whole pancreas, opening into the duodenum below the pylorus. The secretion consists of cylindrical epithelium, the wall being formed of solid connective tissue from which small branches are ending in the gland acini. The acini consist of solid conical cells. The cell form depends upon its functional action. When digestion begins the disappearance of the granules takes place, the large part of the cell being clear. During inactivity, especially if prolonged, the granular and clear parts are about equal. Blood vessels from the splenic supply the pancreas, together with branches from the superior and inferior branches of the hepatic and the superior mesenteric arteries.

The blood passes off from the pancreas through the spleen and superior mesenteric vessels. Around each acinus is a plexus of capillaries. The nerve supply comes from the solar plexus. The pancreas is associated with the spleen.

The pancreatic juice may be obtained by the introduction of a cannula into the duct. It differs from the other juices mainly in the large proportion of proteids in it. It is a clear, colorless fluid, very viscous, under the influence these soaps aiding in the emulsification of fats. These soaps assist in the fatty emulsification of the fats in the intestines, the bile acids causing the neutral fats to become soaps. The fats readily pass through the mucous membrane of the intestine, hence bile assists the absorption of fats and probably the mucous membrane of the intestine. Bile also stimulates the peristaltic movements of the intestines. If bile is diminished the peristaltic action lessens, and the faces become constipated. A large increase of bile produces diarrhea. The bile is freely putrefied although it lessens the putrefaction of the faces by increasing peristaltic action and thus throwing quickly the putrescent matters out of the intestines. If these matters remaining long putrefaction would follow even though the bile be present. Bile has an important bearing on excretion, by removing the waste products of metabolism such as lecithin and cholesterol. The bile acids and pigments become reabsorbed and hence are of further use in the metabolic process. Its chief digestive function is in connection with the fats. It assists in splitting up the neutral fats and then aids in their emulsification and lastly fat absorption.

If a fistula is introduced so as to extract the bile the faces are found to contain a large quantity of fat. This is due in some way to the action of the bile acids upon the fats or rather upon the epithelial cells so as to make them active in absorption. In addition to this the bile acts as a destroyer of the peptic ferment activity. When the chyme comes into contact with the bile and the pancreatic juice it becomes alkaline, preventing the peptic action and developing the precipitation in connection with the formation of some proteids and acids.
PANCREAS AND PANCREATIC JUICE.

sinogen. By the action of trypsin there are formed the proteoses and the peptones but the process is somewhat different. Solids, under the action of trypsin, do not swell but they erode, the indigestible elements retaining the secondary proteoses, by the hydrolytic process, after which the trans-formation takes place directly from the proteid to the proteoses and the peptones. The protease that cannot be further changed, is called anti-peptone, the balance being hemi-peptone representing the final products of trypsic digestion other than the peptones. It is peculiarly active in alkaline solutions, decomposing the albumen. The trypsin is formed by the decomposition of trypsinogen, as it is not formed in the pancreatic cells. Under the action of trypsin the proteins are changed into tryptones, or hemi-peptones, as they differ from the peptones in various particulars. The fibrin in the pancreatic digestion does not swell, remaining opaque and becoming cloudy being hindered by acidification especially with the mineral acids. If the pancreatic juice is mixed with sodium carbonate to the extent of 1 per cent the digestion is facilitated, playing the same part in this mixture as the hydrochloric acid plays in peptic digestion. If the pancreatic juice is heated to over 40°C and mixed with hydrochloric acid 2-10 per cent, its action is destroyed. The mixture of the bile with the pancreatic juice seems to facilitate its action. By the action of this trypsin fermented peptones, or rather triptones are produced, the great difference being that instead of producing acid-albumin as in the pepsin, there is produced alkali-albumin. Before the final formation of alkali-albumin the fibrin is changed into products that are intermediate between albumin and alkali-albumin. They are readily dissolved in water and by a weak solution of copper sulphate yield in small portion a deep purple red color. The decomposition yields the amido-acids, leucin, tryosin and the odorous substances phenol, skatol and indol. Indol may arise in connection with proteid decomposition under the influence of alkalis at an increased temperature. It is in the alkaline medium that the germs find a field for development under the influence of trypsin. This pancreatic ferment can convert the proteides into peptones unaided by microorganisms.

On the other hand, leucin and tryosin are not obtained without these micro-organisms. Indeed, it is claimed, is produced under the influence not of the organized ferments but by the micro-organisms; the micro-organism being necessary for its production, as in a fluid which yields neither proteid nor albumin. Under the influence of the pancreatic juice, the proteid acted upon yields nearly the proportionate proteid products. When the product of digestion is divided so as to separate the alkali-albumin there is yielded by evaporation crystals of tryosin. If these are taken out and precipitated, leucin and tryosin crystals are deposited. Thus the proteides under the influence of the pancreatic juice are decomposed into two portions, whereas tryosin is a phenol compound closely related to benzoic and hippuric acid. These two represent the fatty acids and aromatic bodies. The fermentation is separated so as to prevent the admixture of air gases or if salicylic acid is used in connection with the juice, the germs are prevented from development and the odor is absent. Thus the pancreatic juice is associated with the fermentation of indol under the influence of an organized ferment. We have seen that three ferments act upon the carbohydrates, proteins and fats, reducing, splitting up or emulsifying them, the emulsification taking place chiefly in connection with the combination of the three juices, although largely under the influence of the alkali-albumin.

SECTION XIII. Intestinal Juice.

This juice, succe entericus, is believed to be secreted by the glands of Brunner and Lieberkuhn. The information regarding this juice is limited chiefly on account of the difficulty of obtaining it pure. By opening the abdomen and a loop of the bowel cut being crossed in double section and the upper end of the bowel above the lower part cut across with the upper end of the intestinal canal is continued, the cut part may be formed into a sac. The Carno-Vella fistula consists in cutting out a small part of the intestine without injuring the blood vessels or nerves, and thus slitting the two open ends to the abdominal wall to form a double fistula. By suture the continuity of the intestine is established, the loop being used to collect the secretion. It is a clear, viscous fluid with a palish yellow color and a strong alkaline reaction. The secretion is small and requires stimulation to start it. It is more plentiful in the lower than in the upper part of the intestine. It is freely coagulated by heat and under acid influence, having a specific gravity of 1.060. It contains a small per centage of solid, chiefly albumin, mucin and with the carbonate of soda from 25 to 35 per cent and sodium chloride. The invertive ferment converts the sugar into a form to which it is not inverted. It is thus described as having a digestive influence over proteids, fats and carbohy-drates. In the small intestine, however, casting doubts as to its conversion. The stomach into dextrose and maltose.

The intestinal juice acts upon all kinds of food, its action, however being slow and feeble. The mucin contained in the fluid acts as a lubricator upon the internal surfaces of the intestine, smoothing it so as to assist the contents to pass freely. As soon as the chyme passes into the intestine, the gastric juice ceases to act upon it, the acidity of the chyme producing the flow of bile, pancreatic and intestinal juices. The alkalinity of these juices neutralizes the acidity of the chyme producing the normal alkalinity in the small intestine. In the small intestine all the food elements become changed so as to be prepared for absorption. The alkalinity in the chyme in those layers close to the intestinal wall, the internal layers being slightly acid. The hydrochloric acid of the gastric juice precipitate pepsin and gliocychrome, the taurocholate precipitating the alkali-albumin not formed by the proteides, the peptones and triptones remaining in the solution. The composition that is formed is thick and glairy. At the upper part of the intestine the chyme is of a pale yellow color due to the bile. At the lower part it is much paler. As it passes down the alkalinity increases on account of the passage of the mixture formed by the bile is dissolved but the pepsin cannot act because of the alkalinity in the solution. The remnants of the stomach are changed to mucus, the fatty substances becoming emulsified and the albuminous substances changed to leucin and tryosin.
INTestinal JUICE.

Tinal secretion has no definite action upon the proteids. The sodium carbonates assist in the emulsifying of fats. In connection with the carbohydrates it has an important action. There is an amyloptic ferment more plentiful in the latter part of the starchy food, as it is broken down into dextrin and converting it into malrose and dextrin. In addition to the presence of the invertins, there is the formation of cane sugar into dextrin and laevulose, and the maltose into dextrose. The double sugars, cane sugar, milk sugar and maltose, which are found commonly in all diets, are acted upon by the inverting ferment so as to form simpler bodies, the absorption taking place finally in connection with dextrose which is the final product of conversion. Gallstones are often formed in the gall bladder, sometimes smaller obstruction being found in the bile passages. The most common kind of gallstone is composed of cholesterol, sometimes with a little pigment, at other times being colored with pigment. These are crystalline in structure. Another kind of gallstone consists of bilirubin and calcium, these being dark in color. Sometimes the gallstones consist of bilirubin and calcium and sometimes of fatty salts. These gallstones originate in a neucleus, the matter being collected around this center. The origin of the stone is found in connection with the bile, the cholesterol or bilirubin collecting upon the latter remaining in solution in fluid. During the progress in these various changes the peristaltic action of the muscular fibers propels the chyme along the course of the intestine, the absorption of the soluble matters taking place in connection with the blood vessels and the mucous projections of the intestine. Thus, the chyme is gradually transformed and diminished, these processes preparing it for passage into the great intestine. Very seldom is there any quantity of chyme in the intestine, as it passes quickly in absorption and excretion.

The chyme as it passes into the intestine comes into contact with the bile and pancreatic juice, changing the acidity into alkalinity. In the human subject the chyme becomes alkaline before passing far down the intestine. The conversion of starch to sugar which was stopped in the stomach begins again under the influence of the pancreatic and intestinal juices and is continued until the sugar proportion is digested in the fats, the neutral fats passing to the lacteals. The bile and pancreatic juice furnish the fatty acid, and the bile dissolves the fats. Thus the juices unite in the small intestine, the gray colored chyme becoming in the small intestine, a cream colored. The pancreatic juice thus assists in the changing of fats for absorption in the lacteals. The bile also assists in this process as the removal of the bile by ligature and fistula seems to retard fat digestion, throwing quantities as it into the faces. The intestinal juice does not possess large emulsifying power. This was shown by a case in which the duodenum opened by a fistula so as to separate the upper and lower parts. Fats placed in the lower part were hardly subjected to digestion, because of the absence of the bile and pancreatic juice, so that fat digestion is largely carried on by the mixture of bile and pancreatic juice. In the intestine there is formed the so-called Maltese cross under the influence of micro-organisms, resulting in indol and indican, so that the action of the combined juices in the intestine is modified by the presence of micro-organisms. It is chiefly in connection with the proteids and carbohydrates that this micro-organic decomposition takes place. From the proteids are formed indol, phenol appearing in the faces and urine. There are also formed in connection with the proteids porphyrins in the process of putrefaction. The principal action of the micro-organisms is in connection with carbohydrates. As the food passes down the intestine there is present lactic acid formed by lactic acid fermentation. This is supposed to take place normally in the intestine. The presence of free H in the intestine indicates fermentation changes. If chyme is taken from the intestine and kept at bodily temperature, CO and H will continue to be formed indicating the butyric fermentation process. In this way the sugar becomes transformed to the fatty acid group and may be changed to fat. The H acts as a reducing agent, acting on the dextrins and reducing sulphides and forming faecal and urine pigments. Thus, in the small intestine proteids are changed to peptones and other substances, starch to sugar, and sugar to lactic acid and fat, these passing into the lacteals or the blood vessels, the remainder being faeces or urine.

SECTION XIV. Processes in the large Intestine and Passages to the Rectum.

By the absorption of the soluble elements from the chyme it is lessened in quantity, passing into the great intestine to be subjected to the fermentations arising from glands similar to those of the small intestine. As in the small intestine there are movements of the intestinal contents due to the peristaltic contraction of the muscular fibers of the intestine. These movements, however, is much slower than in the small intestine as the bowels is not so free, being in the greater part than its extent fixed by the peritoneum. The passage of the contents through the large intestine take a much longer time, than is occupied in the small intestine, although the large intestine is only about 1/6 of the length of the small one. It is estimated that from 12 to 18 hours are occupied in the passage through this large intestine. This length of time includes the long time during which substances continue in the stomach, becoming more solid on account of the water being absorbed.

The sharp ridges projecting into the intestines, divide the intestine into a number of compartments, delaying the passage of the contents. The rectum accumulates the materials, the sphincters preventing the rapid passage. The movements of the large intestine are essentially the same as those of the small, the movements of the large intestine beginning at the rectum and small intestinal movements stop, namely, the ileo-cecal valve. The movements are more simple because of the absence of the loops and the absence of the muscular fibers, to any great extent. The movements in the intestine are caused by the succus along the colon, peristaltic contraction, driving the contents from the one to the other, the contraction of the circular fibers being followed by relaxation of the circular and contraction of the longitudinal fibers in the next succeeding successus. The edges of the ileo-cecal valve close the sacculus so that regurgitation of the small intestine is impossible. When the fecal contents arrive at the sigmoid curvature, they are held by the bladder and sacculus so as to press on the sphincter ani.

The connection with the large intestine is as yet unknown. The excitation of the pneumogastric tends to stimulate, while the excitation of the spinal nerve sympathetics does not stimulate the activity of the large intestine. The process goes on in the large intestine. The contents are of a distinctly fecal character, and are acid in reaction, this being due to the acid fermentation of the intestinal contents and not to any acid secretion yielded by the glands in the intestinal mucous membrane. The secretions of the large intestines is composed largely of mucus, having probably a special enzyme of its own. In passing from the small intestine there are still undigested starches and sugars, these are mixed with the enzymes of the small intestine which probably act for some time. In the large intestine the contents are alkaline toward the walls, the secretion of the intestinal glands being alkaline in reaction, while
toward the middle of the intestine and away from the walls they are acted on. In the human subject the intestinal changes consist of the formation of the waste elements of the food of the bile, and other secretions, of fecal substances. In this connection these waste materials become closely packed together on account of the absence of the peristaltic action. The fermentation going on produces certain acids, lactic acid, butyric acid, and also the generation of certain gases as H₂, sulphured H₂, etc. The water becomes absorbed by the blood vessels. In this way the intestinal contents become more and more solid, the water being absorbed. The putrefaction changes also give rise to the formation of certain acids, such as palmitic acid, together with the odorless substances, phenol, cresol, indol and skatol. The bile that passes down into the large intestine becomes changed into tauroin, glycocin, chloalic acid which, together with the pigments and acids of the bile are found in the faces. These faces have a characteristic color which varies with the individual and at different times. The color arises from the decomposition of the contents of the stools and intestines. Another color may be either acid alkaline or neutral. In the case of dieting upon the carbohydrates and faces become characteristically acid. If the diet is albuminous they become alkaline. The color also varies with the food. The dark color arises in the case of an animal diet. In vegetable diet a lighter color and in a mixed animal and vegetable diet a yellowish brown. In jaundice the faces become a dark yellow. Microscopic examination discloses the presence of indigestible materials including ligments from flesh and cellulose, indigested matter as tissous in fragmentary stages. These tissues vary with the diet. Among the other substances found are mucus, fatty cells, starchy globules, fibers in different stages of decomposition, crystals of the triple phosphates.

