ANATOMY AND PHYSIOLOGY

OF THE

NERVOUS SYSTEM

BY

SEDGWICK MATHER, M. A.,

PROFESSOR OF NEUROLOGY, THE AMERICAN COLLEGE OF NEUROPATHY

JOHN JOSEPH McVEY

PHILADELPHIA

1909

PREFACE.

THE preparation of this work has been undertaken in response to what experience in the class-room has shown to be the need of a text-book especially adapted to beginners—a book giving, by itself, a concise, but complete, presentation of the physiology of the nervous system, together with the more important features of its anatomy. In dealing with the physiological phase of the subject, it has seemed best, viewed from the student's standpoint, to confine the statements mostly to the established and generally recognized facts, leaving the numerous theories—fully and admirably discussed in many contemporary works—to be taken up at a later stage of the study, after the facts have been acquired and mastered, this plan, it is found, being the most effective as a time-saver, and resulting in the clearest and most lasting impressions. The anatomical matter included in the volume is only that which seems most necessary for an intelligent understanding of the physiology, and of the most frequent service in clinical work, the general text-book on anatomy always being available for further details. Both the structure and the various functions of the sympathetic system have been set forth with a fullness commensurate with their importance. Of the whole work condensation has been the guiding principle.

S. M.

PHILADELPHIA, PA., *Sept.* 10, 1909.

CONTENTS.

PAGE

PART III.

INNERVATION OF THE SKELETAL PARTS OF THE BODY.

PAGE

PART IV.

THE SYMPATHETIC NERVES AND THE INNERVATION OF THE BLOOD-VESSELS AND VISCERA.

Chapter I.

Chapter II.

Chapter III.

Chapter IV.

LIST OF ILLUSTRATIONS.

PART I.

GENERAL STRUCTURE OF THE NERVOUS SYSTEM AND THE PHYSIOLOGY AND PROPERTIES OF NERVES.

ANATOMY AND PHYSIOLOGY OF THE NERVOUS SYSTEM.

PART I.

GENERAL STRUCTURE OF THE NERVOUS SYSTEM AND THE PHYSIOLOGY AND PROPERTIES OF NERVES.

THE nervous system consists of a *central part*, which comprises the brain and spinal cord, and a *peripheral part*, which comprises twelve cranial nerves, thirty-one spinal nerves and the sympathetic system, the cranial and spinal nerves being arranged in pairs.

The tissue of the nervous system, as a whole, falls into two general classes, *nerve-cells* and *nerve-fibers*. Nerve-cells are found in the brain and spinal cord and in outlying ganglia. Nerve-fibers are present in all parts of the nervous system.

The nerve-tissue of the brain and spinal cord is divisible into two kinds, distinguishable by their color. These are *the gray matter* and *the white matter*. The gray matter is characterized by the presence of nerve-cells. The white matter consists of nerve-fibers. In addition to the nerve-tissue, the brain and spinal cord contain a special type of connective-tissue, termed *neuroglia*, which serves as support for the nerve-tissue.

The cell of nerve-tissue is known as *the neuron*.

Ganglia.

A group of nerve-cells situated outside the substance of the brain or spinal cord, is surrounded by a fibrous sheath, and known as a ganglion. From the functional standpoint a ganglion may be either *sensory* or *sympathetic*. Sensory ganglia are found on the posterior or afferent roots of the spinal nerves, on the trunks of the fifth, seventh, ninth and tenth cranial nerves, and at the peripheral end of the auditory nerve. Sympathetic ganglia are situated along the course of the nerves and in the tissues of many of the visceral organs. In size ganglia vary, the smallest being of microscopic dimensions and the largest an inch or more in length.

Structure of the Neuron.

The neuron is the anatomical unit of the nervous system. It consists of a central part, or *nerve-cell*, with more or less elongated outgrowths of its substance called *processes*. The processes are of two kinds, *axis-cylinder processes* or *axons*, and *dendritic processes* or *dendrites*. The so-called typical neuron has a single axis-cylinder process, which is often of considerable length, and several dendritic processes, which are always branching and microscopically short. There are, however, many neurons with but two processes, both of which are of the axis-cylinder type. Running through the processes, as well as the nerve-cell, are minute threads of nerve-tissue, termed *neurofibrils*, which constitute the conducting part of the neuron.

The *nerve-cell* contains a nucleus, and very often a nucleolus. The nerve-cell and the dendrites also contain many small particles of matter known as *chromophile material*, or, more commonly, as *Nisl's granules*. This substance is believed to serve as nutrition for the neuron. In lesions of the neuron involving a loss of function, the chromophile material breaks up into finer particles, and sometimes dissolves and disappears, the process being known as *chromatolysis*.

The axis-cylinder process is always surrounded by either one or two sheaths. These are the *medullary* or *myelin sheath*, and the *primitive sheath* or *neurilemma*. The medullary sheath is of a color approaching white, and is composed of a soft, fatty substance called *myelin*. This sheath is formed in segments, which are practically uniform and a millimeter or less in length. The intervals between the segments, where the myelin is interrupted, are known as *the nodes of Ranvier*, and the segments are known as *internodes*. The neurilemma is a thin, net-like membrane, of an elastic nature and a somewhat firm consistency. This sheath forms a continuous covering. On its inner surface are nuclei, corresponding in number to the segments of the myelin sheath (where the myelin sheath is present), and in position to the nodes of Ranvier.

Nerve-fibers.

An axis-cylinder process with one or both of the sheaths described above constitutes a nerve-fiber. An axis-cylinder process with either a myelin sheath alone, or with a myelin sheath and a neurilemma, constitutes a *medullated* or *white* fiber. An axis-cylinder process with only the neurilemmal sheath, constitutes a *non-medullated* or *gray* fiber. Nerve-fibers vary in length from a small fraction of an inch to three feet or more, and in diameter from two-millionths to twenty-millionths of a meter, the largest fibers being found in the spinal nerves, and the smallest in the sympathetic system.

All fibers in the olfactory nerve, and the greater part of those in the sympathetic system, have only the neurilemmal sheath. All fibers in the optic and auditory nerves and in the gray and the white matter of the brain and spinal cord have only the medullary sheath. But in all the spinal nerves and in all the cranial nerves, except the olfactory, optic and auditory, both sheaths are almost invariably present. In some cases both sheaths are also found in the sympathetic system.

Classification of Nerve-cells According to their Processes.

Nerve-cells are classified as bipolar or multipolar, according to whether their processes consist of two axis-cylinders, or of one axis-cylinder and dendrites.

The bipolar cells form the ganglia of the posterior roots of the spinal nerves and the ganglia of the trifacial, facial, auditory, glosso-pharyngeal and pneumogastric nerves. The two processes of a bipolar cell coalesce and leave the cell as an apparently single process, but they soon separate and run in opposite directions, one entering the central nervous system, and the other running outward in a peripheral nerve. From the functional standpoint the bipolar cells are sensory cells, and they furnish all the sensory fibers of the nervous system, except those of the olfactory and optic nerves.

The multipolar cells are of two kinds, Golgi cells of the first type and Golgi cells of the second type, distinguished by the behavior of their axons.

The cells of the first type are characterized by an axon that leaves the gray matter in which it arises and forms a single nerve-fiber. These cells are the source of all the fibers in the white matter of the brain and spinal cord, of the efferent fibers in the cranial and spinal nerves and of the fibers in the sympathetic system. *The cells of the second type* are characterized by an axon that divides into several branches, the course of which is confined to the gray matter in which they arise. These cells are found only in the central nervous system, and principally in the cortex of the cerebrum. The branches of the axons all terminate in contact with other neurons, so that the impulses received by these cells are often widely distributed. They are frequently described as "association nerve-cells," in consequence of their role in the higher activities of the brain.

Structure of Nerves.

The fibers that enter a peripheral nerve are grouped in bundles or *funiculi* and held together by connective-tissue. The tissue which surrounds each funiculus is called *the perineurium*, that which extends among the fibers of the funiculus is called *the endoneurium*, and that which envelops the whole nerve is *the epineurium*. The perineurium and the endoneurium are continuous with each other. The epineurium contains the lymph channels and the larger blood-vessels, and is supplied with sensory nerves termed *nervi nervorum.* The branches of the blood-vessels wind among the funiculi, and the capillaries enter the funiculi and wind among the fibers. When a funiculus divides, the perineurium is continued over the new bundles, but grows thinner with each successive division. Around each of the terminal divisions it forms a thin envelope known as *the sheath of Henle.*

Functional Classification of the Fibers of the Peripheral Nerves.