There may also be found the acids, pigments, cholesterol, excrccsin and soaps found in connection with the gastric and other juices. In a mixed diet the amount is usually reduced to 25 per cent of water while in diet upon animal food the amount is 50 per cent of water. The normal human subject is estimated to pass about 200 grams daily as faces. This amount, however, depends somewhat upon the nature of the food. In vegetable diet the amount being largely increased through the amount of indigestible matter, such a diet in some cases 1000 grams. In the large intestine, CO₂ is the chief gas found together with H₂, sulphured H₂ and carbonated H₂. In the rectum the faces remain for a variable time. If they are expelled as the result of relaxation of the internal sphincter contraction of the walls of the rectum and of the abdominal muscles assisted by the fixed action of the diaphragm. The pressure of the faces upon the lower part of the lower portion of the rectum is sufficient to cause the stool to pass. The faces are acted upon by the peristaltic action of the large intestine. The faces are acted upon by the peristaltic action of the large intestine.

Processes in the Large Intestine.

The nerve supply to the rectal muscles consists of motor and inhibitory fibers some from the hypogastric plexus and some from the chord of the lumbar region through the sympathetic and parasympathetic fibers from the superior mesentric ganglia and the hypogastric. This, however, is disputed. The parasympathetic fibers being said by some Physiologists to be due to the in-
In the rectal movements we find distinction of the longitudinal and transverse fibers, the longitudinal movements being directed from above downward, causing the shortening of the transverse movements traveling in the same direction, but following the other contractions, causing a narrowing of the rectum and thus pushing onward the material within the rectum. The special changes in the large intestine without bacterial. Bacteria are usually prevented from being active by the strong acid reaction of the juice. In connection with dyspepsia we find, however, certain bacteriological developments in the case of the carbohydrates. In the small intestine the normal alkalinity of the secretion favors such bacteria. It was formerly supposed that the proteid decomposition involved such a bacterial destruction; but recent experiments have indicated that the conditions are different.

The innervation of the large intestine is finer than that of the small intestine, the nervous system supplies and regulates the movements without originating them, while in the rectum the nervous system carries on the rectal movements and reflex action. In diseases of the central nervous system it is here that constipation is produced, the fecal contents accumulating in the sigmoid flexures and the considerable addition to the rectum by the food contents in the intestines the deficient oxygenation of the blood in the alimentary walls arouses peristaltic action. If the blood is interfered with by clamping the aorta, the special changes in the large intestine is, the interference with respiration produces a discharge of faeces. Thus the absence of blood or deficiency of oxygenation stimulates peristalsis.

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**SECTION XV.** 4—Absorption.

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Absorption.

The mucous lining of the small intestine is covered over with small cylindrical projections of the mucous membrane, very numerous in the human subject being said to number four million. These form conical or cylindrical processes, projecting about 1 mm. out from the mucous lining. This absorption occurs to a slight extent in the mouth becoming more rapid in the stomach and is greatest in the small intestine, being less active in the large intestine. The blood.—The mucous lining of the stomach and the intestines is abundantly provided with blood vessels lying directly underneath the epithelial lining. In the small intestine the capillary plexuses exist in the form of loops changed into the villi while in the large intestine the network of capillaries is regular. These capillaries are normally filled with blood slowly moving and exerting a pressure on the internal surface, separated by the vessel walls, connective tissues and epithelium which contains the soluble food matters. In this way, by the close connection of the blood and the solution containing certain substances we find results in the proportional movement into the blood, of water, salts and peptones and the fats being emulsified so as to be minutely divided.

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villi becoming lacteal, the villus being abundantly supplied with blood vessels. On the internal surface of the villus there is a delicate covering of epithelium constituting a lymphatic vessel. Between this vessels, called lacteal, and the cells that bear them is where a rich blood supply during absorption takes place. These cells be fat substances fat particles are found in these epithelial cells or at the cell membrane and the lymph spaces, in the center of the villus or in the lacteal. Some Physiologists suppose that they are driven through the cell or between that the filament by protoplasmic action absorb the fat and pass through the cell flaments, these filaments being emptied of their fatty contents by a series of sucking movements.

During these amoeboid movements have been noticed in these processes. When the villus empties the blood out of the villus and pushes forward the large lymphatic vessels between the neighboring vili and the lymphatic vessels. When the contractile of this the dilatation of the villus is the relaxing lymph spaces. There is no regular substances left in the cells will be attracted into the lacteals. As soon as these fatty substances reach these filaments the contraction of the muscle fibers substances will cause a large lymphatic vessel, and the lymphatic vessels in the bed of connective tissue until after passing through the larger lymphatics they are all united with the two main lymphatic ducts the thoracic duct and the right lymphatic duct opening into the junction of the subclavian and jugular vein on the left and right sides. As the lymph moves gradually from the lymph spaces to the venous circulation it is changed somewhat under the influence of the glands and the lymphatic vessels. The lymph differs in the various organs in which it arises but the chief variation is found in the lymph arising in connection with the alimentary canal called the chyle. When digestion is not going on the fluid formed is the normal lymph. During digestion it possesses certain peculiar properties. During the digestive process, particularly if fatty substances have been taken in connection with a meal the lymph becomes yellow by the mesenteric lymphatics called the lacteals. If the food has no fat the fluid is clear and slightly yellow with no distinction from the lymph. The mesenteric lacteals unite in the formation of larger vessels which pass into the mesenteric lymphatic glands. As the vessels pass out of these glands they form the lymphatic trunk with a dilated portion called the receptaculum chyli, passing thence to the thoracic duct, into this duct also pass lymphatics from the pelvic organs and the extremities of the body. This main thoracic duct after penetrating the diaphragm in the thoracic cavity unites with the venous system at the junction of the left subclavian and left internal jugular vein. This fluid passes into the thoracic duct called the lacteals. If the food has no fat the fluid is clear and slightly yellow with no distinction from the lymph. The mesenteric lacteals unite in the formation of larger vessels which pass into the mesenteric lymphatic glands. As the vessels pass out of these glands they form the lymphatic trunk with a dilated portion called the receptaculum chyli, passing thence to the thoracic duct, into this duct also pass lymphatics from the pelvic organs and the extremities of the body. This main thoracic duct after penetrating the diaphragm in the thoracic cavity unites with the venous system at the junction of the left subclavian and left internal jugular vein. This fluid passes into the thoracic duct called the lacteals. If the food has no fat the fluid is clear and slightly yellow with no distinction from the lymph. The mesenteric lacteals unite in the formation of larger vessels which pass into the mesenteric lymphatic glands. As the vessels pass out of these glands they form the lymphatic trunk with a dilated portion called the receptaculum chyli, passing thence to the thoracic duct, into this duct also pass lymphatics from the pelvic organs and the extremities of the body. This main thoracic duct after penetrating the diaphragm in the thoracic cavity unites with the venous system at the junction of the left subclavian and left internal jugular vein. This fluid passes into the thoracic duct called the lacteals. If the food has no fat the fluid is clear and slightly yellow with no distinction from the lymph. The mesenteric lacteals unite in the formation of larger vessels which pass into the mesenteric lymphatic glands. As the vessels pass out of these glands they form the lymphatic trunk with a dilated portion called the receptaculum chyli, passing thence to the thoracic duct, into this duct also pass lymphatics from the pelvic organs and the extremities of the body. This main thoracic duct after penetrating the diaphragm in the thoracic cavity unites with the venous system at the junction of the left subclavian and left internal jugular vein. This fluid passes into the thoracic duct called the lacteals. If the food has no fat the fluid is clear and slightly yellow with no distinction from the lymph. The mesenteric lacteals unite in the formation of larger vessels which pass into the mesenteric lymphatic glands. As the vessels pass out of these glands they form the lymphatic trunk with a dilated portion called the receptaculum chyli, passing thence to the thoracic duct, into this duct also pass lymphatics from the pelvic organs and the extremities of the body.
ABSORPTION.

The stomach and removed after digestion so as to observe the changes that take place. It has been found that water, when introduced alone into the stomach, is not absorbed. So soon as the food alone enters the stomach it passes to the intestine almost entirely, none or almost none being absorbed. In the case of alcohol, on the other hand, there is found free absorption, as for example, sodium iodide is absorbed very slowly until the use of mustard or alcohol which produces stimulation of the mucous lining. The different forms of sugar are absorbed in the stomach. The absorption being more marked when the solutions are introduced. The absorption of the sugars and peptones does not take place readily. There is no digestion of fats in the stomach. Stimulation of the mucous lining must precede digestion and this takes place in the small intestine.

The Small Intestine.—It is here that the sugar and peptones are immediately absorbed. When the partly digested food products reach the upper part of the duodenum they are acted on by the juices. These juices act very strongly on the proteins, carbohydrates and fats and the digestive processes take considerable time, the act of digestion cannot be very complete. It is estimated that not less than two hours is occupied in the digestion in the small intestine and this may vary to six hours, much longer time being necessary before it is all passed out of the small into the large intestine. During this process conversion has taken place into soluble form and brought into contact with the mucous membrane which has a large number of villi and also folding values. Experiments have proved the rapid absorption of sugar, peptones and salt solutions, it being estimated that 85 to 90 percent of the protein matter is absorbed during the passage through the small intestine. Water and Salts are also freely absorbed, a large part of the water and salts being used in connection with secretions and the maintenance of the fluid condition of the chyme.

The Large Intestine.—Absorption takes place freely in the large intestine. The passage of the contents takes place very slowly from 10 to 12 hours being occupied in the passage through the intestine during which time the food is from the semi-fluid to the solid consistency as faeces. When entering the large intestine there is usually a small proportion of sugar, proteins and fats. Part of these is decomposed in connection with bacterial action. A part of it is being absorbed even before the commencement of digestion. The absorbing power of the large intestine is indicated by the use of enemata, large quantities of distilled water and other fluids being readily and rapidly absorbed. Even soluble proteins may be absorbed, however, in other ways. For example, proteid dissolved, such as egg or muscle introduced into the rectum will be readily absorbed without any digestive action. In the peptide digestion system is formed and in all probability it is directly absorbed as such, but the large proportion of the converted substances are changed to
peptone. This absorption takes place not simply by dialysis as the albumin of egg that is non-dialyzable becomes readily absorbed in the intestine. Its rapidity also makes it impossible that the process should be simply this peptone. They are then passed directly to the blood, but if the lymph absorption takes place directly to the blood, there does not seem to be any of the lymph vessel is emptied of its contents. By estimating the amount of fat taken in to the blood capillaries keeping up a constant stream of lymph through the villi to the lacteal. By this means the amount of fat taken in a meal and the amount found in the faeces as well as the amount found in the lymph. The inference is that the lymph duct is emptied of its contents into the portal circulation, as there is a quantity of fat filtered through the portal blood during digestion. A large proportion of the fat however passes through the lacteal system. **WATER AND SALT ABSORPTION**—Only a very slight absorption of water takes place in the stomach. Along with the peptones, sugar and salts there is an absorption of water. In the small intestine there is a free absorption of water and salts. Heidenhain has proved that the absorption of water and salts in the small intestine takes place in connection with the blood vessels and not through the lacteals unless there is a large quantity of water in the blood. When the lacteals absorb some of it. In the large intestine the water is absorbed in connection with the blood, the epithelial cells attracting the water into them and then giving them off into the blood. The fats are emulsified by the bile and the pancreatic juice in the intestine, the soaps formed, aiding in the emulsification. The emulsified fats enter by the columnar cells in the villi. The margin of the cell is thought to be active in the entrance of the fat, the leucocyte being active possibly in amoeboid movements. The bile is supposed to assist the passage of the fat particles by breaking the fat more closely together and acting upon the cell substance. The bile enters the chyle from passing to the blood and if the animal is fed on proteid the urea increase will still be observed. This indicates that the soluble proteids do not pass into the chyle but into the blood.

**SUGAR ABSORPTION**—The absorption of the carbohydrates takes place largely in the form of sugar and dextrin. As the intestinal juice sugar is changed in the duodenum to dextrose and lactose. Milk sugar is converted to sorbitol takes place. The sugar found in the blood is the dextrose and lactose. The sugar excreted in the urine is not the sugar excreted in the urine, while dextrose so injected will disappear. The absorption not being directly proportional to the diffusability. Absorption increases with the increase in the maximum of simple diffusion. Hence, it is supposed to be similar to proteid absorption in the blood. If there is a large quantity of sugar in the blood, absorption takes place also into the chyle, the water passing to the lacteal and carrying the sugar with it. In the passage into the large lymph capillary terminating and the lacteal. These fat particles pass from the epithelium cells to the lacteal and thence to the lymphatic system. Thus, the fat passes largely if not altogether into the lacteal system, the adenoid tissue containing a number of minute lymph canals in connection with the lacteal system. The lacteals are supplied by the blood capillaries keeping up a constant stream of lymph through the villi to the lacteal. By estimating the amount of fat taken in a meal and the amount found in the faeces as well as the amount found in the lacteal duct it is estimated that 60 parts out of every 100 parts of fat which leave the alimentary canal pass into the thoracic duct and into the venous system. The question is, what becomes of the balance? Some say that it passes into the portal circulation, as there is a quantity of fat filtered through the portal blood during digestion. This seems to be the case.

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empty the lacteal. By relaxing the villi is lengthened and the lacteal opens to be again filled. According to others, the contraction of the fibers and the shortening of the villus makes the villus broader, and thus permits the lacteal to be filled; whereas, the relaxation lengthens the villus and shortens the lacteal, thus emptying the lacteal. During the digestive process these contractions and relaxations are going on so that there is a constant process of emptying and filling the lacteals. By the contraction of these muscles fibers in the villus compression is brought to bear on the columnar cells. While on relaxation of the muscular fibers the cells will also relax, these muscular contractions and relaxations assisting in the passage of materials from the intestine into the cells. In the case of water passing into the lacteal which as distinguished from the fats are, diffusible, including water, salt, and sugar, which is passed to the lymphatics, there is absorption into the blood vessels rather than into the lacteals. During the digestive process the blood vessels are filled, there is a transudation of fluid from these vessels into the reticular cavity and the lacteals and a similar transudation from the external surfaces of these capillary pipes. Passing through the epithelial cells of the reticular cavity, the diffusible substances are diffused through the vessels walls the diffusion taking place in two stages.

1. From the intestine to the spaces passing through the epithelium cells and ad, from the lymph spaces to the capillary spaces. These substances including peptones pass slowly, the diffusion taking place on the principles of physical osmosis subject to the Physiological structure of the membrane separating the fluids. The rapidity of this diffusion can be determined by placing solutions of these substances in the intestinal loop and carefully watching the process of diffusion. The diffusion will take place at different rates depending on the substances and the condition of the membrane.

2. Absorption by means of the other organs of the body.

Absorption takes place in connection with (a) the skin. Absorption by the skin takes place in connection with gases and to some extent fluids and semi-fluids and solids. By the absorption of gases like sulphuretted hydrogen through the skin after every other passage is closed, the animal may be poisoned. In the case of liquids it seems almost impossible that fluids should be able to make their way through the epidermis and the fatty coating of the outer surface. In addition to the strong coating the pressure is always very strong from the internal surface. This, however, does not prevent the demonstration of the passage of water and even of fatty and oily matter through these surfaces, particularly if associated with mechanical stimulation. Mercurial solutions by external massage may be introduced into the skin to enter freely into the tissues from which diffusion will take place. These substances pass through and into the ducts of the sebaceous layer upon the surface, being absorbed into the vessels found in connection with these glands. It is also possible for certain solid substances in solution to be absorbed into this way, as in the case of saline substances. Any of the mucous surfaces by which such substances are applied will freely absorb them, as the rectum and urethra. The vapor arising from a bath, as for example, in today of barium baths may be absorbed in the skin in this way, the substances appearing very soon in the urine. Alcohol, ether and turpentine may also be freely absorbed by rubbing on the skin.

Absorption—The Serous surfaces represent a large tissue or lymph spaces and their stoma communicate with the lymphatic ves-

absors. During inflammatory stages there is an accumulation of fluid in connection with these serous surfaces such as the peritoneum or pleura, the fluids being absorbed. The absorption of these fluids take place readily with the openings at the margins of the lining cells. The fluid that is found in connection with these serous membranes is very similar to the lymph. It is alkaline in reaction, containing about 4 or 5 per cent of solid matter.

(c) Pulmonary Absorption—In the lining membrane of the air ves-

icles the absorption of gases takes place very readily. Also fluids are absorbed, although not so freely. For example, water passing into the passages and the air cells may be absorbed without any detriment if not excessive in quantities. In the case of persons engaged in certain occupa-

tions small particles of foreign substances may be found in the lungs having been breathed into the lungs and absorbed by or in connection with the delicate cells lining the surfaces of the air cells.

d) The Tissues in General—From the blood nutrient matters are con-

stantly passing out into the tissues and the amount of this matter is always in excess of the tissue requirements. In addition the injection of solutions underneath the skin brings these solutions into close relation with the connective tissue, these solutions being absorbed and passed into the system. This fact lies at the basis of the hypodermic method of subcutaneous injection of medicines. In addition the constant activity of the tissue corpuscles leads to the formation of waste matters and these together with the excess of nutrient matters lie in the tissue spaces from which they are carried off partly by the blood vessels and partly by a special set of vessels communicating with the tissue spaces, the lymphatic capillaries by which they are carried into the general lymphatic circulation.

CHAPTER VI—SECRETION AND EXCRETION.
accompanies the terminal parts end in the tubular or sacular form. In these compound glands it is only in the terminal parts that secretion takes place, all other glands being avellot or acinar, the committing parts being called the ducts, the lining membrane of these ducts having no secretory action. The gland secretions are as different as the structures in which the secretions take place. In general these secretions other than the reproductive secretions are fluid or semifluid, being composed of water, salts and other organic substances. The organic elements differ in the various glands representing the elements which are peculiar to the gland, being formed in connection with gland activity. In other cases the organic elements are found in the blood, the glands simply secreting these elements from the blood so as to be eliminated, as the urea of urine. These last are the excretions of the body, excretion being the process of the elimination of waste matters from the body such as would be disadvantageous to the system if retained. Thus excretion does not refer to any secretion taking place within the body. Some elements being derived from different secretions as in the case of urine of which urea and uric acid are formed in some of the organs, the water and salts being derived from the blood. Similarly, the bile represents an excretion carrying away some waste matters while it is also a secretion containing valuable elements in the digestive action. Excretion, therefore, represents the carrying off of the waste of the body organs or certain parts of some of the secretions which constitute the excretions.

No general theory of secretion can be formulated, because the formation of secretion varies in the different glands. Up to date, however, it is assumed that each gland has its own peculiar form of secretion. Formerly it was supposed by Physiologists that secretion was accomplished by filtration, diffusion and imbibition, the epithelium being supposed to form with the epithelium, the membrane through which filtration and diffusion take place. The differences in the secretions depend upon the differences in the epithelial and the chemical action of the membrane. In this case the epithelial cells were supposed to be inactive and the metabolism of the cells was supposed to be of importance in connection with the secretion. Later in other times, emphasis was laid upon the living membrane. The theory of secretion was brought to the fore again by the microscopic examination of the glandular secretions, and it is now generally admitted that some cells being broken down, the secretions form as in the case of the sebaceous glands. In the case of the stomach, for example, this is an expulsion of part of the mucous from the cells to form the secretion. In the mammary glands the cell substance is broken up and in other glands the material of the substance takes place in the cells in the form of granules which, when the fluid is passed through the cells from the blood or lymph become dissolved. The substance of the gland cells passes through the secretion and represents the metabolic process of the gland. The variations in the secretions are easily explained on this basis as depending upon the metabolism of the different gland cells. In addition to this the existence of nerves connected with these gland cells, the stimulation of which produces secretion is a confirmatory proof of this theory of the cell activity.

Ludwig first pointed out that stimulation of the chorda tympani increased the secretion of the submaxillary gland. Similar nerve fibers have been found in connection with the sweat glands, stomach glands, pancre-
A similar increase in organic matter takes place if the gland has been previously resting, but this very soon stops, the continued stimulation producing a decrease after this point rather than an increase in the solid matter. If the gland, however, has been continually working although the water and salts increase, the organic matter will not increase upon stimulation. These experiments, as led Heidenhain to distinguish between the production of water and salts and the production of organic matters, a distinction he has explained by his theory of the secretory and trophic fibers. According to this theory there are two sets of fibers to the salivary glands, the one regulating the water and salt supply called the secretory and the other producing organic matters in connection with cell metabolism, and hence, called trophic. In the case of the parotid gland, the sympathetic fibers are trophic or almost all trophic, while the cerebro-spinal fibers represent both the trophic and secretory. In the submaxillary gland, the sympathetic fibers are trophic or almost all trophic while the cerebro-spinal fibers represent the secretory or prevalingly so. There may be variations in the individual fibers in the case of particular animals. This may be due to the fact that there is a combination of the two kinds of fibers in the one system. The fibers are supposed to act by setting up metabolic processes in the cells resulting in the formation of certain substances like mucin. That these changes do take place has been demonstrated by microscopic examination. These processes represent the breaking up of complex matters and the formation of simpler substances found in the secretion. Side by side with the katabolism we find anabolic changes forming new materials from the blood supplies furnished to the cells, although the katabolic changes are more prominent, being under the influence of the trophic fibers. The action of the secretory fibers is obscure although it is supposed that the quantity of water is regulated by the gland activity. This gland activity attracting to the gland cells water from the blood, the water being absorbed during the resting condition of the gland from the membrane which collects the fluid from the lymph in turn being supplied from the blood. As the water in the cell increases there is a point reached when the equilibrium is established after which no more water is passed. By the action of the secretory fibers the water is passed. The process of filtration is materially assisted, the water passing from the cell into the lumen of the tubule. Ranvier has pointed out that during secretion there is the formation of minute vacuoles in the substance of the cell these being filled with water. During the activity of the glands there are very marked changes in the cells both of the mucous and serous glands. In the parotid gland during rest the cells are large, solidly filled with granules, the nucleus being small. After the stimulation of the sympathetics the cells become smaller, the granules more closely compacted, and the nucleus more regular in size and round. The granules are beaded, the granules being arranged in two layers, the outer and inner, the latter being more dense. By increased stimulation the granules are decreased and are collected around the margin, the increase of stimulation resulting in the breaking up of the granules during the resting condition, the ptyalin formation taking place during activity. During activity these granules change and are removed from the cells and new substances are built up out of the materials derived from the blood and lymph, representing the nongranular matter. During the resting of the cell there is formed new granular matter. In the mucous cells we find during rest the cells large and clear with flat nuclei toward the cell base. During activity the nuclei are rounded and approach the center of the cell, the cells being smaller. By prolonged activity the cells become still smaller, some of them being broken up and their places being never filled by new granules appear from 100 to 200 in every cell, the granules being composed of mucin or something from which mucin is formed. As smaller, the granules being used in the formation of the secretion. There are thus two processes in the act of secretion, the process of water diffusion from the blood including salts and the production of the organic constituents of the saliva in connection with cell metabolism.

These constitutions when formed in the cells are washed out into the ducts by the water from the blood. If small quantities of atropine are injected into the blood or into the duct of the gland, the activity of the cerebro-spinal fibers, is suspended on account of the paralysis of the fiber ending these fibers produce secretion. On the other hand, if pilocarpin is injected into the blood, or the gland ducts the secretory fiber endings stimulate a different effect, stopping the action of the secretory fibers by producing paralysis of the cells in the ganglia, through which the fibers pass to the gland cells. If the chorda tympani is divided after a few days, the secretion time until the gland becomes atrophied. This is called the paralytic secretion, the secretion on the side opposite to the one divided, being called anti-paralytic by Langley. He explains the phenomena as due to the action of the excessively venous blood the continuous secretion.

Anabolic fibers of the gland are inhibitory of the katabolic fibers, the gland cell is handshake over to the continuous action of the secretory fibers, producing a continuous secretion until the sensory fibers, the gl Morocco-pharyngeal and lingual nerves, of the mucous and transmitted by the effenter fibers along the chorda tympani or the sympathetic nerve to the glands by reflex action. If the chorda is divided the reflex action of the saliva a reflex action there would normally take place with the saliva, and it has been located in the medulla not far from the vasomotor center. If the medulla is destroyed no salival flow can be produced. The direct irritation of the saliva can be stimulated through the vagi, the sciatic or the splanchic nerves, as well as through the psychic centers as in the case of nausea, coughing, menstruation and other similar processes. It is under the influence of the higher centers as in the case of emotion, fear or fright.

**SECTION III. Pancreatic Secretion.**

The pancreas in the human subject is found behind the stomach in the abdominal cavity. It is found to be a long narrow gland, its upper end
PANCREATIC SECRETION.

The pancreas is one of the compound tubular glands, the alveolar cells being secretory, the outer part of the cell being composed of non-granular substances, the inner part toward the cavity being granular. In addition to the secretory products out of which certain substances which fill the cell so that during secretion these are discharged from the cell and unite with the water for forming the secretion. It is supposed that the pancreatic ferments are taken from the granules of the cells, the granules containing the zymogen from which the ferment is formed. If the gland is taken from a dog that has been fasting and the gland is prepared with glycerin there is almost no ferment found in it. If the gland is kept heated about 35°C and then afterwards one day is prepared in glycerine the extract of glycerine will exhibit strong fermentative action. This indicates that the pancreatic secretion is due to the action of certain ferments which we have found to be present in the gland.

The secretory fibres are formed in connection with the granular matter, the granules being formed inside the cell. The action of the cell is to secrete a fluid in which the ferments are dissolved, the fluid being then discharged from the cell and united with the water for forming the secretion. This indicates that the pancreatic secretion is caused by certain ferments which are formed within the cell and discharged from it.

The secretion of the pancreas is closely connected with the digestive action. As soon as the food enters the stomach there is a flow of the secretion which increases until it reaches its maximum. Afterward it gradually diminishes until the fourth or fifth hour and then increases again until the sixth or seventh hour after which it gradually diminishes. These estimates have been made in connection with the dog and would require modification in application to the human subject, depending closely on the variation in the time of meals. In human beings and lower animals the beginning of the secretion seems to be almost simultaneous with the beginning of digestion in the stomach. This indicates that pancreas secretion is aroused by the stimulation upon the mucous membrane of the stomach, the action taking place reflexly. In some animals it has been found that by the use of condiments like pepper or mustard introduced into the stomach and intestine the pancreatic secretion is greatly increased. It has been found that acids have a stimulating action while alkalies have the opposite effect. The acidity of the gastric juice is probably the chief ferment in the origin of the pancreatic secretion. The action probably takes place by stimulation of the sensory fibers of the mucous membrane. The nerves of the pancreas come from the solar plexus of the sympathetic system, from which come the secretory fibers. If the gland is active secretion will be arrested by the stimulation of the central end of the vagus. This effect follows from the stimulation of the sympathetic system indicating the inhibition of the center in the medulla. The medulla is stimulated by some that even after cutting off all nerve connection the gland will continue to secrete. The effect of the vagus on the pancreas during secretion is very much analogous to the action of the salivary glands.

SECTION IV.--Gastric Secretion.

The gastric glands are simple tubular glands which possess no system of ducts such as are found in the compound glands. There is a large opening in each gland, the opening being lined by the epithelium of the columnar type. The longer part is narrower and forms the secreting portion, being lined with cells of the cuboidal type. The pyloric glands differ from the fundic glands,
having only one kind of secreting cell while the fundic glands have two kinds of cells. In the fundic glands the lining is of cylindrical epithelial cells which Heidenhain calls the principal cells. It is in these cells that pepsin is formed. There are also oval cells lying close to the basement membrane, and not ex- tending as far as the cavity of the gland. These are called marginal cells, some- times giving rise to fusiform cells because of the formation of the acid of the gastric juice in these cells. These cells are spoken of as undeveloped cells of the principal type. It seems that they are cells of a peculiar kind, having a special function of their own. In these cells it is found that there exist often a number of nuclei, as many as five or six. In the cells are also found vacuas which de- velop, after the beginning of digestion becoming larger, and then after becoming smaller gradually disappear. This seems to be connected with the forma- tion of the secretion. The duct of the gastric gland is not continuous from beginning to end, it is not lined with a single lining cell, and it is not closed at the oral end. The cells have direct communication with the central cavity, the mucus cells being the only cells in the gland which are distinct from the central cells. In the secretion of the glands upon the mucous membrane we find the gland cells mixed with mucus derived from the cells upon the surface of the mucous membrane. In this secretion there is a high water content, the mucus and the salts, there is the hydrochloric acid and the ferments pepsin and rennin. According to Heidenhain the secre- tion of pepsin takes place in the pyloric end. The pyloric end was, by him, made in a separate sac and bound to the abdominal walls so as to be separated from the rest of the stomach, so that the secretion of the pyloric end was ob- tained free from the secretion of any other part of the gland. This forms the negative proof which Heidenhain finds for the secretion of the hydrochloric acid in the marginal cells of the fundic glands, the pepsin being formed in the pyloric end where principal cells only are found. Some have denied this be- cause they have found the character of the solution found in the pyloric end they say is that of a non-acid. The marginal cells, the mucus cells, the stimu- lation of the vagi and the sympathetic nerves give no positive results, and their division does not retard or arrest the secretion. In cases reported, the sight of food, in the case of starving animals, and in a case reported in which the whole closure of the esophagus produced a flow of gastric juice, there is an indication that impulses are sent down from the higher centers. In the usual case the chewing of food in the mouth, although no swallowing could take place produced a flow of secretion indicating the reflex stimulation in connection with the mucous membrane of the mouth. By making two fistulous openings, one in the upper part of the esophagus and one in the stomach so that food masticated and passed to the esophagus, passed out at the posterior opening, the masticatory and insalivation processes produced the flow of gastric juice is no longer any gastric secretion, indicating that by the passage of impulses through the vagi, the first secretion was produced. In confirmation of this it was proved that stimulation of the vagi resulted in the increase of the secretion. The secretion is increased after a long latent period. From it is concluded that there are secretory fibers from the vagi to the glands of the stomach, these fibers receiving impulses reflexly from the stimulation of the sensory nerves of the mucous membrane of the mouth. Heidenhain removed a portion of the fundus making it into a blind pouch, attaching one end to the abdominal wall in order to form a fistula. The cut part were stitched together so that the stomach remained continuous, the fundic pouch being entirely cut off from the alimentary canal. When food was digested there was found a secretion in this pouch, the secretion beginning shortly after the food had passed through the stomach. By the swallowing of water a similar secretion took place although indigestible matters did not produce any such secretion. The secretion, therefore, depends upon the stimulation of the food and is limited to the pouches where the stimulation takes place. Following this initial secretion there is a secondary secretion which takes place when absorption begins in the stomach. This secretion in the isolated pouch was found to belong to the sec- ondary secretion, the stimulation arising in connection with the absorbed prod- ucts of the food in the stomach, acting either upon the glands or the stomach or upon the fundus of the stomach. These experiments have been repeated by recent physiologists, preserving the nerve connection intact with direct results.