The activities of nerve-fibers are carried on under the influences of external agencies or stimuli. When a nerve-fiber is acted upon by an external agency, that is, when it is stimulated, a movement is started at the point affected by the stimulus and the movement is propagated along the fiber. This movement, whatever it may be, is called *an impulse*, and its propagation along the fiber is termed *conduction.*

A nerve-fiber normally conducts in only one direction. In the fibers of the peripheral nerves conduction is either from the central nervous system to other parts of the body, or from other parts of the body to the central nervous system. The peripheral fibers, therefore, are of two general classes: *efferent fibers,* whose conduction is outward or centrifugal; and *afferent fibers,* whose conduction is inward or centripetal.

The efferent fibers consist of the following groups:

(1) **Motor Fibers.**—These are distributed to muscles, both voluntary and involuntary, and the effect of their activity is muscular contraction. The motor fibers of the involuntary muscles are divided into three sub-classes: *the viscero-motor fibers,* which supply the visceral organs; *the pilo-motor fibers,* which supply the erector muscles of the hair, and *the vaso-constrictor fibers,* which supply the arteries.

(2) **Inhibitory Fibers.**—These are distributed to the

visceral organs, where they are known as *viscero-inhibitory fibers*, and to the arteries, where they are known as *vaso-dilator fibers.* The activity of this class of fibers is manifested only in muscles in a state of contraction, and in these it produces a lessening of contraction or relaxation.

Note.—The efferent fibers of the arteries are known collectively as *vaso-motor fibers.*

(3) **Secretory Fibers.**—These fibers have been physiologically demonstrated in connection with some of the glands, particularly the salivary and gastric glands and the pancreas and sweat glands. The secretory fibers of the sweat glands are derived from the spinal cord and reach the glands by way of the cutaneous nerves, but those to all other glands reach their destination in the nerves that supply the vaso-dilator fibers.

(4) **Trophic Fibers**—The normal nutrition of all tissues is dependent upon their connection with normally acting nerves. But trophic nerve-fibers, or fibers whose exclusive function is the regulation of nutrition, have not as yet been anatomically separated, nor is there conclusive physiological evidence that such fibers form a distinct class. Nutrition is in intimate association with blood-supply. In disorders of nutrition accompanied by hypertrophies it is commonly observed that the blood-supply is increased, and in atrophies that the blood-supply is diminished. From these and other similar observations it is evident that the fibers controlling nutrition, even if they have an independent existence, are at least in close functional relation with the vaso-motor nerves. Until fibers of a strictly trophic function have been discovered, it may be assumed that the vaso-motor fibers are the main nervous factors in nutritional control.

The afferent fibers are distributed to all classes of peripheral tissues and to the cerebral and spinal meninges. These fibers are so connected at the nerve-centers that the final effect of their impulses is manifested both as reflex action in the periphery and as sensation in the brain. They are commonly known as "sensory nerves," and, in most cases, they each mediate a distinct and characteristic kind of sensation. They are classified with the different sense-organs, of which they form the conducting parts.

Irritability and Conductivity.

The term irritability signifies the property or attribute in consequence of which living animal tissue may be made to manifest or modify its regular functional activities under the influences of external agences or stimuli. The term conductivity is used to designate the power which tissue possesses of conducting through its substance the effects produced upon it by an external agency acting at a given point. These properties are common, in some degree, to all tissues, but attain their highest development in the tissues of the nervous system, where they constitute indispensable conditions of activity. Both properties may be modified by various means, being increased, for instance, by moderate heat, and diminished by moderate cold, while by very high or by very low temperatures they are entirely suspended. They are also affected, in the way of reduction, by anæsthetics, narcotics and mechanical compression.

Nerve Stimuli.

The regular activities of nerves are carried on under the influences of what may be termed their normal stimuli, in contradistinction to stimuli employed artificially.

The normal stimuli vary for different nerves, the optic nerve being stimulated by light waves, the auditory nerve by sound waves, the olfactory nerve by odoriferous substances in the form of gas, and the gustatory nerves by sapid substances in solution, while the other afferent nerves are stimulated by such agencies as pressure, heat, cold, etc., according to the special stimulus to which they are each adapted, by their peripheral endings, to respond. The normal stimuli of the afferent nerves act first on the structures in which these nerves have their peripheral terminations, that is, on the sensory end-organs, and these in turn act on the nerve-fibers. The efferent nerves are normally stimulated at the nerve-centers, either by an inflow of impulses through the afferent nerves, or by impulses originating in the cortex of the cerebrum or other parts of the brain.

The artificial stimuli capable of affecting the activity of nerves are of four kinds, chemical, electrical, thermal and mechanical. Any of these agencies applied to a nerve will produce some change in the activity of its fibers, depending on the manner in which they affect one or both of its properties of irritability and conductivity.

Nerve Impulses.

In the efferent nerves of the voluntary muscles the impulses are transmitted with a velocity approximating one hundred and twelve feet per second, and discharged from the nerve-centers at an average rate of ten per second. The rate of discharge, however, varies in different individuals, in different nerves, and in the same nerve under different circumstances, a rate as high as twenty or more per second not being uncommon in some of the finer and more delicate muscular movements. The strength of the motor impulses may be modified at will, within certain limits, and both the strength and velocity may be affected by any of the agencies that produce alterations in the irritability and conductivity of nerves, being either increased or decreased according to the action of the agency on these properties. The strength alone is sometimes modified in the same ratio as the intensity of the stimulus, though this is not an invariable rule. Very frequently the intensity of the stimulus and the movement it provokes are out of all proportion.

So far as known the quality of nerve impulses is the same in all nerves, and the different effects which they produce in nerves of different functions is due to a difference either in the mode of ending of the nerves or in the kind of tissue in which they end. Motor and inhibitory nerves, for example, conduct the same kind of impulses, but produce different effects on muscle because they end differently in the muscle-cells, and afferent and efferent nerves produce different effects because of a difference in their terminal tissues.

Nerve Degeneration and Regeneration.

A nerve-fiber is a branch of a nerve-cell and dependent for its nutrition and physiological integrity upon connection with the cell from which it originates. Any part of a nerve-fiber cut off from its cell soon degenerates and dies. In a peripheral nerve when cut the fibers on the distal side of the section break up into fragments and are finally absorbed by the lymphatics. But during this process the nuclei of the neurilemmal sheath multiply and, in the place of the original fiber, form a new strand of protoplasm called *an embryonic or band fiber.* If connection is now established between the band fiber and the central stump of the original fiber, the band fiber, brought under the nutritive influence of the nerve-cell, eventually develops into a complete new nerve-fiber, of which the axis-cylinder process is believed to be a development from the central stump.

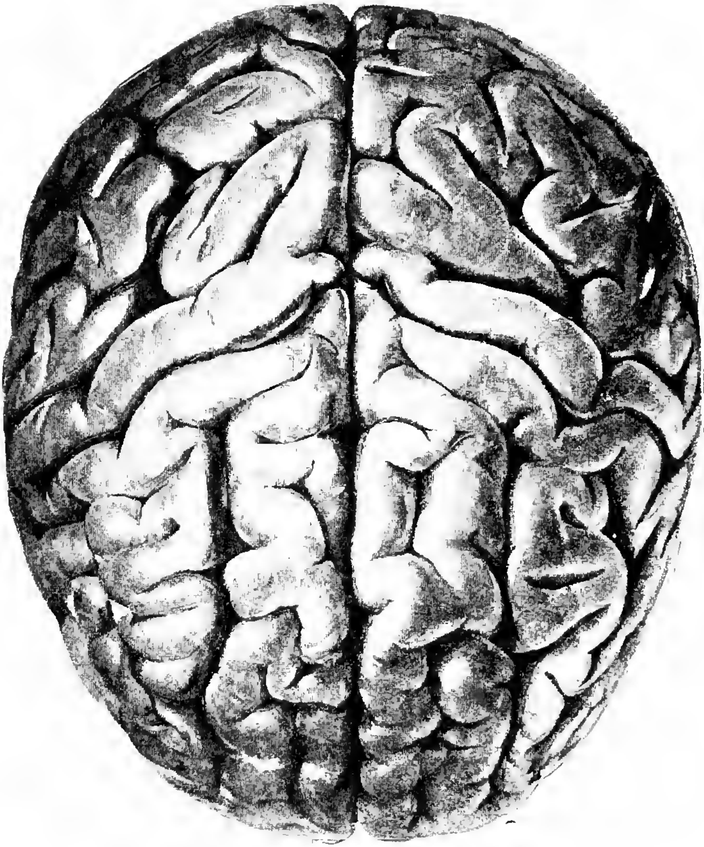
On the central side of the section the fiber undergoes degeneration for a few internodal segments, but regenerates again in the same way as the fiber on the peripheral side. The nerve-cell is also affected, undergoing swelling and a loss of Nisl's granules. These changes begin almost immediately after the section and continue for about three weeks, when restoration begins and the cell finally regains its normal condition. In course of time, however, unless the fiber is restored and its functions resumed, both the cell and the attached segment of fiber undergo degenerative changes that are chronic, or what is known as *atrophy from disuse.*

Regeneration of nerve-fibers is confined to the periphery. In the central nervous system, where the neurilemmal sheath is lacking, regeneration never takes place.

PART II.

THE STRUCTURE AND FUNCTIONS OF THE CENTRAL NERVOUS SYSTEM.

PLATE 1.



The cerebrum viewed from above.—(Modified from Spalteholz.)

CHAPTER I.

THE CEREBRUM.

THE cerebrum is the largest and uppermost part of the brain and occupies the greater part of the cranial cavity. It consists of lateral halves, called hemispheres, between which is the longitudinal fissure. In front and behind, this fissure forms a complete separation, but at the middle two-fourths of its lower half it is interrupted by the corpus callosum, which extends from one hemisphere to the other and forms their chief connecting bond. Below the corpus callosum the separation is continued by the third ventricle, a narrow, vertical crevice bounded on each side by the optic thalamus. Each hemisphere presents three surfaces, the mesial, the outer and the lower. The mesial surface is flat and the outer surface is convex. The lower surface is of varied conformation. Its front part, which lies in the anterior cranial fossa, is flat and horizontal. Its middle part, which lies in the middle cranial fossa, is irregular and slopes downward and outward from the median line. Its hind part, which overlies the cerebellum, is irregular and sloping.

THE GRAY MATTER OF THE CEREBRUM.

The gray matter of the cerebrum comprises the cortex, which covers the surface of each hemisphere, and several masses embedded in the hemispheres at their base. These latter are the amygdala, the caudate nucleus, the lenticular nucleus, the claustrum and the optic thalamus.

The Cortex.

The cortex is arranged in more or less distinct layers, the cells of which vary in size and form and in the destination of their processes.

The first or molecular layer, lying at the surface, contains small cells the processes of which run in the gray matter and end in the layer in which they arise. Their dendrites receive the terminal arborizations of fibers coming from other regions, and their axons arborize either about cells of their own layer or about the dendritic processes that extend outward from cells in the layers underneath. These cells may be considered as the receivers and distributors of impulses, many of the impulses received coming through afferent neurons and being distributed to efferent neurons. They are classed as association cells and are generally considered as the part of the brain in which the higher and more important mental processes are mediated.

The second layer contains small cells, pyramidal in form, with the apex directed towards the surface. Their dendrites arise from the apex and end in the molecular layer. Their axons arise from the base and terminate somewhere in the gray matter, many of them dividing into branches that run at right angles to the main stem.

The third layer, also, contains pyramidal cells, but of a larger type than those in the second layer. Their dendrites extend outward and end in the first layer, but their axons enter the white matter of the interior of the hemispheres, those that arise in the motor areas ultimately forming the pyramidal tracts in the spinal cord.

The fourth layer is composed of small cells of irregular and varied conformation, the processes of which, both dendrites and axons, terminate in the gray matter of the cortex.

The fifth layer contains small, irregular cells, the dendrites of which terminate in the pyramidal layers, while their axons enter the white matter of the interior.

The Amygdala and the Caudate Nucleus.

The amygdala is a small, thickened area of the cortex, lying at the apex of the temporal lobe, not far from the under surface of the hemisphere. Continuous with it is a narrow, oval-shaped band of nerve-tissue, which forms *the caudate nucleus.* This at first runs backward in the lower part of the lateral ventricle. Then curving upward to the roof of the ventricle, it runs forward to the front of the ventricle and expands into a large pyramidal mass, which forms *the lenticular nucleus.* On its median border is a band of nerve-fibers termed *the tænia semicircularis.*

The Lenticular Nucleus.

The lenticular nucleus, extending deeply into the substance of the hemispheres, presents a rounded base that faces outward, and an apex that points inward. In front and below, it is continuous with the caudate nucleus, but in other parts it is separated from it by a thick layer of fibers, which forms *the internal capsule.*

The Claustrum.

The claustrum is a thin layer of polymorphic cells which have become separated, by a layer of white matter, from the island of Reil. It is situated outside the lenticular nucleus, and is continuous with it at the anterior part of its lower border. In other parts the two structures are separated by *the external capsule.*

The Optic Thalamus.

The optic thalamus is the largest of the gray masses. It is situated farther back than the lenticular nucleus, and is separated from it by *the internal capsule.* Though embedded, for the most part, in the hemisphere, its flat, mesial surface forms a side wall of the third ventricle, and a part of its rounded, upper and posterior surfaces lies under the ventricular roof. On its upper surface, in front, is a small elevation, called *the anterior tubercle*, and on the rear of this surface is another prominence which continues back to the posterior surface and is known as *the pulvinar.* The two thalami are connected by two commissures: *the middle*, which crosses the third ventricle at about its center; and *the posterior*, which crosses farther back.

THE FISSURES, LOBES AND CONVOLUTIONS OF THE CORTEX.

The surface of the cortex presents many grooves or fissures, which, though not unvarying, are of sufficient regularity to serve as the boundary lines of fairly uniform and constant divisions. These fissures divide the surfaces of the hemispheres into lobes, and the lobes into convolutions or gyri.

The Outer Surface.

Three fissures, the central, Sylvian and parieto-occipital, divide the outer surface into the frontal, parietal, occipital and temporal lobes.

The central fissure or the fissure of Rolando begins at about the middle of the upper margin of the hemisphere and runs downward and a little forward, dividing the surface into two nearly equal parts.

The Sylvian fissure, beginning about the middle of the lower surface and extending upward and backward as a deep cleft, cuts through to the outer surface and forms the anterior and the posterior limb. The anterior limb is short and runs forward ; the posterior limb is much longer and runs upward and backward, ending about two-thirds of the way from the front to the back of the hemisphere and about half way from the vertex to the base.

The parieto-occipital fissure begins far back on the upper margin of the hemisphere and runs downward and forward on the mesial surface, cutting off a triangular area at its posterior end. On the outer surface it is conceived as an imaginary line running in the same plane with the fissure and ending at the pre-occipital notch.

The frontal lobe comprises the area lying in front of the central fissure and above the Sylvian. Its convolutions are the pre-central and the first, second and third frontal. The pre-central convolution is situated in front of the central fissure, occupying a narrow, elongated area that extends from the posterior limb of the Sylvian fissure to the upper margin of the hemisphere. Its anterior boundary is the pre-central fissure. The first frontal convolution lies along the antero-superior margin of the hemisphere, with the second and third convolutions in numerical order below. The third convolution extends down to the Sylvian fissure, the anterior limb of which it contains.

The parietal lobe is an area of somewhat irregular outline, extending from the central fissure back to the parieto-occipital line and from the posterior limb of the Sylvian fissure to the superior margin of the hemisphere. Its convolutions are the post-central, superior parietal, supra-marginal and angular. The post-central convolution—an area of about the same dimensions and conformation as the pre-central—lies along the posterior side of the central fissure; the superior parietal convolution, along the upper border of the hemisphere; the angular convolution, in the postero-inferior angle of the lobe, and the supra-marginal convolution, above the termination of the posterior limb of the Sylvian fissure.

The occipital lobe is the triangular area lying behind the parieto-occipital line. Its convolutions are the first, second and third occipital, numbered from above downward.

The temporal lobe lies in the lower part of the hemisphere, with the frontal and parietal lobes above and the occipital lobe behind. Its convolutions are the first, second and third temporal. The first convolution is situated along the lower border of the Sylvian fissure, with the second and third convolutions running parallel with it below.

The Mesial Surface.

The lobes of the mesial surface are the frontal, parietal and occipital, all of which are continuations of the corresponding lobes from the outer surface.

The frontal lobe is here continued in the marginal convolution, which runs along the lower, front and upper margin of the hemisphere, to a point a short distance behind the beginning of the central fissure. In the posterior end of this convolution is a small quadrangular area described as the para-central convolution. It extends beyond the frontal lobe and invades the territory of the parietal.

The parietal lobe is continued on to the mesial surface in the pre-cuneus convolution, a quadrangular area that lies behind the para-central convolution and extends back to the parieto-occipital fissure.

The occipital lobe is continued in the cuneus, a triangular area bounded by the parieto-occipital fissure above and by the calcarine fissure below, the two fissures meeting and forming the apex of the triangle.