The activity of different kinds of food upon the secretion and its acidity have been studied. During inactivity the gastric mucous membrane is of a pale color not moistened, covered with mucus and in flapping condition. In activity it becomes red and moist, the folds disappear, and the water is found at the openings of the glands. If active secretion takes place the blood flow is rapid, the blood being color in color that vascular dilatation accompanies the gastric secretion. As the food is brought into close contact with the mucous membrane, it is probable that the secretion takes place under the influ- ence of local stimulation. This is proved by the application of stimulation to a particular part when the secretion takes place at that point. The secretion is found to begin almost immediately after the taking of food, increasing rapidly until it reaches the maximum about the second hour, after which the flow decreases. With the increase of the flow there is an increase in the acidity, fol- lowed by the decrease in the amount of the secretion. The action of digestion becomes very decided after the second hour. It has been found that the great- est digestion takes place in the vagi and the sympathetic nerves. One variety of a mixed diet, especially if it consists of animal meat, causes the secretory glands to become very red, the blood vessels opened by the administration of acids, alkalies and neutral waters indicated an increase in the gastric secretion. The most important stimulation of the gastric secretion occurred in connection with the pep- tones, producing a large secretion of the gastric juice. It is supposed that the water and peptones directly stimulate the sensory nerve fibers in the mucous membrane, reflexly affecting the secreting glands by the efferent fibers. Thus, the normal secretion takes place on the basis of nerve stimulation, constituting a secretion. The posterior nerve is distributed in the posterior part of the stomach. The majority of the fibers pass to the solar plexus. These vagi branches are almost all non-medullated, only a few being medullated. The posterior nerve fibers pass with the collateral artery from branches to the stomach. The fibers from the solar plexus and the stomach are non-medullated. These nerve fibers all lie beneath the peritoneum, passing inward with the arteries to form a plexus between the longitudinal and circular coats, and another plexus in the submucous coat. It is from this plexus that the fibers pass to the mucous coat.
HEPATIC SECRETION.

The bile capillaries have direct connection with the cells by means of fine ducts. Much discussion has arisen in regard to the relation of the hepatic cells to the epithelial lining of the bile ducts and the question of the existence of a distinct wall in the bile capillaries. The majority believe that there is no distinct membranous wall in the bile capillaries, these representing simply the spaces between the cells, forming canals along which the bile passes. At the place where the capillaries unite with the ducts the hepatic cells unite with the epithelial lining of the ducts forming a continuous membrane. These hepatic cells are the secretory cells. Several physiologists have traced nerve fibres to these cells, indicating that the cell activity is controlled by the nerves connection.

Some recent experiments have pointed out the terminations of the nerve fibres where the capillaries meet the cells without entering into the cell substance. The bile is a composite secretion of a reddish brown color in the human subject. In addition to the pigments salts, acids and nucleo albumin there is a large proportion of CO₂, loosely combined with the secretion, indicating the great changes that take place in connection with the metabolic processes in the liver. The amount of bile secreted daily can be estimated by means of a canula establishing connection with the bile duct or the gall bladder. It is estimated from 700 to 800 CC daily, or 10 to 14 CC per kilogramme of body weight. The bile must be secreted continuously, the secretion being stored in the gall bladder so as to be thrown out into the duodenum as occasion requires in the digestive process. Its movement from the liver into the alimentary canal is not continuous but intermittent, the excretion taking place in jets like the flow of blood from an artery, this being due to the contractions of the muscular coats of the large ducts. Thus, while the secretion is continuous the excretion is intermittent.

The secretory activity is closely connected with digestive action. In the case of dogs it has been observed that the secretion becomes much more rapid three or four hours after the beginning of the digestive process, a diminution taking place, followed by another increase toward the ninth or tenth hour. It is said that the relation between the secretion and the condition of the bile depends upon reflex action, some believing that it depends upon the increase in the supply of blood to the liver. If bile is present in the blood it stimulates the activity of the hepatic cells. From this some have concluded that by the absorption of substances from the bile into the intestine the secretion is increased. There seems to be a variation in the bile depending upon the nature of the food, the secretion being greatest where an animal food is used and less when the diet consists largely of fats. The amount of the bile changes with the blood-flow through the liver. The blood is supplied through the portal vein and the hepatic vein, although the bile secretion continues even after shutting off one of these sources. The material most abundantly supplied to the hepatic cells is carried to them by the portal vein. The material forming bile also being brought into the cells by the portal vein. If the portal circulation is obstructed the bile secretion is diminished. By the stimulation of the spinal cord the abdominal visera contract, producing the lobes of the portal circulation. The secretion is also diminished. If the spinal cord is divided, the bile flow is lessened on account of the paralysis of the vascular system. If the splanchics are then divided the stimulation of the splanchics produces a still further lessening of the secretion. If the splanchics are divided without dividing the spinal cord it increases the bile flow, the dilatation of the alimentary vascular system increasing the portal circulation. These facts seem to indicate that the bile secretion depends upon the blood pressure, and it is, therefore, a...
HEPATIC SECRETION.

Filtration.

- If the pressure in the bile ducts exceeds the pressure of the portal circulation, the secretion continues. The quantity of the secretion, however, will depend upon the quantity of blood flowing through the portal circulation rather than upon the pressure. The actual secretion depending not so much on the amount of blood as on the amount of elements found in the portal circulation, as these are brought from the alimentary canal in connection with digestion. In the formation of the hepatic plasma associated with the portal vein, the hepatic artery and the bile duct. The nutrition supplied to the solar plexus is the abdominal splanchine and the terminal of the right vagus. From the left vagus there are special musculature to the ducts and the bile ducts. If the splanchine are divided and stimulated peripherally, the bile ducts and gall bladder will contract, stimulation of the central and producing dilatation. If the central end of the vagus is stimulated, contraction of the gall bladder takes place inhibiting the opening of the bile duct into the duodenum. This would indicate that the hepatic fibers are found in the vagus, the effluent running in the splanchine through the solar plexus. Thus the secretion of bile takes place continuously in the hepatic cells, being ejected into the bile capillaries, the amount depending upon the amount and composition of the blood flowing through the liver, the actual formation taking place in connection with the activity of the cells. When digestion is going on the bile secretion increases. When the bile reaches the ducts it is ejected by the secretion of the new bile, and the contraction of the walls of the ducts. The storage of bile in the gall bladder from which it is ejected intermittently into the duodenum. On account of the vasomotor action in connection with the stomach and intestines there is a full supply of blood to the alimentary canal resulting in an increased flow of blood to the portal circulation. Some think there are also rhythmic pulsations in the portal vein resulting in the rapid driving of the blood to the liver and therefore assisting in the secretion.

SECTION VI.-The Kidney Secretion.

The kidney is a compound tubular gland which consists of a secreting part including the capsule, the tubules and the loops and a collecting part forming a straight tubular part. In the secreting part, the epithelial lining differentiation is different in different parts of the kidney. The solid part consists of a cortical pith, the apex of these bodies opening into the sinus. The cortical part, a blood vessel portion, the glomerulus and the capsule, a continuation of the tubule. The glomerulus consists of a small artery which divide into a number of capillaries, these uniting to form a vein. The entire area represents a peculiar structure so that the blood vessels very slow and the blood pressure high. Enveloping these glomeruli is the capsule with two walls, the one close to the capillaries composed of flat epithelial cells so that between the blood ves- sel and medullary part, the medullary part consisting of conically shaped cells, the blood pressure is lower and the capillaries united by the glomerular epithelium. In this way the filtration from the glomeruli to the blood takes place freely. The epithelium of the convoluted tubule has cells of the cuboidal or cylindrical type granular in appearance. These cells have important secreting action. The secretion of urine takes place in the cortical part, which will depend upon the quantity of the medullary part to the sinus, from which it passes through the ureter into the bladder. The actual secretion, however, is a number of smaller glands closely bound together. The tubules pass almost straight through the medulla, but are very much convoluted in the cortical portion. Every minute tubule starts in the cortical part and forming loops. In the loop there is a descending and an ascending part. The urine composition is very complex, containing as it does the final excretions of the body in connection with the various body metabolic processes. It is a yellowish secretion with a normal acid reaction due to the presence of the acid sodium and lime phosphate. Its specific gravity is 1016 to 1020. In connection with the secretion it is important to consider the water together with the inorganic substances, the sodium chloride, the sulphates, phosphates and CO₂ and the nitrogenous products, urea and uric acid. The nerve connection is very complete, the nerve fibers being traced into the basement membrane with terminals between the cells. The blood vessels course freely in the interstitial connective tissue, the veins and arteries running freely through the medullary and cortical substances. The lymphatics are found in connection with the minute arteries and around the capsule, the vessels accompanying by nerves, the nerve fibers passing through the basement membrane and terminating between the secretory cells. The blood vessel connections are held in regard to the secretion in the kidneys.

Two theories are in regard to the secretion in the kidneys. (1.) That of Ludwig, that the secretion takes place simply by diffusion and filtration, the water being filtered through from the blood in the glomeruli bearing along with it the urea and the inorganic salts. The diffusion of the fluid takes place in the passage through the cortical tubes by the process of diffusion in connection with the lymph. The filtered blood passes through the glomerulus and the vessels between the cells of the glomeruli. It has been supposed that the process of filtration is a correct term for the process of water secretion. The filtration process, however, in the main consists of secretion in connection with the blood flow in other secretory tubules, a peculiar secretion, as we will see, due to the peculiar flow through the kidney. The amount of water secreted depends upon the volume of blood circulated, as well as upon the pressure of the blood.

Heidenhain believes that the epithelial cells of the glomeruli, are active in the process of water secretion. The formation of the water depends upon the physiological condition of these cells, the quantity of urine secreted depending more upon the quantity of blood circulating than upon the pressure of the blood. In this way the filtration from the glomeruli is the capsule of the tubules. The formation of the water depends upon the quantity of urine secreted depending more upon the quantity of blood circulating than upon the pressure of the blood. In this way the filtration from the glomeruli is the capsule of the tubules. The formation of the water depends upon the quantity of urine secreted depending more upon the quantity of blood circulating than upon the pressure of the blood.
kindred substances. If the medulla is divided and urea, urates or sodium acetate are injected into the blood, there is an abundant secretion. It is not accompanied necessarily by a rise in blood pressure. There is a distension of the renal pelvis and the urine secretion is increased by any local increase in blood flow. These substances seem to excite the renal cells, producing a very abundant secretion in the tubule cavity. It is accompanied by the vascular dilatation but not sufficient to cause the removal of the pressure. By the compression of the veins the theory is correct it would increase the flow of urine. If there is compression of the renal artery the secretion of urine is stopped for a considerable time after the removal of the pressure. This seems to indicate that the increase in renal secretion is due to the influence of the vasomotor system. The excretion of the kidneys of some experimenters have kept up the kidney activity, proving that the amount of the blood flow regulated the secretory activity. This indicates that the greater part of the water is secreted in connection with the living cells of the tubules, although there is also a secretion of water and salts at other parts of the tubules.

According to recent investigations definite changes are found to take place in the cells, the secreting matter collecting in the interior of the cells being afterwards discharged into the cavity of the cell. In birds, for example, urates can be found in the cells of the tubules and none in the capsules. When inactive, the cells are small and granular. The cavity of the tube being wide and the cells towards the cavity exhibit sequestered processes. When the secretion takes place the fluid being thrown out by filtration, the cells being ruptured in the ejection of the substances of the vesicles. The epithelial cell activity takes place in connection with the glomerular epithelium. The question of where the take place by simple filtration, the cells being ruptured in the ejection of the substances of the vesicles. The epithelial cell activity takes place in connection with the glomerular epithelium. The question is, does it take place by simple filtration, or is it an active secretion? If it is a simple filtration the amount of the urine would depend upon the blood pressure in the glomerulus. The kidney is very vascular organ favoring a rapid flow of blood. The renal arteries contain a large number of arteriolar capillaries in which the blood pressure is very high. The renal arteries cut off directly into the veins where the blood pressure is very low. Between the beginning of the renal artery and the end of the renal veins, there is a great difference in the pressure, the blood flow depending upon the difference in pressure, a difference equivalent to that found in the entire lower extremities of the body. If the blood pressure rises in the aorta, the blood flow will be greater and, therefore, the pressure would be greater in the blood vessels of the glomerular capillaries and vice versa. Experiments have proved that if the arterial pressure is below normal, the urine secretion is suspended or arrested. If the renal arteries are constricted, there is a diminution of the secretion accompanied by a fall of the blood pressure and a diminution of blood flow. Distension of the renal arteries increases the flow of urine and also the pressure in the glomerular capillaries and the amount of blood flowing through the vessels. It has been concluded that as the pressure of the blood and the amount of urine vary together, the urine secretion depends upon the filtration process of the water from the blood. The variation depends, however, not only upon the pressure but also upon the quantity of blood flowing through the glomeruli. Heidenhain believes that it is the quantity of blood that determines the amount of urine. The epithelial cells can readily secrete water and do not act simply in epithelial function. If the urine secretion is too great to be accounted for by the renal arteries becoming slower, or may be arrested entirely. By the compression of the veins theory is correct it would increase the flow of urine. If there is compression of the renal artery the secretion of urine is stopped for a considerable time after the removal of the pressure. This seems to indicate that the increase in renal secretion is due to the influence of the vasomotor system. The excretion of the kidneys of some experimenters have kept up the kidney activity, proving that the amount of the blood flow regulated the secretory activity. This indicates that the greater part of the water is secreted in connection with the living cells of the tubules, although there is also a secretion of water and salts at other parts of the tubules.
flow. The increase in volume may be produced in connection with the enlargement of the blood vessels, the latter being the most important element. In this way it has been shown that constrictor fibers act upon the blood vessels of the kidneys, these constrictor fibers coming from the constrictor region of the spinal cord in the medulla oblongata. It is to be from the 6th dorsal as low down as the 3rd or 4th lumbar mainly, however, from the 11th, 12th, and 13th dorsal nerves, passing the sympathetic connection in the spinal ganglia through the solar plexus and the renal plexus to the kidneys which they reach as nonmedullated fibers. If these nerves are stimulated there is contraction of the arterial arteries, the kidneys decrease in size and the urine secretion is diminished. These effects are marked in the case of stimulation of the 11th, 12th and 13th dorsal nerves and less marked in the higher series. If these fibers are divided dilatation takes place in the arteries, the kidney is enlarged and the amount of blood flowing through it is increased and the urine secretion is also diminished. These nerves are also connected to the kidneys which produce when stimulated dilatation of the arteries and an increase in the blood flow. These nerves come from the spinal cord by the anterior roots of the 11th, 12th and 13th spinal nerves. The vasodilator fibers also exist in the higher roots and are accompanied when stimulated by dilatation of the vessels of the other abdominal organs leading to the general fall in the blood pressure counteracting the kidney dilatation. They are stimulated reflexly and thus act upon the secretion of the kidneys through the increased blood supply. In this way there is a direct nervous mechanism controlling the blood supply and therefore controlling the secretion of the urine. This is the only direct influence of the nervous system upon the secretion. Aside from these local influences and influences affecting the general arterial pressure and flow will have a modifying effect upon the secretion of the kidney. The kidney is very subject to influences due to chemical action, for example, injecting a small quantity of water into the blood produces great distention after a brief period of shrinkage. Urea injected into the blood produces red blood clotting. Similarly, sodium chloride solutions and diuretics like sodium acetate. These changes take place even after separate from all nervous connection external to the kidneys. Increase in blood pressure associated with asphyxia or poisoning by strychnine tends to lessen the amount of blood flow through the kidney, and lessen the urine secretion. If, on the other hand, from any cause the skin vascular system is dilated the blood pressure is lowered and consequentl the blood flow is diminished. Any change in the blood that will alter the relation of the blood vessels to the kidney will alter the blood flow unless this is changed by the contraction of the renal blood vessels. Any dilatation of the renal blood vessels on the other hand will increase the flow of blood uncoupled and decrease the amount of blood flow through the kidneys. With the increase in general circulation in the abdomen the rise in the abdominal aorta there is a greater flow through the kidneys, if the renal arteries are not constricted. This may be caused by the heart pulsation and the respiratory movements.