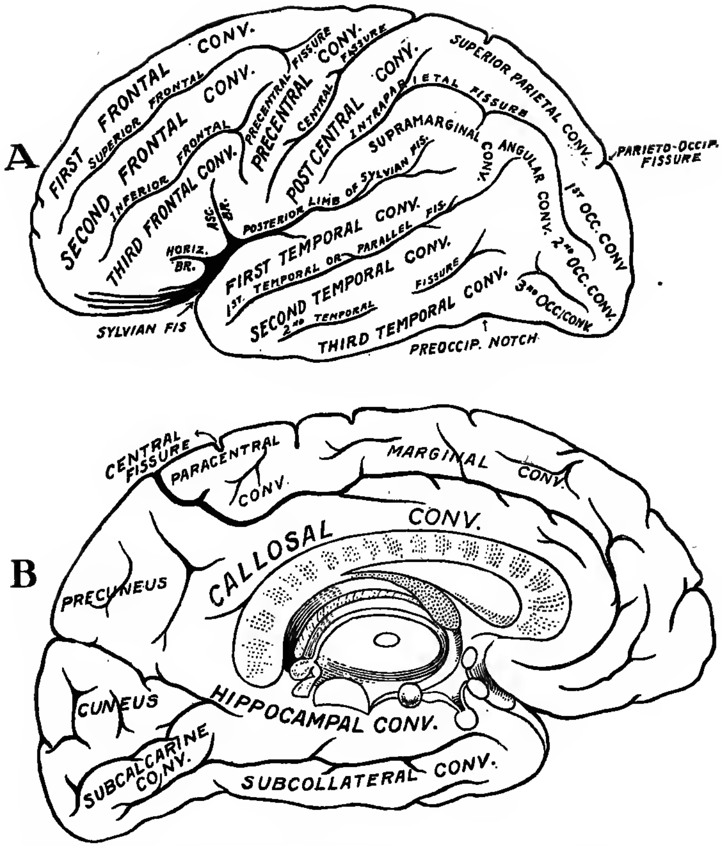
The remainder of the mesial surface is occupied by the callosal convolution, which runs along the free surface of the corpus callosum, separated from the marginal convolution by the calloso-marginal fissure. Its posterior end is continuous with the hippocampal convolution, of the lower surface, and the two convolutions form what is sometimes termed the limbic lobe.

The Lower Surface.

On this surface the first, second and third frontal convolutions are continued from the outer surface and extend back as far as the Sylvian fissure, the first convolution lying next to the great longitudinal fissure, and the others running parallel with it at its outer side.

The remainder of this surface is occupied by the temporal lobe and is often designated as the tentorial surface, from its

PLATE 2.



Diagrammatic representations of the fissures and convolutions of (A) the outer surface and (B) the mesial surface, of the cerebrum, left hemisphere.

resting on the tentorium, which lies between the cerebrum and the cerebellum. Its convolutions are the hippocampal, subcalcarine, subcollateral and third temporal. The hippocampal convolution borders the central region and extends from the rear end of the corpus callosum to the Sylvian fissure. The subcollateral convolution lies below the hippocampal and is separated from it by the collateral fissure. The subcalcarine convolution lies below the cuneus, from which it is separated by the calcarine fissure. The third temporal convolution is a continuation of the same convolution from the outer surface.

The Insula.

The insula, otherwise known as the central lobe or the island of Reil, is a part of the hemisphere which, in early foetal life, was superficial, but which was later crowded to the interior by the more rapid development of the surrounding tissues. It is situated externally to the claustrum and separated from it by a layer of white matter. Its cortex looks towards the surface of the hemisphere and is marked off from the adjacent tissues by the circular fissure. It presents five convolutions, named numerically.

THE INTERNAL CAPSULE.

The internal capsule is a narrow, fore-and-aft slit in the base of the hemisphere, through which nerve-fibers pass on their way to and from the cortex of the cerebrum. It is bounded externally by the lenticular nucleus, and mesially by the caudate nucleus and the optic thalamus, and its general direction from above is downward and towards the median line. Near its middle is a bend formed by the rounded apex of the lenticular nucleus and known as *the genu*, which divides the capsule into *an anterior* and *a posterior limb.* Within the hemisphere the fibers that pass through the capsule spread out in nearly every direction towards the cortex, forming what is known as *the corona radiata.*

THE EXTERNAL CAPSULE.

The external capsule, smaller than the internal, lies between the lenticular nucleus and the claustrum. It is composed in part of afferent fibers entering the cerebrum and in part of commissural fibers derived from the anterior commissure.

THE ANTERIOR COMMISSURE.

The anterior commissure is a bundle of fibers that connects the front part of the temporal lobes. It crosses the median line a little below and behind the front part of the corpus callosum, and then, curving downward and backward, passes through the lenticular nucleus to the external capsule, from which it spreads out in the temporal lobe.

THE CORPUS CALLOSUM.

The corpus callosum is a solid band of commissural fibers that run transversely and connect the corresponding parts of the cortices of the hemispheres. These fibers consist to a large extent of the axis-cylinder processes of cortical cells, but they also comprise many collaterals from the efferent projection fibers that pass through the internal capsule. They connect all parts of the cortices except those connected by the anterior commissure. The corpus callosum, into which they are compressed as they cross the longitudinal fissure, has a fore-and-aft measurement of about five inches and a thickness of nearly an inch at the ends, but less in other parts. In front it curves downward and backward and forms *the genu.* The genu grows thinner as it continues backward and finally presents a sharp extremity, called *the rostrum.* The rear end bends downward and forms *the splenium.* The intermediate part is *the body.* From each side the fibers radiate to the various parts which they connect. The fibers that make up the genu radiate in the frontal lobe and form *the forceps anterior;* those that make up the splenium radiate in the occipital lobe and form *the forceps posterior;* those that form the body radiate in the remaining parts, and those passing to the temporal lobe form a plate called *the tapetum.* These commisural fibers interlace with the projection fibers, and the two sets of fibers constitute the white matter of the interior of the hemisphere.

THE ASSOCIATION FIBERS.

The association fibers connect different parts of the cortex and associate its various activities, their origin, course and destination all being in the cortical gray. They are grouped in bundles, which vary in length from those connecting adjoining convolutions to those connecting different lobes. The longer of these bundles are the following :

(a) *The uncinate*, connecting the third frontal convolution with the uncinate process of the hippocampal convolution.

(b) *The superior longitudinal*, connecting the middle of the frontal lobe with the upper part of the occipital lobe and the anterior part of the temporal lobe.

(c) *The inferior longitudinal*, connecting the anterior part of the temporal lobe with the lower part of the occipital lobe.

(d) *The striæ longitudinales*, running in the callosal convolution and connecting the Sylvian region in front with the hippocampal convolution behind and below.

(e) *The fornix*, connecting the optic thalamus with the uncinate process of the hippocampal convolution.

Structure of the Fornix.

The fornix is situated under the corpus callosum, attached to its under surface behind, but separated from it above and in front by the septum lucidum. It consists of lateral halves united in the middle, the union of these parts forming the body of the structure. In front it takes a curving course downward and forward, and the halves, becoming separated, form the anterior pillars. Each pillar continues the curving course and finally reaches the under surface of the cerebrum.

Here the pillar bends on itself and forms a loop known as *the corpus albicans* or *the corpus mammillare*, after which it runs upward as *the bundle of Vicq-d'Azyr* and ends in the optic thalamus. The halves, also becoming separated behind, here form the posterior pillars. These are connected with each other by a thin band of fibers, called the lyra, and externally they are bordered by fibers that continue along the body of the structure and form the fimbria. Each pillar bends downward, backward and outward and then runs forward, ending in the hippocampal convolution and the neighboring gray.

THE SEPTUM LUCIDUM.

This structure, which lies between the fornix and the corpus callosum, forms the partition between the lateral ventricles. It consists of two thin layers of nerve-tissue, an outer of white and an inner of gray, inclosing a narrow crevice, which contains serous fluid and has no communication with any other cavity of the brain.