2. Secretion in connection with the epithelium of the uriniferous tubules, both of these different from ordinary secretion such as we find in the case of salivary gland secretion.

(1.) Glomerular secretion. By dilatation of the renal artery there is a rise of rapid blood flow, and through the glomeruli, and it exerts a greater pressure upon the walls of the glomeruli. We cannot at present increase the blood flow without increasing the blood pressure, but pressure may be increased without affecting the flow. If the blood is prevented from flowing out through the renal vein the pressure is increased in the glomeruli. This results in a reduction of the flow of urine instead of an increase. This proves that mere pressure does not produce the passage of water through the glomerular loop walls, and therefore, it is not a mere filtration process. All that passes through the loop walls is water and some soluble substances found in the blood, some are produced while others are present in the vein. In the case of the loop wall we find not only a membrane but also a layer of epithelial cells. The materials found in the urine must pass through these epithelial cells, the cells determining what shall pass through. In order to accomplish this there must be a rapid arterial blood flow assisted by a high pressure. In the epithelium is a condition of derangement as in the case of the curtailing of the blood supply to the glomeruli the uriniferous secretion will be arrested. On removing the obstruction to urine secretion begins and it will be found to be albuminous so that the albumin which does not usually pass through the epithelium passes through when the epithelium is injured. This indicates the presence of albumin in the urine indicates an abnormal kidney condition, especially of the epithelium. This indicates the activity of the epithelium of the glomeruli as well as diffusion and swelling. Similarly sodium is also indicated in producing the secretion.

(2.) Epithelium of the uriniferous tubules. The epithelial cells of the tubules are active in secretion. If the kidneys are extirpated, or if they are damaged there is an accumulation in the blood of urea. This indicates that urea is not formed by the epithelial cells from blood taken from the blood but that the epithelial cells have the power of selecting the urea and extracting it from the blood and then driving it into the cavities. We have evidence of any process of up formation in the pressure between the kidney. If urea is injected into the blood there is no increase in the amount of urea in the blood, but an increase in the urine secretion and flow. In the case of hippuric acid found in the human urine it is formed by the comb of both the blood and amine and acid in the kidney. If a kidney is removed from the body and the circulation is kept up and then hippuric acid and glycine are added to the blood before it enters the kidney. Hippuric acid will appear in the blood as it leaves the kidney. The parts of the kidney is allowed to die this will not take place so that it is a living process. The cells of the kidney must be supposed to have the power of selecting these substances from the blood and forming hippuric acid. The action of the cells seems to be in accordance with the general kidney function that of preparing for the discharge of the waste matters from the body, in some cases combining these substances so as to excrete them in a peculiar form. There is a great variation in the substances of urine, especially as between water and solids. It is often advantageous to the system to discharge a large
THE KIDNEY SECRETION.

amount of water. This may take place when the cutaneous discharge is arrested or suspended as in the case of constriction by cold of the cutaneous vessels. The same term is used in the case of the gland tissue. The same term is used in the case of the gland tissue. The same term is used in the case of the gland tissue. The same term is used in the case of the gland tissue. The same term is used in the case of the gland tissue.

SECTION 7. Epidermal gland secretions.

SWEAT GLANDS.

The sebaceous glands are either simple or compound and are found over the superficial surfaces of the body, sometimes associated with hairs and sometimes not, as in the case of the lips and prepuce. In connection with hairs, the sebaceous ducts connect with the hair follicles. The cells of the sebaceous glands are found arranged in layers, those lying nearest the cavity being filled with fat and being destroyed in the formation of the secretion. By the formation of new cells around the basement membrane the secretion becomes continuous. The secretion or sebum is an oily substance containing fat and soaps, cholesterol and albumin, inorganic salts and broken down epithelial cells; the secretion varying in character in the different glands in which its formation takes place. The sebaceous prepuce is that of the auditory meatus blended with the sweat glands of the nose. On the nose of a new born child there is a sebaceous secretion called vernix caseosa. This sebum is shown in connection with the hair and the epidermis. It provides lubrication to the skin and also to the hair shaft, preventing the hair from becoming hard and brittle. In addition it furnishes a protection against the rapid loss of heat from the body by evaporation, maintaining normally the epidermal character of the skin.

SWEAT GLANDS.

Sweat is a secretion in connection with the sweat glands of the outer surface of the body. In particular in the palms of the hands and the soles of the feet. They are estimated to number between two and three million glands over the whole body. In the human subject they are small tubular glands with the end parts of which contain the secretory cells, these cells being grouped into that the secretion of the sweat gland at the periphery. In the secretory part the cells are columnar in form, consisting of a cytoplasm that is granular. The secretion varies with changes of temperature and with the presence or absence of the secretory cells. In the average subject the normal secretion varies from 700 to 900 grams daily. The difficulty in determining the composition of the sweat secretion is that it is mixed with the secretion of the sebaceous glands. This is due to the fact that the sweat gland tissue is made up of gland cells with the sweat glands being divided from the spinal cord the action of certain stimuli still produces the sweat secretion. It has led to the opinion of some that the sweat glands are entirely absent in this subject. Thus we find that the sweat is furnished both by the sebaceous glands and the sweat glands. The sweat secretion depending upon the character of these two secretions. There is little variation in the sebaceous glands; hence when the sweat is profuse the sebaceous glands have little influence and when it is scarce the glands are subjected to an external fluid. Hence, normally the sweat glands may be considered as the sweat secreting glands. There is a slight fluid transudation in connection
Themammary glands are found in the male and female at birth about the mg for an accumulation of the milk. The fluid secretion consists of a plasma, serum in it includes a colostal globulin. In the disintegration of the alveoli we find the colostal granules. The macrophages multiply by a kind of cell genesis, during the period of lactation providing for an accumulation of the milk. The fluid secretion consists of a plasma, and a great number of globules which float in the plasma. These globules consist of the milk fat, especially the neutral fats, olein, palmolin and stearin, which are together with traces of the fatty acids, lecithin, cholesterol and the milk pigment. The milk plasma consists of water holding in solution proteins, carbohydrates and salts. Among the proteids we find casein, lacto-globulin in much smaller quantities. The principal carbohydrate is the lactose. A nuclear-proteid is also found in the milk—glyco-proteid. Traces of urate and creatin are also found in the plasma together with citrate of calcium, lecithin and cholesterol. This secretion takes place in connection with the epithelial cells as there are matters found in connection with the milk not found in the blood or lymph. During the resting period the gland manifests its vesicles in a condition in which flattened or cuboidal cells appear with a single nucleus and with a few fat granules. After the lactation commences these cells enlarge the nucleus divides and each cell is found with two nuclei. The fat matter and the granules pass through a process of change, the cell itself being elongated and these being discharged from the cell end, the discharge and the disintegrated part of the cell being passed into the secretory ducts of the milk and part of it forms the constituent elements of the secretory fluid. Sometimes only a part of the cell becomes disintegrated. Sometimes the entire cell is dissolved. When the entire cell is dissolved the place is supplied by the process of karyokinesis. In the first milk secreted there are found peculiar colostal granules. Heidenhain accounts for these by certain rounded epithelial cells which in the process of development develop fat cells that are thrown into the gland. Others regard them as due to the dissolution of cells of connective tissue which degenerate and are discharged in the gland during its earlier stages of activity. The milk secretion varies from 1,028 to 1,035 in its specific gravity and if quite fresh is alkaline in its reaction. As soon as it ceases to be fresh it becomes acid. In milk we find various substances.

(1.) Proteids. The chief proteids are casein and lacto-albumin. Under the influence of rennin the casein becomes curdled and insoluble. It mixes with neutral salts or distilled with acetic acid and then a stream of carbonic acid passed through it, precipitation takes place, the lacto-albumin being discovered by means of heating. In the process of curdling the milk is divided up into tyrohesin and an albumose called lacto-protein. The lacto-albumin does not coagulate in the natural milk being hindered by the alkaline character of the milk.

(2.) Fats. In addition to olein, palmolin and stearin we find other fats furnished by the combination of butyric acid and glycerin. There is great variation in the kind of fats present in milk. The milk represents fat in its most refined condition.

(3.) Lactose. This represents the milk sugar which under the influence of a ferment may become lactic acid. The chief salts in milk are lime phosphates, potassium and sodium chlorides and magnesia phosphates. There are also small traces of iron and sulpho-cyanide. The milk secretion at the commencement of lactation is called colostum. It is the subject of normal milk in containing a large number of colostal corpuscles very much like the leucocytes, some of them being regularly formed cells and others disintegrated parts of cells some of which are characterized by amoeboid movements. In the colostum there is also a large proportion of globulin as well as a quantity of albumin. In the disintegration of the alveoli we find the colostal granules. The mammary glands are found in the male and female at birth about the

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same condition. After birth the glands become active and discharges a milky fluid after which they remain dormant in the female till puberty when they begin to develop, while in the male they remain dormant through abnormal conditions. Thus, the mammary secretion while in common with other glandular secretions certain characteristics of gland activity have certain peculiarities. In the case of the mammary gland the activity is definite. As the empty cells become filled, or refilled with secretion the cells it is thrust out into the cell cavity. The nucleus divides and the new nuclei become imbedded in the cell substance. While the cell substance actually is an excretion of the secretion. The fat globules are first ejected from the cell substance and then the cell division takes place, the parts of the cell pass through certain changes. Thus the elements consist of the cell substance in part and in part of the elements secreted in the cell substance. Thus the nucleus of milk probably arises from the broken up nucleus. In this case the secretion is a manifestation of cell activity. From the time of the formation of fat takes place in the alveoli, this formation taking place even from protists when insufficient fat may not be present in the food, the cell making this transformation and not simply collecting it from the blood. Similarly the casein is formed in the cell as it cannot be gathered from blood being the lacto-albumin. The lactose, or milk sugar, is also secreted in the cell as it is not found anywhere else in the body. Some think that the glycogen like body found in the cells is the preliminary substance in the formation of lactose. The gland is active, therefore, in the formation of casein. It is supposed that mammary secretion is under the control of the nervous system. It has been found that strong psychic influences such as emotions have destroyed or suspended the activity of the gland although this is disputed by some. The external spermatic by some of its branches furnishes vaso-motor fibers to the glandular blood vessels, indirectly influencing the milk secretion by the influence exerted upon the blood flow in the gland. The division of the inferior branch has been found to increase the secretion while stimulation results in the diminution of the secretion. It has been found that the stimulation of the secretion in the case of goats lessens the milk secretion. If the mammary glands are severed from blood connection with the central nervous system, then the secretion of milk stops. The secretion continues to take place and the gland becomes enlarged as a result of lessened secretion. In these cases the diminution does not take place. But comes on gradually. Even after the extrinsic nerves are entirely cut off from the spinal cord the secretion continues to take place and the gland becomes enlarged as usual with lessened secretion. If the central nervous system is divided on one side only, there is no change in the secretion. In these cases the diminution does not take place but comes on gradually. Even after the extrinsic nerves are entirely cut off from the spinal cord the secretion continues to take place and the gland becomes enlarged as usual with lessened secretion. The mammary gland, therefore, must be subject to the control of the central nervous system, but whether this takes place by automatic action or by the influence exerted upon the secretory fibers in the central nervous system there is no certain determination. Recent experiments indicate the close connection between the mammary glands and the uterus depending upon the blood rather than upon the the cells with the secretory fibers but whether this will be confirmed or not remains unsettled. The secretory cells are not formed until after the first pregnancy the secretion beginning only after parturition, although the cells increase in number during pregnancy. The first secretion is that of colostrum differing from the milk in the character of the cells which have wandered about and have passed through a stage of degeneration. After a few days the colostrum produces place to milk which is secreted in the cells and collected in the lactophoric duct, the secretion continuing until the colostrum is exhausted. When the formation of the secretion is inhibited as soon as the ducts are emptied a new secretion begins. This process of emptying forms the stimulation necessary to the secretion in the cells. As soon as this stimulation ceases to act the secretion itself ceases.

SECTION VIII. The Ductless Glands.

The internal secretions are formed within the gland, and are passed from the gland, either into the blood or the lymph. In every eutopic in connection with the metabolism there is a waste which is carried into the blood and the lymph. The internal secretions, however, refer to those secretions which take place in definite glandular organs which are used either by the organs or for the metabolism of the entire body. This was first discussed in connection with the testis and pancreas. These secretions are found in connection with what have been called the ductless glands. As yet our knowledge of these glands and their secretions is very incomplete. In connection with the liver there is a substance formed in connection with the hepatic cells which passes into the blood that falls under this head, namely, urea. It is the principal nitrogenous waste of the protein metabolism. It passes off from the body through the kidneys, but it is not formed in these glands. It seems to be formed in the liver in connection with certain substances that arise out of the protein metabolism, these substances being carried to the liver where urea is formed. The urea is secreted in the liver and from hence it is given off to the blood. The hepatic cells perform this metabolism for the entire organism, the liver seems to assist in the utilization of the iron arising in connection with disintegration of the corpuscles. There is also formed in connection with the glycogen in connection with the sugars and proteins brought to the liver by the portal circulation. This stored up substance is eliminated by the liver in connection with the hepatic metabolism, in connection with which we will discuss it.

In connection with the pancreas it has been found that there is also an internal secretion. The pancreas has been removed without any immediate fatal results. After the removal of the pancreas it was found that the urine possessed in large excess of saccharine matter. In this case it has been found that this condition of glycosuria follows even when the carbohydrates are taken out of the food. The urine increases in quantity accompanied by a thirsty condition. If these conditions continue the animal becomes weakened and emaciated death ensues in two or three weeks. Experimental have been made in animals of other species to prove that the partial removal of the pancreas prevents the accumulation of sugar in the urine; 1-4 or 1-5 of the pancreas being removed is sufficient to prevent this accumulation of sugar in the urine. From this it is concluded that there is a secretion in the pancreas which either consumes the sugar, that is produced in the organs of the body, or else prevents it from being eliminated from the liver and the body tissues. It is claimed that recent experiments prove that in cases of diabetes there is post mortem proof of the body tissues being connected with certain variations in the metabolism of sugar.
THE DUCTLESS GLANDS.

alveoli connected together in connective tissues which send septa into the interior, separating the alveoli from one another by oval spaces. In connection with these septa we find numerous blood vessels springing from the superior arches of capillaries. From these the veins collect the blood, forming plexuses in the organ surface ending in the inferior and middle thyroid veins. Around these, the nervous connection springs chiefly from the cervical sympathetic, from the middle and lower cervical ganglia. They consist of a large number of closed cells of varying sizes, each cell being covered with epithelium and characterized by the presence of secretory apparatus connected with the thyroid glands.