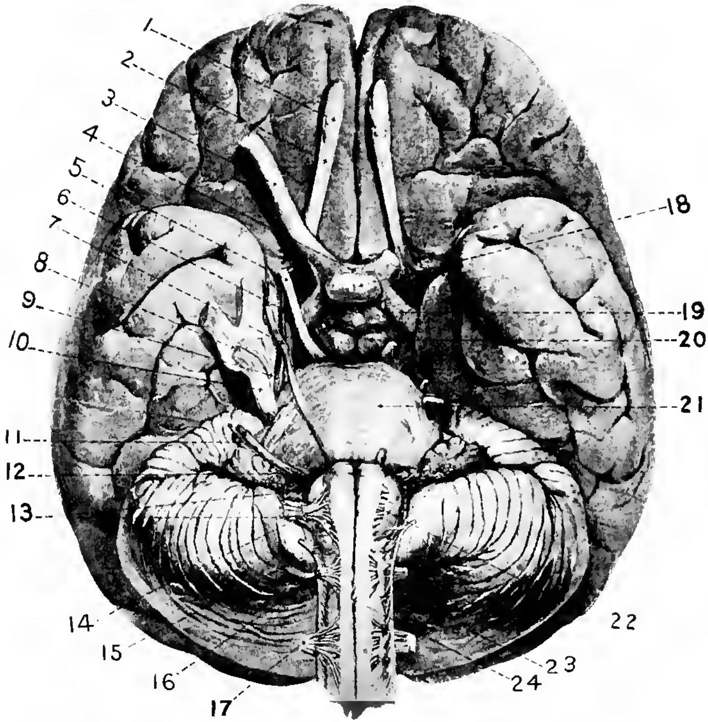
THE LATERAL VENTRICLES.

In each hemisphere of the cerebrum is an irregularly shaped cavity extending in a general fore-and-aft direction and forming the lateral ventricle. It consists of a main part or body, with a forward and outward projection in front, called the anterior horn, a backward projection behind, called the posterior horn, and a third projection which extends downward, outward and forward and forms the middle horn. Each lateral ventricle communicates with the third ventricle by means of an opening situated near the front of the body and known as the *porta* or *the foramen of Munro.*

THE THIRD VENTRICLE.

This is a narrow, vertical crevice, situated below the fornix and in line with the longitudinal fissure. It is bounded in front by the anterior pillars of the fornix, above by the body

PLATE 3.



The brain as seen from below and in front: 1, olfactory bulb; 2, olfactory tract; 3, optic nerve; 4, optic chiasm; 5, oculomotor nerve; 6, trochlear nerve; 7, abducent nerve; 8, Gasserian ganglion; 9, 10, trifacial nerve; 11, auditory nerve; 12, facial nerve; 13, glosso-pharyngeal and vagus nerves; 14, hypo-glossal nerve; 15, spinal accessory nerve; 16, first cervical nerve; 17, second cervical nerve; 18, hypophysis; 19, optic tract; 20, corpus albicans; 21, pons; 22, oblongata; 23, cerebellum; 24, decussation of pyramids.—(Modified from Spalteholz.)

of the fornix, and laterally by the optic thalami. Behind it are the epiphysis, the posterior end of the callosum, the posterior commissure, and the opening of the aqueduct which connects it with the fourth ventricle. It is crossed by the middle commissure, and in the front part of its floor are the corpora albicantia and the hypophysis.

PHYSIOLOGICAL AREAS OF THE CORTEX.

(1) **The Motor Area,** which controls the voluntary movements, extends over the para-central and pre-central convolutions. The uppermost part of this area—the para-central convolution and the upper end of the pre-central—controls the movements of the legs and trunk; and below this come in succession the areas that control the movements of the arm and hand, the neck, the head and eyes, and the face, mouth and throat. Through the axons of its pyramidal cells, this area is connected with the motor nuclei of the cranial nerves and with the efferènt spinal neurons whose fibers are distributed to the voluntary muscles.

(2) **The Sensory Areas** are the cortical terminations of the sensory paths and the centers in which sensations are felt and interpreted. So far as these areas have been outlined and the senses which they mediate discovered, they are as follows:

(a) *The body-sense area* lies in the parietal lobe behind the central fissure, occupying the post-central convolution and a part of the superior parietal and supra-marginal convolutions. It is connected with widely distributed afferent paths, and the distinct senses which it mediates are, so far as known, the sense of temperature, the sense of pressure, the sense of touch and the muscle sense.

(b) *The olfactory area,* which mediates the sense of smell, lies at the anterior end of the hippocampal convolution, chiefly in its uncinate process. It is connected with the olfactory end-organ in the nasal fossæ, through the first cranial nerve.

(c) *The gustatory area*, which mediates the sense of taste, lies in the same convolution with the olfactory area, being situated directly behind it. It is connected with the taste-buds through branches of the facial and glosso-pharyngeal nerves.

(d) *The visual area*, which mediates the sense of sight, lies on the mesial surface of the occipital lobe, in the neighborhood of the calcarine fissure. It is connected with the retina through the second cranial nerve.

(e) *The auditory area*, in which all impressions of sound are received, is situated on the outer surface of the hemisphere, in the first temporal convolution. It is connected with the ear through the eighth cranial nerve.

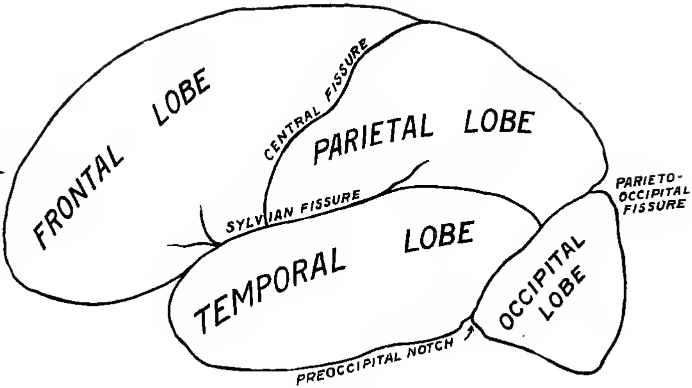
(3) **The Motor Speech Area**, or "Broca's convolution," is situated in the posterior part of the third frontal convolution, its connections being with the motor area that lies directly behind it and controls the movements of the face, mouth and throat. In this area are recorded the memories of the motor innervations necessary for producing the sounds habitually associated with the expression of words or ideas. It is generally developed on only one side—on the left side in the right-handed and on the right side in the left-handed. Lesions in this area result in more or less loss of the power to express thoughts in spoken language—a condition termed *motor aphasia*.

(4) **The Auditory Speech Area** lies behind the auditory area in the first temporal convolution. This area serves as the center for recording the memories of words and sounds heard and for associating them with the ideas which they represent. Impressions produced on the auditory area are here interpreted. Lesions in this area result in more or less loss of the ability to understand spoken language—a form of *sensory aphasia* known as *word-deafness*.

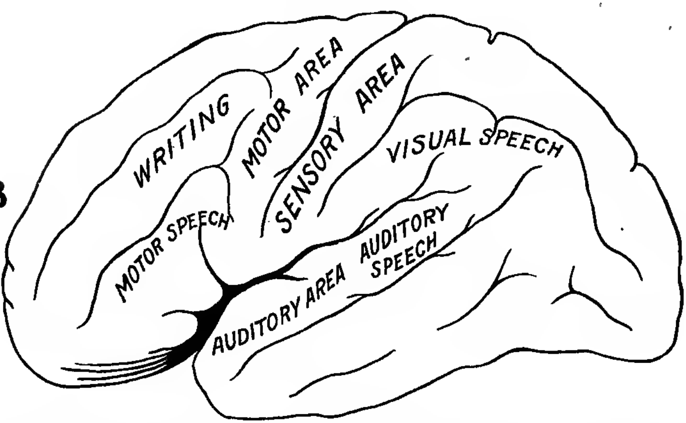
(5) **The Visual Speech Area** is situated on the outer surface, in the angular convolution of the parietal lobe. In

PLATE 4.

A



B



Diagrammatic representations of the outer surface of the left cerebral hemisphere: A, showing the lobes; B, showing the approximate location of the physiological areas of the cortex.

this area the memories of written or printed symbols are recorded and such symbols are associated with their meanings. Lesions in this area affect the power to understand written or printed language—a form of *sensory aphasia* termed *word-blindness.*

(6) **The Writing Area** is situated in the posterior part of the second frontal convolution, adjoining the motor area that lies behind it and controls the movements of the arm and hand. In this area are recorded the memories of the motor innervations necessary for forming the symbols by which ideas are expressed in writing. Lesions in this area cause *agraphia*—a loss of the power to write. Like the motor speech area, the writing area is developed unilaterally, and on the side opposite the trained hand.

(7) **The Association Areas**, which occupy the remainder of the cortex, are three in number: the anterior area, lying in front of the motor area; the posterior area, lying behind the body-sense area; and the median area, or the cortex of the island of Reil. Their connections are with all the other areas of the cortex. Their function is to associate sense impressions and record memories. They constitute the organ of thought.

THE SENSES AND THEIR PERIPHERAL FIBERS.