The ductless glands are accompanied by a dyspnoea and a febrile condition, and the physiological effects of these glands are manifested in a peculiar exophthalmic goitre with protruding eyeballs. According to others, the thyroid secretes a fluid which is a true internal secretion and when discharged exercises a potent and alluring influence on the physiology, especially that of the nervous system. In proof of this it is claimed that to inject thyroid extracts produces good results. This substance formed in the gland reaches the blood through the lymphatic system after it has been secreted within the cells of the gland. This last fact proves that there is a true internal secretion, and if this is so, then it must have an important bearing of some kind upon metabolism. Some have been successful in extracting from the gland a substance called thyroid which is found to contain a large quantity of iodine, often as much as 1% per cent of the dry substance and which is found to have good results in cases of goitre and myxoedema. This proves that the thyroid produces an iodine compound and it has been shown that this compound consists of a combination with proteins. Recent experiments have indicated the presence of a number of these protein substances and of which are found to be valuable in the body metabolism. The larger part seems combined with the smaller part being combined with a thyroid-globulin. These substances when given to animals upon whom thyroidectomy has been performed have good results.

The suprarenal capsules or adrenal bodies form another of these ductless glands. Surrounding the connective tissue capsules, septa passing inward from the capsule forming a framework of cells of different structure. The substance of the cells is of a yellowish color, sometimes containing yellow oil globlets with distinctly marked round nucleus. In the cortical part the cells are different, the substances of the cells being clear and transparent and distributed as follows: the outermost part by the absence of blood vessels and nerves. The nerves are chiefly modulated nerve fibers from the sympathetic and the plexuses, the phrenic and vagi nerves entering suprarenal body and forming plexuses of the fibers emerging from the plexuses. These substances found in the suprarenals consist of proteins and also contain other substances containing peculiar color reactions. The histological character of the cells suggests that certain substances process take place in the cells in connection with the pigment metabolism of the body. As proteins the nervous connective tissues are present, the nerve connection is very complete there seems to be a close connection with the nervous system. The complete excision of these bodies is followed by death, the fact that the result following their removal is much more rapid than in the case of the thyroid gland is due to the more rapid death in the case of the latter.

In the lower animals it is claimed that fatal results may be obviated by the grafting of the part of the gland in some other portion of the body easily accessible to the blood. Also results are brought about with the conditions of Addison's disease, in which case there is a suprarenal disturbance. Addison's disease is characterized by the presence of a substance that the suprarenals involve a bronzing of the skin, accompanied by muscular and mental exhaustion and a marked blood depression. These results correspond with the conditions of Addison's disease, in which case there is a suprarenal disturbance. Addison's disease is characterized by the presence of a substance that the suprarenals involve a bronzing of the skin, accompanied by muscular and mental exhaustion and a marked blood depression. These results correspond with the conditions of Addison's disease, in which case there is a suprarenal disturbance. Addison's disease is characterized by the presence of a substance that the suprarenals involve a bronzing of the skin, accompanied by muscular and mental exhaustion and a marked blood depression. These results correspond with the conditions of Addison's disease, in which case there is a suprarenal disturbance. Addison's disease is characterized by the presence of a substance that the suprarenals involve a bronzing of the skin, accompanied by muscular and mental exhaustion and a marked blood depression. These results correspond with the conditions of Addison's disease, in which case there is a suprarenal disturbance.

Therefore, there are three stages during the removal of the thyroids. (1) The neurotic period during which muscle twitchings and nervous excitement are manifested, accompanied by a dyspeptic condition. (2) The mucous period during which the mucous is developed, mucin being deposited in the tissues, and (3) the atrophic stage during which the mucous is absorbed. The thyroids, therefore, have an important function in connection with the body's normal metabolism. According to some their function is to absorb and take out of the blood certain noxious substances which would interfere with the metabolic processes. The removal of these bodies produces a condition, it is said, of atrophy, and the physiological effects of these glands are manifested in a peculiar exophthalmic goitre with protruding eyeballs. According to others, the thyroid secretes a fluid which is a true internal secretion and when discharged exercises a potent and alluring influence on the physiology, especially that of the nervous system. In proof of this it is claimed that to inject thyroid extracts produces good results. This substance formed in the gland reaches the blood through the lymphatic system after it has been secreted within the cells of the gland. This last fact proves that there is a true internal secretion, and if this is so, then it must have an important bearing of some kind upon metabolism. Some have been successful in extracting from the gland a substance called thyroid which is found to contain a large quantity of iodine, often as much as 1% per cent of the dry substance and which is found to have good results in cases of goitre and myxoedema. This proves that the thyroid produces an iodine compound and it has been shown that this compound consists of a combination with proteins. Recent experiments have indicated the presence of a number of these protein substances and of which are found to be valuable in the body metabolism. The larger part seems combined with the smaller part being combined with a thyroid-globulin. These substances when given to animals upon whom thyroidectomy has been performed have good results.

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Therefore, there are three stages during the removal of the thyroids. (1) The neurotic period during which muscle twitchings and nervous excitement are manifested, accompanied by a dyspeptic condition. (2) The mucous period during which the mucous is developed, mucin being deposited in the tissues, and (3) the atrophic stage during which the mucous is absorbed. The thyroids, therefore, have an important function in connection with the body's normal metabolism. According to some their function is to absorb and take out of the blood certain noxious substances which would interfere with the metabolic processes. The removal of these bodies produces a condition, it is said, of atrophy, and the physiological effects of these glands are manifested in a peculiar exophthalmic goitre with protruding eyeballs. According to others, the thyroid secretes a fluid which is a true internal secretion and when discharged exercises a potent and alluring influence on the physiology, especially that of the nervous system. In proof of this it is claimed that to inject thyroid extracts produces good results. This substance formed in the gland reaches the blood through the lymphatic system after it has been secreted within the cells of the gland. This last fact proves that there is a true internal secretion, and if this is so, then it must have an important bearing of some kind upon metabolism. Some have been successful in extracting from the gland a substance called thyroid which is found to contain a large quantity of iodine, often as much as 1% per cent of the dry substance and which is found to have good results in cases of goitre and myxoedema. This proves that the thyroid produces an iodine compound and it has been shown that this compound consists of a combination with proteins. Recent experiments have indicated the presence of a number of these protein substances and of which are found to be valuable in the body metabolism. The larger part seems combined with the smaller part being combined with a thyroid-globulin. These substances when given to animals upon whom thyroidectomy has been performed have good results.

The suprarenal capsules or adrenal bodies form another of these ductless glands. Surrounding the connective tissue capsules, septa passing inward from the capsule forming a framework of cells of different structure. The substance of the cells is of a yellowish color, sometimes containing yellow oil globlets with distinctly marked round nucleus. In the cortical part the cells are different, the substances of the cells being clear and transparent and distributed as follows: the outermost part by the absence of blood vessels and nerves. The nerves are chiefly modulated nerve fibers from the sympathetic and the plexuses, the phrenic and vagi nerves entering suprarenal body and forming plexuses of the fibers emerging from the plexuses. These substances found in the suprarenals consist of proteins and also contain other substances containing peculiar color reactions. The histological character of the cells suggests that certain substances process take place in the cells in connection with the pigment metabolism of the body. As proteins the nervous connective tissues are present, the nerve connection is very complete there seems to be a close connection with the nervous system. The complete excision of these bodies is followed by death, the fact that the result following their removal is much more rapid than in the case of the removal of the thyroids. Following the removal of these toxic substances accumulating in the blood. In proof of this is it claimed that the blood and urine of animals from which the thyroids are removed has
muscular contraction became more protracted, the blood pressure being greatly increased; and as the result it is concluded that the secretion of the suprarenal glands is a stimulant. In regard to the pituitary body it is claimed that fatal results follow its complete destruction and that it follows the same course as death from thyroidectomy indicating that they perform the same function or similar functions in the body metabolism.

In connection with the reproductive glands Brown-Sequard has made a number of experiments. Fresh testes injected into the blood has a remarkable tonic influence on the nervous system, especially in connection with respiration.

The splenic circulation is carried on large vessels by the nervous system. The expansion of the spleen does not take place according to the blood pressure for there is a resistance on the part of the muscular tissue and also the change in calibre of the arteries, both of these changes being regulated coincident with the respiratory movements. These alterations are determined by the contractions and relaxations of the muscular fibers of the spleen and also the change in calibre of the arteries, both of these changes being regulated by the nervous system. The expansion of the spleen does not take place according to the blood pressure for there is a resistance on the part of the muscular tissues and also the change in calibre of the arteries, both of these changes being regulated by the nervous system.

The spleen is an organ whose functions as yet are not distinctly understood. The spleen may be removed without any fatal results, the noticeable effects being that after its removal there is an enlargement of the lymphatic glands and an increase in the bone marrow together with an increase in the activity of the medulla. It has been found that one result of the removal of the spleen is the decrease in the number of red corpuscles and the amount of the haemoglobin. From this it has been inferred that the spleen has some thing to do in the formation of the red corpuscles. The chief known facts about the spleen are in regard to its movements the spleen is known to increase in size during digestion attaining its maximum about five hours after its removal. This is possibly due to the action of the splenic nerves containing both inhibitory and acceleratory fibers. The splenic circulation is carried on large vessels by the nervous system. The expansion of the spleen does not take place according to the blood pressure for there is a resistance on the part of the muscular fibers of the spleen and also the change in calibre of the arteries, both of these changes being regulated coincident with the respiratory movements. These alterations are determined by the contractions and relaxations of the muscular fibers of the spleen and also the change in calibre of the arteries, both of these changes being regulated by the nervous system.

SECTION IX—2. Excretion.

We have seen how the food passes through the digestive process and by absorption passes through the blood to the different tissues of the body. In passing through the blood and tissues, certain changes take place, the excess of fluid being carried as waste into the lymphatic system and through the lymph into the blood. The various food elements, proteins, fats, carbhydrates, salts and water become changed, the proteoid fats and carbohydrates into ures, \(\text{CO}_2\), aqueous vapor, (\(\text{H}_2\text{O}\)), the proteoids producing nitrogen. From the proteins also are found sulphur and phosphorus which becomes changed by oxidation into the sulphates and phosphates being excreted along with the salts. These waste substances that find their way into the blood are not only excess but they represent dangerous elements if continuously accumulated in the blood. These substances that are eliminated by the kidneys are the products of cellular catabolism. Generally speaking, these waste elements consists of urea, \(\text{CO}_2\), salts and water. These waste matters are eliminated through five different channels. We have seen how the intestines, the liver, the skin, and kidneys are in connection with the respiratory lungs excrete \(\text{CO}_2\) and also a quantity of aqueous vapor. In connection with the intestines we find then in the form of feces, the undigested parts of food and the matter secreted in the intestines are excreted as fecal matters. There remain to be considered, the two main excretory organs, the skin and the kidneys.

(1.)—THE SKIN.

It is concerned physiologically with the functions of sensation, protection, respiration and excretion. It presents a sensory surface between the internal and external elements. It has a variety of nerve fibers distributed over its surface that give rise to various reflex actions that keep the body in adaptation to its surroundings. It has an important part to play in connection with animal heat and body temperature. The skin consists of two layers, the deep layer of connective tissue called the corium or dermis, and the superficial layer of epithelium called the epidermis. In connection with the skin we find two kinds of glands, the nails and hair, developed in connection with the epidermis. The corium consists in its upper surfaces of furrowed and cross furrowed areas forming either rounded
SECTION XI.—Sweat and Sebaceous Excretion.

In connection with the integument we find two glands. (a) The sudoriferous or sweat gland. These were first discovered by Malpighi. These are simple, tubular glands, ball shaped, at the end, being the secreting part and the elongated, 264

or grooved shaped areas, the rounded areas appearing on the surface of the skin and the furrows on the palms of the hands. Between the furrows are being largest in the palms of the hands and the soles of the feet. This epidermis consists of keratinized thickest where the circumference is with connective tissue interlaced with elastic which are important, the papillary and the reticular, two of fat cells are beneath the papillose epidermis. The muscle fascia of the deeper subcutaneous tissue with wide meshes and the other in the papillary stratum with very narrow meshes, the branching lymphatics arising around the hair follicles and the glands. The nerves and deeper layer in which fat cells are abundant. The subcutaneous layer of connective tissue passes into the deep stratum with at least two strata, the deep or subcutaneous stratum called the Malpighian papillary stratum, being cylindrical and the deeper or corny stratum, both strata consist of those above being round or flattened cells. In the corny stratum are the hitherto developed Malpighian layer cells. The pigment of the epidermal regions as in the hair, gland, and sweat, there is a middle layer lying between the surface, are hair consisting of the shaft, that part above the skin, the radiolipid the root with a tubular recess filled with tissue called the papillar. The sebaceous glands open into the follicle.

In the papillary stratum arise the veins in connection with the papilla, the hair follicles and the sebaceous glands, the small vein branches entering close to the arteries and receiving branches from the sweat glands and passing into the fatty subcutaneous tissue. The lymphatics consist of two layers, one of which extends deeper subcutaneous tissue with wide meshes and the other in the papillary stratum with very narrow meshes, the branching lymphatics arising around the hair follicles and the glands. The nerves and deeper layer in which fat cells are abundant. The subcutaneous layer of connective tissue passes into the deep stratum with at least two strata, the deep or subcutaneous stratum called the Malpighian papillary stratum, being cylindrical and the deeper or corny stratum, both strata consist of those above being round or flattened cells. In the corny stratum are the hitherto developed Malpighian layer cells. The pigment of the epidermal regions as in the hair, gland, and sweat, there is a middle layer lying between the surface, are hair consisting of the shaft, that part above the skin, the radiolipid the root with a tubular recess filled with tissue called the papillar. The sebaceous glands open into the follicle.

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(a) Sweat. The sweat yielded by the sudoriferous glands is a colorless, watery fluid transparent with the peculiarly saline taste and a characteristic odor varying in the different parts of the body. The sweat in the human subject is acid in reaction; although it is alkaline when very abundant. If a part of the skin is well washed, the sweat collected afterwards from the skin is alkaline. It is concluded from this that the pure sweat is alkaline, but that when mixed with fatty secretion it becomes acid. This acidity is increased from decomposition of the sebaceous matter found in connection with the sweat glands. The specific gravity is about 1.004. On microscopic examination there are found oil globules and crystals and sometimes some epidermal cells. Normally perspiration contains 97.5 to 99 per cent of water, and from 1 to 2.5 per cent solids. About two thirds of the solid matter consists of organic matters and one third of inorganic substances in the form of salts, sodium chloride and the phosphates and the pentagonal cells known as Tyson's secretion. The sweat glands vary in development deep into the subcutaneous tissue. The subcutaneous tissues consist of three capillaries, the deeper lying in the fatty subcutaneous layer, the middle superficial forming the terminals of the artery, furnishing branches to the papilla, the hair follicles and the sebaceous glands in the papillary layer.
There are also found the neutral fats, cholesterol and small traces of albumin, various fatty acids such as butyric and acetic acid, indicating the odor. In pathologic conditions, such as with capric and caprylic fatty acids in the sweat, there has been found lactic acid and bile also in large quantities. Anything that assists the blood to supply the skin, tends to assist sweating, since it varies in different conditions of sweat secretion, and if the watery evaporation is greater from the glands than normal the surface of the skin is covered over with a profuse perspiration. Secretion of sweat is produced by exercise, profuse drinking of water, hot baths, high temperature, and friction applied to the surface of the skin. Morphine, nicotine and camphor increases the sweat flow. Mental excitement, joy, anger or grief increases the secretion of sweat.