Every distinct sense has, as its anatomical basis, what is known as a sense-organ. This consists of three parts : a peripheral structure or end-organ upon which the stimulus acts; afferent fibers to conduct the impulses, and a cortical center in which the sensation is finally produced. Besides the visual, auditory, olfactory and gustatory senses, each of which is mediated through a single end-organ, there are other senses which are quite as distinct and special as these, but of which the peripheral organs and the mediating fibers are more or less widely distributed. These are *the sense of temperature* (heat and cold), *the sense of pressure*, *the sense of pain*, and *the* *muscle sense.* The fibers whose impulses give rise to the sensations of temperature and pressure, are distributed in all the cutaneous nerves and in the nerves supplying the mucous membrane of the mouth and the lower part of the rectum. The fibers whose impulses produce sensations of pain, are distributed in all peripheral parts of the body, being especially numerous in the nerves of membranes and the skin. The skin areas, the stimulation of which will produce the different cutaneous sensations, consist of mere points. They are designated as "warm spots," "cold spots," "pressure spots" and "pain spots." Each of these reacts only to its own peculiar kind of stimulus.

The Muscle Sense is that by which we become conscious of the varying conditions in the voluntary muscles, particularly the conditions that arise in connection with contraction. This sense is indispensable in the direction and co-ordination of voluntary movements, and in this lies its chief physiological value. The fibers concerned are a distinct set, distributed to the muscles and tendons, and are estimated to constitute from one-third to one-half of all the fibers in the muscular branches of nerves. Their impulses produce such sensations as those of weight and resistance, and, in case of prolonged muscular effort, they also convey the sense of fatigue.

The Sense of Touch, commonly counted as one of the senses, is not a separate sense. A feeling of contact does not arise apart from a sense of pressure, with which there may also be associated a sense of heat or cold. Touch sensations are generally composed of the pressure and temperature elements.

The Sense of Hunger is mediated by nerves of the stomach. But whether the fibers concerned are special or general, whether they are distributed in the lining membrane or the muscular coat, and what the acting stimulus is, are questions to which, as yet, final answers cannot be given.

The Sense of Thirst arises from the pharynx and is mediated by nerves supplying the pharyngeal mucous membrane. It is probable that the fibers which conduct the exciting impulses are a distinct set, ending peripherally in a special end-organ of thirst.

MEMBRANES OF THE BRAIN.

The cerebrum, as well as all other parts of the brain, is surrounded by three meninges or membranes, all more or less closely attached to one another and forming virtually a single structure.

The inner membrane, known as the **Pia** or **Pia Mater,** is a thin, delicate covering, consisting of blood-vessels supported by areolar tissue. This is nutritive in function, and is closely adherent to the entire surface of the brain, dipping into all fissures and crevices and sending blood-vessels into the underlying tissue. It also extends outward along the nerve-roots and become continuous with the sheaths of the nerves. The vascular structures, known as *the choroid plexuses,* are the fringed edges of the pial membrane projecting into the cavities of the brain. Among these the plexus known as *the velum interpositum,* which appears in the lateral and third ventricles, is the most prominent.

The outer membrane, known as the **Dura** or **Dura Mater,** is a thick, highly vascular membrane, of which, besides the blood-vessels, white fibrous tissue is the main constituent. Its outer surface is firmly attached to the cranial bones, of which it forms the internal periosteum. The dura consists of an inner and an outer layer, which, for the most part, are in apposition. But in certain places the layers separate and form channels or *sinuses for the venous blood.* This occurs along the longitudinal fissure, along the fissure between the posterior part of the cerebrum and the cerebellum, and along the fissure between the cerebellar hemispheres. In each case the two plates of the internal layer, after forming walls of the sinus, reunite and project towards the center. In this way are formed *the falx cerebri*, which projects into the longitudinal fissure, *the tentorium*, which lies between the cerebrum and the cerebellum, and *the falx cerebelli*, which enters the fissure between the cerebellar hemispheres. By again separating along their central edges, the layers of the falx cerebri and the tentorium form other sinuses along the central structures of the brain. The dura, like the pia, extends outward through foramina at the base of the cranium and becomes continuous with the sheaths of the nerves.

The third membrane, called the **Arachnoid**, lies between the other two, to both of which it is more or less closely attached by bundles of fibrous tissue. Between the arachnoid and the dura is a space which, under normal conditions, is only potential, but which sometimes becomes actual in disease. It is called *the subdural cavity*. Between the arachnoid and the pia is another space, more extensive than the former and containing a little serous fluid. This is *the subarachnoid cavity*. It is essentially a lymph space, and, by means of openings into the fourth ventricle, is connected with the brain cavities, which also subserve the same function. The fluid contained in all these cavities, though resembling lymph in its general character, is thinner than lpmph and of somewhat different constituents. It is designated as cerebro-spinal fluid, being common to both brain and spinal cord. In some places, principally along the longitudinal fissure, the arachnoid presents little outgrowths which press into the dura and even make depressions in the bone. They are termed Pacchionian bodies and often contain small particles of calcareous matter, called "brain sand."

The membranes of the brain are innervated by sympathetic fibers and by sensory fibers branching from the trifacial, glosso-pharyngeal and pneumogastric nerves.

CHAPTER II.

THE ISTHMUS CEREBRI.

THE isthmus cerebri or midbrain extends downward and backward from the base of the cerebrum to the upper end of the pons, and connects the cerebrum with the lower parts of the brain. Its main elements are fibers, but it also contains some scattered collections of cells. Two columns of fibers, *the crura cerebri*, converging from the base of the hemispheres, are present on the anterior surface. Between them is a triangular area that forms the posterior part of the interpeduncular space. Four gray masses, *the corpora quadrigemina*, mark the rear surface, and each lateral surface presents two smaller masses, *the corpora geniculata internum and externum*, or the internal and external geniculate bodies.

The isthmus is composed of lateral halves, with an intermingling of transverse and longitudinal fibers and some cells between them, the whole forming *a median raphe* or seam. Each half consists of *the crusta*, which forms its anterior part, *the tegmentum*, which forms its posterior part, and *the substantia nigra*, a plate of gray matter between the crusta and tegmentum.

The crusta is formed by efferent fibers that arise in the cortex of the cerebrum and descend through the anterior limb of the internal capsule. As nearly as their exact cortical origin can be determined, the mesial fibers arise in the frontal lobe, the outer fibers in the occipital and temporal lobes, and the central fibers in the area that controls voluntary movements. The outer group end by arborization in the gray matter of the isthmus and pons; the central group enters the anterior pyramid of the oblongata; and the mesial group have an uncertain ending, though it is probably, for the most part, in nuclei of the oblongata.

The tegmentum presents a type of structure described as *formatio reticularis.* It consists of longitudinal and transverse fibers interlacing with each other and holding gray matter in their meshes. Among the longitudinal fibers is one distinct group, *the posterior longitudinal bundle*, which is connected with Deiters' nucleus and with the nuclei of the oculo-motor and abducent nerves. It also extends downward through the pons and oblongata into the antero-lateral tract of the cord, where it is further connected with cells of the anterior horns. The remaining longitudinal fibers are mainly afferent fibers ascending from lower levels, either to end in the gray matter at the base of the cerebrum, or to pass through the internal capsule and end in the cerebral cortex. The majority of the transverse fibers come from the cerebellum, by way of the superior cerebellar peduncles. In the posterior part of the tegmentum is the Sylvian aqueduct, which runs longitudinally and connects the third and fourth ventricles of the brain.

Besides the *substantia nigra*, the groups of gray matter in the isthmus are: the *lamina quadrigemina*, which lies under the quadrigeminal bodies; *the red nucleus*, which forms a terminal station for some of the fibers in the superior cerebellar peduncle of the opposite side; and *the oculo-motor nucleus*, *the trochlear nucleus* and the *trifacial motor nucleus*, which lie in the gray wall surrounding the Sylvian aqueduct.

The Corpora Quadrigemina.

The corpora quadrigemina are four rounded knobs of gray and white matter, lying in the median region under the posterior ends of the optic thalami. They consist of an upper pair, the superior quadrigeminal bodies or *the nates*, and a lower pair, the inferior quadrigeminal bodies or *the testes.*

The two bodies of each pair are connected internally, but superficially they are marked off by a longitudinal groove. The pairs are separated by a transverse fissure. The superior bodies serve as nuclei for some of the fibers in the optic nerves, and the inferior bodies form one of the final relay stations in the central course of the auditory nerves.

The Corpora Geniculata.

The internal and external geniculate bodies are small masses of gray and white matter, lying at the sides of the isthmus, the external body farther front and at a slightly higher level than the internal. A bundle of optic nerve fibers, *the anterior brachium*, runs back from the external geniculate body to the superior quadrigeminal body and unites the two structures. A bundle of commissural fibers, *the posterior brachium*, unites in a similar manner the internal geniculate body and the inferior quadrigeminal body. These are fibers of Gudden's commissure, which runs round the front of the isthmus with the optic nerves and connects the inferior quadrigeminal and internal geniculate bodies of the two sides. The external geniculate bodies are central nuclei for some of the fibers in the optic nerves, and the internal geniculate bodies are among the final relay stations in the central course of the auditory nerves.