The kidneys are partially arrested as in certain abnormal conditions, the skin is considered as the excretory function more generally. It is estimated that about 900 C.C. of water is discharged by the kidneys. There is a sympathy between the two organs, which is excreted from the body. This represents a much more useful fluid in proportion than that excreted by the kidneys. It seems to be important not so much from the standpoint of water excretion from the body as in connection, rather, the greater is the heat loss. The first sweat secreted is more rich in perspiration becomes alkaline. Free perspiration of the urine. Iodine, alcohol and odoriferous elements may be discharged through minute capillaries, the development of the skin, and the nerve supply to the sweat glands. Smooth muscular fibers find between the cells and the membrane. The innervation of the sweat glands depends upon the trophic or secretory fibers. Perspiration is more general on the right side than on the left. The vasoconstrictors and the secretory fibers are active. There is no doubt that special secretory fibers are in existence. If the secretory fibers are in existence, the perspiration is applied to the peripheral end instead of being formed on the foot pads. In the case of the cat perspiration in the blind feet depends upon nervous impulses conveyed through the sciatic nerve fibers. A cat four or more years old perspires freely on the three feet in which the sciatic nerve was divided while in the foot in which the sciatic was not divided perspired only slightly.

The excretion of the sebaceous glands. The substance secreted is of an oily character, semi fluid and of a characteristic odor. The fatty substances are formed by the epithelial cells of the glands, the sebaceous secretions consist of about 31 percent of water, 61 percent of albuminous matter and broken-down cell substances, 5 percent of fatty matter and soaps including olein, palmatin and sodium palmitate with 1 to 1.5 percent inorganic salts including chlorides and phosphates. Its chief function seems to be in connection with the hair keeping the hair soft and flexible. It has also a function in connection with the skin, lubricating the skin and preventing the loss of water, but also hindering the absorption of aqueous substances through the skin. This includes the wax formed in connection with the hair, and the secretion of the eyelids. The ear wax is said to contain fat cells and cholesterol crystals together with a bitterned substance not yet named. The amount of oily matter secreted varies among animals according to the species and even among individuals being largest among the negroes.

The excretion of the sebaceous glands is concerned in the exchange of gases. The capillary vessels in the outer layer of the conum contain O and CO and as the epidermis is the only separation of the gases and sweat evaporation, the exchange takes place upon the bases of the loss of diffusion the CO being given off and the O being taken in to unite with the hemoglobin. Aqueous vapor, H₂O, is also excreted through the skin when the surrounding air is not saturated. It is only filled with such vapor. In the case of a frog whose lungs have been taken out of the water, the respiration continued for some time, O being taken in and CO₂ eliminated, the frog being able to breathe without lungs, the respiration being carried on by the skin. In the human subject this respiration is limited on account of the thickness of the skin. By the enclosure of the human body in a tight glass chamber it has been found that by shutting out the respiratory gases the quantity of CO₂ given off in a day amounts to from 6 to 10 grams, similarly from 0 to 10 grams of O₂.
THE KIDNEYS.

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The kidneys are excretory organs through which the urine is secreted and drained off from the body. Through them the nitrogenous waste of the body is excreted and the solid matters of the excretions are excreted chiefly through the urine, only a small quantity being thrown through the skin and almost none through the lungs. Thus, all the substances excreted through the urine except the faces, these substances vary considerably in quantity and in composition.

The normal urine is a clear yellowish, slightly phosphorescent fluid with a peculiar odor and a saline taste. It is acid in reaction, the acidity being due, not to a free acid but to the presence of an acid salt, phosphates of sodium, the degree of acidity depends upon the diet, being said to be in inverse proportion to the acid secretion in the stomach. Thus, it varies with the kind of food. After taking a meal, the urine may be neutral or nearly neutral, increasing after digestion in the stomach ends. In carnivorous animals it is stronger, concentrated, alkaline, if living on vegetables but if starving or living on animal diet then it is acid. When the food is animal there is more acid production than can be neutralized. When the food is vegetable there is less acid production sufficient to neutralize the acids. With a vegetable diet the urine becomes less acid, neutral, or even alkaline in reaction. When the gastric juice is being secreted as when food is taken into the stomach the acidity of the urine is decreased. As digestion becomes more complete the urine becomes again distinctly acid. On exposure to air the urine becomes more markedly acid, as fresh acid is formed by putrefaction and urates or uric acid

SECTION XI. THE KIDNEYS.

The kidney consists of a cortical and medullary part, the medullary part being formed into the pyramids of Malpighii conical shaped masses whose apex opens into the pelvis of the kidney. The cortical portion is soft and of a dark color. The secretion takes place largely in the cortical part after which it passes through the ureters and thence into the bladder. In the kidney we find a large number of tubules originating in a small sac constricted at the neck encompassing Malpighian bodies in the cortex, the tube in convoluted form running into the medulla, consisting of a descending and ascending portion. The ascending portion becomes spiral and forms the inter-calary tube and then straightens out into the excreting tube. These collecting tubules as they pass to the medullary part unite together forming larger tubes which become progressively larger in the papilla. These minute tubules vary in size at different points of the path, the smaller ones passing into the inter-calary ducts and finally into the wide collecting tubes. These tubes lie in the midst of loose areolar tissue, interstitial connecting tissue in the midst of which the minute blood vessels are found. The Malpighian corpuscles form a plexus of blood vessels, known as the glomerulus, which is accompanied by the expanded section of the uriniferous tubule terminating in Bowman's capsule. This capsule consists of two portions, the internal covering of the capillary and the external consisting of polygonal cells passing to the neck and forming the convoluted tubule wall. The small veins are formed by the fall of temperature in the kidney and prevent its being rapidly lost life may be prolonged.

The skin also absorbs heat rapidly and if the skin remains intact, it will not pass through the intact skin. There is evidence that even solid substances should not pass through the skin as solid particles rubbed into the skin if in a fatty medium become quickly absorbed in the lymphatics.

The formation of sweat is influenced by the same circumstances that influence the formation of other excretions, namely: (1) the supply of blood; (2) where cutaneous vessels are dilated, as when the surrounded atmosphere is warm the excretion of the skin is increased under opposite conditions the metabolism of the blood supply to the sweat glands upon the lower animals. The phenomena of increased sweat under excitation, as a well known example of these influences in connection with the higher centers. Similarly the local affection of pith with in pathologi cal condition there is not an excessive but a defective blood supply to the body perspiration.

SECTION XII. Urine Composition.

The kidneys are excretory organs through which the urine is secreted and drained off from the body. Through them the nitrogenous waste of the body with a considerable quantity of water, certain solids, and gases are excreted. The solid matters of the excretions of the body are excreted chiefly through the urine, only a small quantity being thrown through the skin and almost none through the lungs. Thus, all the substances excreted through the urine except the faces, these substances vary considerably in quantity and in composition.

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Urine Composition.

Urine is the fluid waste material excreted from the body through the urinary system. It is composed of a complex mixture of water, salts, and waste products. The composition of urine can vary depending on factors such as diet, hydration, and health status.

(1) Water.—The solid matter in the urine consists of about 1.5 percent of the total volume of urine. The solid matter varies with the specific gravity, and degree of dilution. The urine that has undergone the renal filtrate, the blood, and the kidney tissues. These consist of chlorides, phosphates, and various other substances.

(2) Inorganic Salts.—These consist of chlorides, phosphates, and various other substances. They are present in the urine in various amounts depending on the individual's dietary intake and hydration status.

(3) Gases.—The gases consist of carbon dioxide, nitrogen, and oxygen. The carbon dioxide is derived from metabolism and is normally present in urine. Nitrogen and oxygen are also present in small amounts.

(4) Pigments.—Urine is always colored. Urobilin, which is always present in urine, is derived from the breakdown of hemoglobin in the body. Other pigments, such as bilirubin and indican, are also present in small quantities.

(5) Nitrogenous Elements.—Aside from the special nitrogenous substances introduced along with the food, the urine contains the nitrogenous elements. These include urea, uric acid, and creatinine.

(6) Albumin.—Albumin is a protein that is found in the blood and urine. The presence of albumin in urine indicates kidney damage or dysfunction.

Sodium chloride is the most abundant, amounting to about 1 percent in normal conditions derived chiefly from salt taken in food. Phosphoric acid is derived from the breakdown of phosphorus-containing compounds in the diet and is excreted as phosphate in the urine. Calcium and magnesium are also present in small quantities in urine and are derived from the diet and bone turnover.

Hyperuricemia, the presence of excess uric acid in the blood, can be due to a variety of factors, including a diet high in purines, increased production of uric acid, or decreased renal excretion. In some cases, hyperuricemia can lead to the formation of uric acid stones. Urinary tract infections are another common cause of abnormalities in the composition of urine.
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URINE COMBINATION.

This, however, is not in the urine. If a precipitate containing phosphates and a ferments are entangled in fibrin by washing out, ferments may be secured that will convert starch into sugar and if hydrochloric acid is added the pepsin will escape into the urine.

(7) NON-NITROUS ELEMENTS.—Small quantities of various acids, tomatoes, etc., are used as food and in small quantities with any kind of diet. Ascorbic acid, butyric acid, formic acid, acetic acid, and lactic acid are also present normally in the urine.

The ferments are found to be amylolytic and proteolytic if the urine is cooled. The nature of the diet very much alters the urine; hence, if an animal is fed upon a diet rich in alkaline salts the blood is rich in these salts and this influences the urine. In the case of a mixed diet the urine is intermediate in character. Of the water excreted from the body in the human subject about 40 per cent is eliminated by the skin and lungs, and 60 per cent by the kidneys. If the diet is wholly or almost wholly animal flesh the amount of water excreted by the urinary system is increased to 70 per cent. If the quantity of urine excreted is increased the amount of solid matter eliminated will also be increased, urea being generally increased from 3 to 4 per cent. If the supply of water is cut off from the body the system the amount of urine is diminished normally about one fourth to one fifth. In the case of the use of drugs that are quickly dissolved, the substances in solution may be found very shortly after being taken, in the urine, for example, iodide of potassium.

(1) UREA. The chief organic constituent of urine is urea, \( \text{NH}_2\text{CO} \). It is generally regarded as an amide of carbonic acid. The average amount of urea excreted in 24 hours is about 30 to 35 grams. It is the principal nitrogenous waste excreted from the body. It contains about 46 per cent of nitrogen and contains less carbon in proportion to nitrogen than any other organic substance, the result of proteid oxidation. If we know the amount of urea excreted in a given time, we can estimate the amount of proteid destroyed in the process. The quantity of urea excreted depends principally upon the food and its nature. When an animal is starved the amount excreted is increased gradually diminishing until a minimum is reached before death takes place. The formation of urea takes place in the liver and as the blood in the renal vein has less urea than the blood in the renal artery, it is said that no urea is formed in the kidneys. Even after the kidney is extirpated, urea is still found in large quantities in the blood. It is brought to the kidneys for excretion in the blood, the epithelial cells taking it out of the blood and passing it to the tubular lumen for elimination. Containing, as it does, N it must be derived from proteid substances or from the albuminoid tissue elements or from nitrogenous proprimate principles of the food. The quantity of urea excreted is not influenced by muscular activity but is distinctly increased when a diet rich in albuminous materials is taken.

Hence, it is concluded (a) that muscle when actively working does not produce nitrogenous waste and that, therefore, its contractile activity is not accompanied by oxidation of its own substance in the form of N, but rather by the burning of certain carbohydrates and fats. The quantity of urine excreted is not influenced by muscular activity but is distinctly increased when a diet rich in albuminous materials is taken.

(b) A part of the proteid food material is in some way converted into urea. We have seen that the tryptase of the pancreatic juice converts some portions of the proteids in the food substance into leucin, tyrosin, etc. When leucin and tyrosin are introduced into the alimentary canal the amount of urea in the urine is increased, but no leucin appears in that fluid. There is, therefore,
good ground for believing that the leucin formed by the pancreatic juice in the digestive process is at least one of the sources of the urea of the urine. If leucin is not taken in the alimentary canal it will doubtless be absorbed and carried to the liver in which the urea is found. This substance is not problematically the proteic, nervous, glandular and glandular tissues of the body aside from the liver. This leads to the conclusion that one of the functions of the liver is to transform leucin, tyrosin, etc., into urea. This conclusion is strengthened by the fact that in acute atrophy of the liver, a diseased condition, in which the activity of the hepatic cells is seriously interfered with, the urea of the urine is replaced by leucin and tyrosin. We said before that muscle does not by its contraction increase the excretion of nitrogenous waste but that the processes which compose muscles, as well as those found in nervous and glandular and their tissues are the centers of constant metabolic changes involving changes which imply the formation of certain waste products such as kreatinin, xanthin, etc., which are to be regarded as resulting from the chemical changes connected with the existence and development of the reproductive system. These substances are more or less readily diffusible and will be carried off from the blood, ultimately reaching the kidneys, but the urine contains very little or no kreatinin. It was once held that the renal epithelium took up the kreatinin and converted it into urea, excreting it as such in the uriniferous tubules. It is now known, however, that the excretion of the kidney leads to the accumulation in the blood not of kreatinin but of urea. From this it is concluded that the formation of urea is not dependent upon or caused by the activity of the renal epithelium. As we have said, there are reasons for believing that the liver is actively engaged in the formation of the urea from leucin. It is concluded from this by analogy that the liver also contributes kreatinin into urea. If this is so, then the urea of the urine has a double source, being derived partly from kreatinin formed by the ordinary chemical changes taking place in connection with muscles and other tissues, and partly from the leucin resulting from the hydrolysis of the proteid food stuffs.

Both the kreatinin and leucin according to this would be changed in the liver and possibly by the spleen into urea and the function of the renal epithelium would be confined to gathering up the urea so formed from the blood and to the excretion of it into the uriniferous tubules. If the urea and other forms of nitrogenous waste should fail to be separated from the blood as we find in certain renal diseases, their accumulation in the blood and in the body will lead to convulsions and other symptoms, and under the term ammonia Leibig defended the theory of the derivation of urea from the muscles. Muscular activity he believed to be carried on at the expense of nonnitrogenous substances either taken from the food or from the tissues. The food stuffs of the proteins and fats either tissue forming or heat-producing, the former being albumin and the latter carbohydrates and fats. The albuminous matters he claimed was used in tissue building and in the production of muscular activity. Proteins, carbohydrates and fats by oxidation processes were converted into heat in connection with the formation of CO2 and H2O in the decomposition of nonnitrogenous matters urea and uric acid are formed while in the decomposition of nonnitrogenous matters CO2 and H2O are formed. If Leibig's theory is true muscular activity would increase the amount of urea and uric acid. Various experiments have been made to test this.