CHAPTER III.

THE PONS.

The pons Varolii or the tuber annulare, commonly known as the pons, extends from the isthmus to the oblongata, connecting not only these structures but other parts of the brain, as well. Though containing a considerable quantity of gray matter, its main elements are horizontal and vertical fibers. The greater part of its horizontal fibers are derived from the cerebellum, through the middle cerebellar peduncles, which emerge from the cerebellum and run forward along each side of the pons to its front, where they spread out and form its anterior surface. In the front of the pons are two vertical bundles of fibers descending from the crustae of the isthmus to the anterior pyramids of the oblongata, and behind these descending bundles are two other vertical bundles ascending from the oblongata to the isthmus and thence to the cerebrum. These latter bundles are *the lemnisci* or *the fillets*, which form the sensory path between the spinal cord and the brain.

The region behind these vertical bundles constitutes *the tegmentum of the pons*, which is continuous with the corresponding region of the isthmus and like it in formation. It contains some distinct groups of fibers and most of the pontal gray matter. In its lower and anterior part are fibers that run from one side of the pons to the other and form *the trapezium* or *the corpus trapezoideum*, which lies in the central course of the auditory nerves. Farther back is the posterior longitudinal bundle, continued down from the isthmus. There are also numerous afferent fibers coursing upward from lower levels to the cerebrum, and the roots of cranial nerves running in various directions between their nuclei and the surface of the pons. The gray matter comprises the motor and sensory nuclei of the fifth nerve, the nuclei of the sixth, seventh and eighth nerves, and *the trapezoidal and superior olivary nuclei*, which receive the terminal arborizations of the trapezial fibers. There are also a few smaller collections of cells that have no individual names.

The posterior surface of the pons is concealed by the superior cerebellar peduncles and a plate of nerve-tissue that stretches between them, the peduncles running upward and forward and converging at the lower border of the quadrigeminal bodies. The plate of nerve-tissue, triangular in shape, consists of an outer layer of gray and an inner layer of white, and is variously referred to as *the valvula*, *the valve of Vieussens* and *the anterior medullary velum.* Under the valvula and the mesial border of the peduncles lies the posterior surface of the pons, which forms the upper part of the floor of the fourth ventricle.

CHAPTER IV.

THE CEREBELLUM.

THE cerebellum is an ovoid mass, lying in the posterior cranial fossa and beneath the posterior end of the cerebrum, from which it is separated by a dural projection, termed *the tentorium*. In front of it are the isthmus, pons and oblongata, with all of which it is physiologically related. It presents a comparatively flat upper surface and a rounded lower surface, which meet behind at *the transverse fissure*. Though one continuous structure, it is considered as consisting of lateral hemispheres and a median segment termed *the vermis*. On the upper surface the vermis appears as a rounded elevation running fore and aft through the middle and bounded on each side by a groove that marks it off from the adjacent hemisphere. On the lower surface the vermis is nearly concealed in *the vallecula*, a deep depression which here forms the dividing line between the hemispheres. Both surfaces are marked by fissures that run in a generally transverse direction and cut deeply into the tissue, dividing it into segments or *folia*.

On the upper surface the folia are continuous through the vermis and the hemispheres. The folia of the vermis, from front to back, are the lingula, the central lobe, the culmen, the clivus and the cacumen. The corresponding folia of the hemispheres are the frenulum, the ala, the anterior crescentic lobe, the posterior crescentic lobe and the postero-superior lobe.

On the lower surface the folia are not continuous through the different parts and the arrangement is more complicated.

Here the folia of the vermis, from front to back, are the nodule, the uvula, the pyramid and the posterior tuber. The folia of the hemispheres, in the same order, are the flocculus, the amygdala, the digastric lobe, the slender lobe and the postero-inferior lobe.

The Cerebellar Gray Matter comprises the cortex, the nucleus dentatus, the nucleus emboliformis, the nucleus globosus and the nucleus fastigii.

The cortex covers the surface of the cerebellum and extends inward along the fissures. Its cells are arranged in three layers, an outer or molecular layer, an inner or granular layer, and a middle layer consisting of Purkinje cells. The connections of the cells of the different layers are as follows: The dendrites of the Purkinje cells pass outward in numerous branches and end in the molecular layer. The axons from the cells in the molecular layer either remain in the layer and connect with the dendrites of the Purkinje cells, or they pass to the middle layer and arborize about their bodies. The axons from the cells of the granular layer pass out to the molecular layer and divide into two branches, which run at right angles to the parent stems. The branches connect in part with the dendrites of Purkinje cells and in part with cells of the layer.

The dentate nucleus lies in the center of the hemisphere. It consists of an outer layer of gray matter surrounding an interior of white. On its median surface is an opening through which the fibers from its gray matter make their exit.

The remaining nuclei are smaller masses and are situated in the vermis.

The Cerebellar White Matter consists of a central part, termed *the trapezium*, with extensions into the folia, the entire mass resembling a cedar tree and being known as *the arbor vitæ* or the "tree of life." It is composed in part of efferent fibers derived from the Purkinje cells of the cortex, and in part of afferent fibers derived from the pons, oblongata and spinal cord. Of the afferent fibers some pass to the molecular layer and end in direct contact with the dendrites of the cells of Purkinje. The remaining afferent fibers end about the cells of the granular layer, but are probably connected with the Purkinje cells, through these intervening neurons.

PHYSIOLOGICAL RELATIONS OF THE CEREBELLUM.

All connections of the cerebellum with other parts of the brain and with the spinal cord are formed through its superior, middle and inferior peduncles.

(1) Fibers arising from the cells of Purkinje course forward in the middle cerebellar peduncles to the pons, where they cross to the opposite side and end in the pontal nuclei. Fibers from the nuclei ascend through the isthmus and internal capsules and terminate in the motor areas of the cerebrum, thus completing a path through which each cerebellar hemisphere may affect the motor discharges from the opposite hemisphere of the cerebrum.

(2) Other fibers arising from the cells of Purkinje end in *the dentate nuclei*, from which new fibers, forming a second relay, run forward in the superior peduncles to the isthmus, where they cross to the opposite side and end, some terminating in *the red nucleus* and the remainder in *the optic thalamus.* The fibers arising in the red nucleus cross to the opposite side and descend in *the rubro-spinal tract* of the cord, where they end in relation with the efferent neurons of the voluntary muscles, completing a path through which, with its double crossing, each hemisphere of the cerebellum may affect the action of the motor nerves of the same side of the cord. Before the superior peduncles cross in the isthmus they each give rise to a branch called *Cajal's descending cerebellar bundle.* These descend without crossing, and, by means of collaterals, connect the cerebellum with the motor

nuclei of the cranial nerves. The destination of the path through the optic thalamus is undetermined.

(3) Afferent fibers entering the cerebellum by way of the superior peduncles and the restiform bodies form connections by which the cerebellum receives impulses from the end-organ of equilibrium and the muscles, and perhaps, also, to some extent, from the skin.

Through these various connections the cerebellum exerts a co-ordinating influence on the movements of the voluntary muscles—particularly the movements involved in locomotion and the maintenance of equilibrium.

Note.—For the origin and course of the afferent paths to the cerebellum, see pages 62, 63.

CHAPTER V.

THE OBLONGATA.

THE oblongata, otherwise known as the medulla and the spinal bulb, lies on the basilar process of the occipital bone. It is about an inch in length, and extends from the pons to the spinal cord, with both of which it is continuous. Its lower half is cylindrical in form, like the cord, and resembles the cord in formation. Its upper half is widened transversely, somewhat flattened from front to back, and constructed in a manner peculiar to itself.

The Anterior Surface of the oblongata is marked in the middle by a longitudinal groove called *the anterior median fissure*, which is an upward continuation of the fissure of the same name in the spinal cord, and which here separates two white masses known as *the anterior pyramids.* Each pyramid is bounded laterally by *the antero-lateral fissure*, which has no counterpart in the cord but is in line with the superficial origins of the anterior roots of the spinal nerves. In the upper half of the oblongata this fissure forms the dividing line between the pyramid and an oval-shaped mass called *the inferior olive.* The pyramids consist of efferent fibers which arise in the motor areas of the cerebrum and descend through the isthmus and pons to the oblongata. In the lower part of the oblongata the greater part of these fibers—generally from ninety to ninety-seven per cent.—cross from one pyramid to the other, forming *the pyramidal decussation.* The remaining fibers descend without crossing and form *the direct pyramidal tract* of the spinal cord. In a few cases—about eleven per cent.—the pyramidal decussation is complete and the direct pyramidal tract is then wanting.