Pick and Wislicenus made an ascent of one of the Swiss Alps. For almost a day before ascending no nitrogenous food was taken, after which they spent 6 hours in ascending. They collected the urine (a.) prior to the ascent, (b.) during the ascent, (c.) 6 hours after the ascent, and (d.) after taking a meal of nitrogenous food, and (e.) during the following night. The work accomplished in ascending must have depended either upon nitrogenous food or albumin from the body. By estimating the work done and the energy produced by the albuminous materials it was found that less than 1 gram of albumin contained the energy expendied represented energy from the albumin. One gram of protein is estimated to yield 1.3 gram of urea. Part of the proteid nitrogen assumes other forms as uric acid and kreatinin so that we cannot accurately determine the proportion. This indicates that the urea did not correspond in any sense with the wastes of the muscles. It was found that by the use of nonnitrogenous foods there was a diminution of N excreted both during the ascent and the period of rest and by the use of nitrogenous food the amount of nitrogen excreted increased. The amount of work done in the ascent was much in excess of the nitrogenous changes measured by the excretion of urea. The muscular changes depend, therefore, upon the metabolism of carbohydrates and fats and not upon the changes taking place in connection with nitrogenous food. This view has been confirmed by others who have shown that muscular exercise involves the increase of CO2, a fact that depends upon the use of carbohydrates and fats in connection with muscular exercise. In addition it was found that there is found in connection with the muscular exercise small traces of urea. This amount not being increased by muscular effort or exercise and no increase taking place in the amount of urea circulating through the muscles. These points seem to negatice the theory of Liebig as to the muscle formation of urea leaving the liver as the chief if not the only source of urea.

Cryan made several experiments in transfusing blood through fresh liver at the temperature of the body finding an increase in the amount of urea after transfusion, some urea may have been washed out which already existed in the liver even in this case some must have been formed as there was an increase from .08 to .176 grams of urea.

Shroeder experimented upon the liver of a dog when fasting and during digestion. He found that in the former condition the liver is atrophied and that there is no urea increase was found, while in the latter condition there was an increase amounting to nearly 30 per cent. In addition to this it has been found that when the liver becomes atrophied urea disappears altogether. Liebig concluded that in the dissociation of albumin in connection with the tissues urea was formed. Experiments by various physiologists have negatice this theory, the amount of urea found in muscles being very small and muscular activity not tending to increase the amount of urea. The amount of carbonic acid is increased by muscular activity, the muscular energy being derived from nonnitrogenous food elements more largely, than that derived from nitrogenous food elements.

How is the urea formed? It is closely connected with the ammonia group and the process of hydrolysis, it being easily changed to ammonium carbonate. This arises from the proteids by hydrolysis and oxidation, in which ammonia compounds are formed, being carried to the liver and changed to urea. It was found that carbonic acid was found in the urine which and that ammonium carbonate could be converted into urea by deprivation of a molecule of water. According to him there are three processes: (a) Oxidation resulting in the loss of H. (b) Reduction in the loss of O and (c) dehydration resulting in the loss of water, the result being the production of urea. As the ammonium carbonate exists in the body, he claims that in this way urea is produced. It has been shown that by removing the liver of dogs the urea is decreased and the amount of carbonate is increased. It has been found recently
PHYSIOLOGICAL CHARACTERISTICS OF THE URINE.

that the amount of ammonia in the blood of the portal vein is three or four times that in the arterial blood, normally. It is claimed that these ammonia

that the liver has degenerated and a large amount of ammimia is found in the blood and produces fatal results. This amount of ammonia seems to be neutralized by the act of secretion. The ammonia carbonate arises originally from the proteids and albuminoid foods, Drechsel thinks these are subjected to hydrolysis forming CO₂, H2O, and NH₃, the CO₂ and NH₃ uniting to form ammonium carbonate which passes to the liver and forms urea. This forms the basis on which Dr. Drechsel is regard to the formation of urea. Urea is found in other body tissues may be changed to urea in other parts of the body.

Noel-Paton has shown that the bile secretion and the urea formation are directly related to each other. Therefore, he concludes that the chief source of urea formation is the destruction of the red blood corpuscles in the liver and in the spleen.

URIC ACID. It is found constantly in the urine but in smaller quantities than the urea. It is closely allied to urea and is a result of metabolical changes. It is a complex substance than the urea, one of the metabolic products of the disintegration of two molecules of oxalic acid. Next to urea, the most important element in the urine is uric acid. Normally, chiefly in combination with creatinin and xanthine is 5 mgm. per 100 grams of meat per day. It is probably the chief product of proteid metabolism, as the same quantities are the human subject that it has not been investigate as an intermediate stage in the metabolic changes in the proteids which immediately precede urea. It is formed from the uric acid. Xanthine and homoxicfic acid is produced from these by oxidation. Harbachewsky has shown this in the lymphoid tissue including the spleen there is a substance from which uric acid is formed. He thinks that uric acid represents a product of metabolism in connection with white blood corpuscles, and in as much as uric acid is formed in birds and reptiles and is produced in the liver. The creatinin is found in the case of birds, uric acid accumulates in the blood indicating that the kidney do not produce the uric acid. The removal of the liver, however, leads to the diminution of uric acid. Ammonium salts taking place, from this it is concluded that the proteid metabolism produces ammonium salts which are

carried by the liver and therefore transformed into uric acid. Uric acid can be produced from urea and glycogen, a large amount of ammonium salts are found in the urine in cases of liver atrophy and phosphorus poisoning. In certain physiological conditions such as fevers and leucocythemia there is an increase of uric acid. This last confirms the view of the formation of uric acid in connection with the white blood corpuscles. In human urine, it exists not as a free acid but as an acid salt in connection with potassium and sodium, ammonium and calcium. These salts are soluble in urine but when the urine cools they deposit as urates, later forming the uric crystals. If uric acid and urates are used to find several nitrogenous substances with the xanthine family which are found in the urine, in very small quantities. They represent a certain amount of proteid metabolism, but until something is known.

In connection with the waste of nerves and muscular tissue creatin is formed. Close related to it is creatinin which is found in the kidneys being always present in the urine. Creatinin is not formed by the creatin of creatinin does not take place in the blood so that it is probably transformed in the kidneys or at least in the urine as it is collected in the kidneys, creatinin occurs in urine in the human subject about one gram daily. It is closely connected with creatin, being secreted in the urine and being segbred from muscle food and eliminated as creatin. It is partly derived from muscle food and partly from the metabolism of the body tissues. Urea is not found in connection with the muscles, while creatin occurs in large quantities, this large quantity being transformed according to some into urea and into creatinin. Hyppnic acid is found in place of uric acid in the urine of herbo. Hpyppnic acid is a benzol and an acetic acid. It is bound in the protoplasm, it is 11 gm. per 100 grams of meat per day. It is always found in very small quantities in human urine to the extent of 3.5 mgm. per day. 1 g of creatinin is used this amount is increased. If benzoic acid is fed to animals hyppnic acid is found in the urine, the urine acid unifying with glyceral in the kidneys. The vegetables yield benzoic acid, and herbivorous animals are the chief of the new kidneys. The uric acid in the urine in the urine normally. The small quantity, however, found in the urine is probably produced from the proteid probably a product of protod metabolism, especially in the proteid putrefaction in the large intestines. In addition to uric acid, creatinin, and creatinin in the urine of the intact, with the creatinin and creatinin in the urine in the form of other. Phenol, indol, skatol and cresol are formed in the large intestine in connection with the decomposition of some of the fats of the food. The amount of these products is increased and excreted as such in the urine. Tyrosin is also excreted as such in the urine. Tyrosin is also excreted as such in the urine. Tyrosin is also excreted as such in the urine.
times to be excelled till death results. Phosphates are derived from the food elements and from the tissue metabolism. Sulphates arise from the albuminous decomposition. 

Various physiological phenomena have a bearing upon the urine. In the case of a child, the amount of urine is much larger in relation to size, also a larger proportion of urea and salts. In old people, the amount of urine is decreased and the solid substances are also diminished. The male excretes more urine than the female and the male urine is more fully supplied with solids. During sleep the urine accumulates, being more solid and having more of the pigments and acids. The excretion in connection with the skin uses up more of the water so that the solid matters are increased. The phosphates being increased and the other solid substances decreased. During pregnancy, the urine becomes deeply colored and manifests a greater density due to the presence of triple phosphate crystals, particles of fat and fungal organisms.

**SECTION XIV—Mechanism of the Excretion of Urine.**

The kidney is a compound tubular gland the ultimate terminations of the tubules; the glomeruli being lined by a layer of single squamous epithelium while the other parts of the glandular tract, for example, the convoluted tubules have an epithelium which is much more distinctly of a glandular character and which, from the shape and appearance of its cells we should expect to be engaged in the separation of materials from the blood. The blood reaches the kidneys through the renal artery immediately upon the arterial system, the branches of which pass into the substances of the kidney and by dividing ultimately form the afferent vessels to the glomerulus. In each glomerulus, the afferent pressure the breaks up into capillary loops which being reuniting from the efferent vessel. This being of smaller calibre the afferent; hence, the blood in the glomerulus is at a considerable pressure and the rate of the flow is slow. Under the influence of this pressure water containing highly soluble and fusible salts in solution filters through the walls of the capillary loops of the glomerulus and the epithelium covering the glomerulus into the Bowman's capsule. From there it passes into the convoluted tubules and is distributed over the surface of the convoluted tubules and it is believed that the large epithelial cells in these tubules extract from the blood in the glomerulus certain substances, the nitrogenous matters and perhaps also pigments and excrete them into the uriniferous tubules. As the blood passes through the tubules it is separated from the blood by the kidneys may be said to be the matter which after secretion in the kidneys is transferred by the urters to the bladder. This waste may take place by a transudation from the blood by the active secretion of the epithelial cells or both of these processes, and the process of secretion is dependent upon blood pressure. Increase in blood pressure producing an increased secretion. If the renal circulation becomes too slow indicating a great fall in blood pressure the secretion is arrested. The process of secretion by active or by osmotic pressure is considered in all cases. The rate of the flow assists in the secretion of the urine by bringing these substances into close contact with the cells and inducing activity upon the part of the secretory processes. The secretory processes, therefore, take place in connection with the cells, urea, uric acid, and salts, being first secreted in these cells, these being washed out by the water which is filtered in connection with the glomeruli. The cell activity, however, in reference to these substances depends upon the rapidity of the blood flow and upon the amount of water found in the blood. An increase, therefore, of the water or of the velocity of the blood flow will increase the urine secretion. The blood pressure in the small vessels of the
INNERVATION OF THE KIDNEYS.

The actions and influences of the central nervous system upon urine secretion and excretion is not well known, as very little investigation has been made in connection with the minute nerve connections of the kidney. The animal model for study has been the dog. The sacral nerves, which have fibers from the dorsal and upper lumbar region of the spinal cord, are stimulated, it produces vesical contractions chiefly in connection with circular fibers at the neck of the bladder. Thus, it is concluded that the longitudinal coating of the bladder is regulated by the circular fibers. The sacral nerves are located along the spinal column at the lumbar region of the spinal cord. In confirmation of this, it has been observed that when the urinary bladder is paralysed or inured in some way, this fact is true in both cases. The impulses all pass through the micturition center, which is regulated by the reflex action of the spinal cord. The bladder is emptied reflexly from sensorial stimulation. The afferent impulses in this case pass to the center in the spinal cord. The spinal cord is paralyzed or injured in some way. The same is true of micturition reflexes from sensory stimuli in this case pass to the center in the spinal cord. The urine is empty, there are found numerous and powerful contractions of the vesical walls which are purely involuntary. These are insufficient to empty the bladder, produces great pain sometimes. This is because the bladder is not paralyzed, but producing rhythmic contractions. From this it is concluded that micturition is involuntary in certain abnormal conditions. In the case of the spinal cord is paralyzed, or a reflex action is taken, the reflex contraction is affected. It is often stated that the bladder is not empty, as the uterus is obstructed, the involuntary bladder contraction may give rise to strong contractions sufficient to empty the bladder, but in other cases the fibers become more actively contracted. In this way the simple distention of the bladder is one of the factors in the bladder pressure increase. The bladder pressure is stimulated by the reflex action of the bladder muscles. The bladder contraction is affected by the reflex action of the bladder muscles. The same is true in both cases.
this is taken as the symptom of cerebral or spinal diseased conditions. The real reason is the effect produced upon the micturition center, either destroying its action or weakening its force. In cases in which we find in the excitement on the reflex center in the spinal cord, the outflow of the urine is due to the archaic nerves into the calices and are collected in the renal pelvis. It is then carried along the ureters partly by pressure, partly by the force of gravity and partly by peristaltic contractions of the muscular walls of the ureter is then discharged into the bladder. It is then ejected from the bladder through the urethra. When collected in the bladder its regurgitation into the ureter is prevented by the oblique manner in which the ureter is attached to the bladder and by the small valves formed by the vesicle mucous membrane at the mouth of each ureter.

If one of the ureters in the living animal is laid open and subjected to stimulation at a point along its path peristaltic waves may be seen originating at the point of stimulation and passing to the kidney and the bladder. Even when there is no stimulation applied artificially there are waves of contraction sometimes regularly and sometimes irregularly, these peristaltic contractions all moving in one direction depending upon the force and frequency of these contractions depending upon the urine excretion and secretion. That these contractions do not depend upon the presence, or action of urine, however, may be shown by the fact that these contractions occur when the kidney and ureter have been taken out of the body. These contractions seem to be of a muscular character and also rhythmic originating in the muscular coating of the ureter just as we found the muscular contractions of the heart. These do not depend upon nervous connections as when a portion of the ureter is entirely isolated at the center of the ureter in which no nervous connections exist, these contractions are found to take place. While these contractions are not caused by the urine excretion, they occur with greater frequency when the urine secretion is active, indicating that the degree of peristalsis of the renal pelvis and the ureter depend upon the secretion of the urine.

There are three layers in the walls of the ureter, the intima consisting of a mucous membrane inside of which is a muscular coating and outside a fibrous coating; connective tissue fibers constitute the tunica propria of the ureter. These fibers form a membrane in the midst of which are found cellular elements, the tunica propria passing into a submucous coat. The tunica propria is covered with stratified tesselated epithelium. In the pelvic portion of the kidney there are racemose glands and also in the upper portion of the ureter. The muscular layer consists of two coats or tunics, the outer being circular and the internal longitudinal. In the lower portion of the ureter there is a third layer or tunic consisting of the other two, consisting of longitudinal fibers. The same layers are found in the muscular coating of the ureter just as we found the muscular contractions of the heart. The muscular coating of the pelvis and ureter in the bladder there are also groups of general centers. The female urethra is lined with a mucous membrane whose tunica propria consists of delicate connective tissue with numerous capillaries at the external orifice. It is very vascular and contains a number of racemose glands. In the male urethra there are some differences. The epithelium of the prostatic portion is like the epithelium of the bladder, while in the membranous portion it becomes stratified cylindrical epithelium and in the cavernous portion the simple cylindrical epithelium. The flat stratified epithelium exist in the fossa navicularis. Probably the
Micturition.

urine is driven through the ureter by peristaltic contractions of the walls. If the bladder is only partially filled, the contraction may be sufficient to empty the bladder completely. In the case of a full bladder, the contraction may be insufficient to empty the bladder completely.

When the bladder is filled, the ureters are stimulated to contract, producing a peristaltic wave that moves along the ureters towards the bladder. This wave is initiated by the filling of the bladder, and it continues until the bladder is emptied.

The contraction of the bladder is under the control of the autonomic nervous system. The detrusor muscle, which lines the bladder, is responsible for the contraction. The contraction is initiated by the transmission of action potentials along the nerve fibers innervating the bladder.

The contraction of the bladder is initiated by the filling of the bladder, and it continues until the bladder is emptied. The contraction is spontaneously initiated by the filling of the bladder, and it continues until the bladder is emptied. The contraction is initiated by the filling of the bladder, and it continues until the bladder is emptied.