The Posterior Surface is largely formed by an upward continuation of the columns and fissures of the cord, but the columns undergo changes in name and form on reaching the oblongata. What is termed in the cord the postero-median column becomes, in the lower half of the oblongata, *the fasciculus gracilis*, at the upper end of which is a group of cells, *the nucleus gracilis*, corresponding to an enlargement called *the clava.* From the middle of the oblongata the two fasciculi diverge and run upward and outward through the upper half, being here known as *the posterior pyramids.* The postero-lateral column of the cord, on reaching the oblongata, becomes *the fasciculus cuneatus*, which lies at the outer side of the fasciculus gracilis and is capped by *the nucleus cuneatus.* This surface also presents *the fasciculus of Rolando*, a rounded longitudinal elevation produced by the expansion of *the substantia gelatinosa*, which is continued upward from the tip of the posterior horn of the cord. It extends through the lower half of the oblongata and lies at the outer side of the fasciculus cuneatus, with which it finally blends. Its upper end contains *the nucleus af Rolando*, which corresponds to a superficial prominence called *the tubercle of Rolando.* At the outer side of each posterior pyramid lies the large bundle of fibers which forms *the restiform body* or the inferior cerebellar peduncle. The triangular area between the posterior pyramids is continuous with the posterior surface of the pons and forms the posterior half of the floor of the fourth ventricle. The downward-pointing apex of the triangle is called *the calamus scriptorius.*

The Lateral Surfaces are formed by the upward continuation of the lateral columns of the cord. They are each bounded in front by the antero-lateral fissure, and behind by the postero-lateral fissure.

The Internal Structure of the oblongata exhibits marked changes in passing from the lowest level upward. At the lower extremity the gray matter is centrally located and forms a single mass. Above this the gray is gradually invaded by the white and divided by it into smaller and smaller masses, some of which approach the surface in the floor of the fourth ventricle.

The first pronounced change in arrangement is seen at the pyramidal decussation, where the crossing fibers, running at first horizontally from one pyramid to the other and then obliquely backward to the lateral columns, sever the heads of the anterior horns, each head henceforth forming *the lateral nucleus.* Here, too, the posterior horn becomes thicker and turns outward, and the nucleus gracilis appears, projecting backward from its base.

Above the pyramidal decussation a change occurs in the posterior region similar to the preceding in the anterior region. Here the posterior horn presents a new structure, the nucleus cuneatus, which also projects backward from its base, outside the nucleus gracilis. These two nuclei give rise to a bundle of fibers that constitutes the greater part of the lemniscus or fillet. This runs horizontally forward and inward across the median line to the back of the opposite anterior pyramid, where some of the fibers turn upward towards the cerebrum. In their forward passage the two fillets each sever the head of the posterior horn of their own side, and form with each other, at the mid-line, a criss-cross of fibers called *the sensory decussation* or *the crossing of the fillets.*

From this level upward the important changes are more in the position of the gray matter than in its division. The nucleus gracilis begins to curve outward and to come nearer and nearer to the surface, and at the upper end of the oblongata it is blended with the posterior horn, the resulting mass lying near the median line in the floor of the fourth ventricle. The nucleus cuneatus retains its identity and is more deeply situated in the interior.

The anterior area of the oblongata contains a little gray and much white, the white consisting principally of the pyramids and the fillets. The lateral and posterior areas consist of longitudinal and horizontal fibers and many collections of cells. They are often referred to as the tegmentum.

The Gray Matter comprises the following groups: (1) the cells whose fibers form the first cervical nerve; (2) *the nucleus ambiguus*, which extends nearly the entire length of the oblongata and gives origin to the motor fibers of the ninth and tenth nerves and to the spinal fibers of the eleventh nerve; (3) *the hypoglossal nucleus*, which also extends nearly the entire length of the oblongata and gives origin to the twelfth nerve; (4) a long column of cells that serves as *the sensory nucleus* of the seventh, ninth and tenth nerves; (5) *the dentate nucleus*, which lies in the interior of the inferior olive and gives rise to fibers that join the inferior cerebellar peduncles and pass to the cerebellum; (6) *the vaso-constrictor center*, which lies near the median line in the floor of the fourth ventricle; (7) *the cardio-inhibitory center*, which is closely related to the nucleus ambiguus and probably forms a part of it; (8) *the respiratory center*, which lies at the level of the calamus scriptorius; (9) *the nucleus gracilis*, which forms the terminal station for the main fibers that ascend in the postero-median column of the cord, and (10) *the nucleus cuneatus*, which forms the terminal station for the main fibers that ascend in the postero-lateral column of the cord.

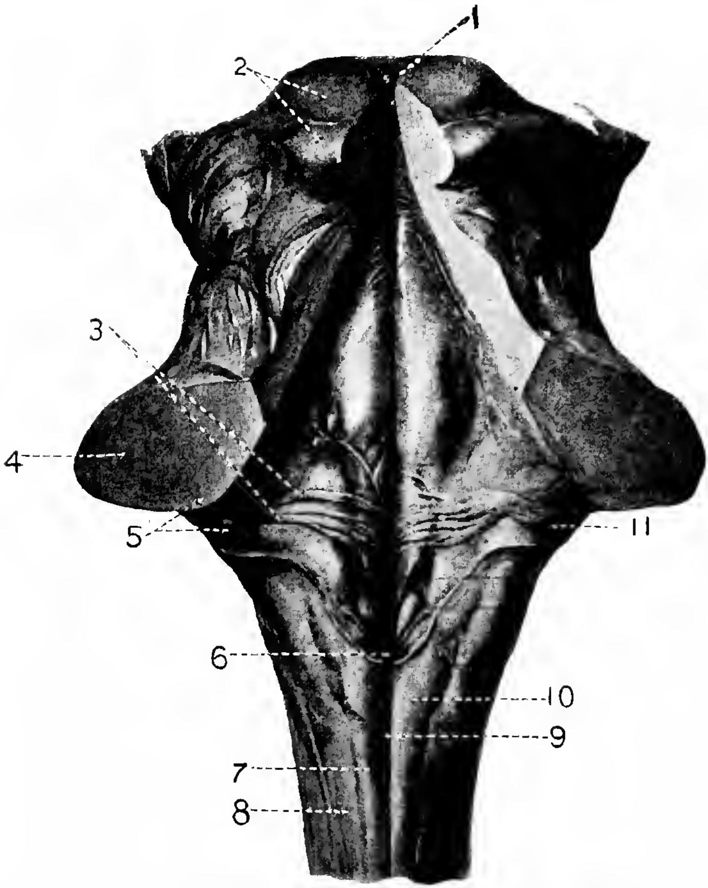
DISTRIBUTION OF THE FIBERS FROM THE NUCLEI GRACILIS AND CUNEATUS.

A few of the fibers that arise in these nuclei—*the posterior external arcuate fibers*—pass directly to the cerebellum, through the inferior cerebellar peduncle of their own side. The great majority, however, cross in the decussation of the fillets to the opposite side of the oblongata. Of these fibers those known as *the anterior external arcuate fibers* continue forward to the anterior surface of the oblongata, and then, winding outward round the anterior pyramid and the inferior olive, pass to the cerebellum by way of the inferior cerebellar peduncle of the side opposite to their origin. The rest of the decussating fibers—*the internal arcuate fibers*—turn upward behind the anterior pyramid and form *the lemniscus* or *fillet*, which courses upward to the cerebrum. In the oblongata and pons the fillet receives some accessions from the sensory nuclei of cranial nerves, and in the isthmus it is further augmented by fibers from the spinal tract of Gowers. The fillet eventually reaches the cortex of the cerebrum, in part directly and in part through fibers from the optic thalamus. Its cortical terminations are about association neurons. It forms the main sensory channel through which impulses from each side of the body reach the opposite side of the brain.

THE FOURTH VENTRICLE.

The fourth ventricle presents a roof, a floor, an upper angle, a lower angle and two lateral angles. The roof is formed in front by the superior cerebellar peduncles and the intervening valvula, and behind by the inferior cerebellar peduncles and an intervening projection of the pial membrane, termed the metatela. The valvula and the metateld are continuous with the cerebellum, through the lingula and the nodule, respectively. The floor, which slopes downward and backward from above, is formed in its upper part by the posterior surface of the pons, and in its lower part by the posterior surface of the upper part of the oblongata. It is rhomboidal in form, with the angles at the ends and sides. Its upper boundaries are the superior cerebellar peduncles, and its lower boundaries are the posterior pyramids of the oblongata. The lower angle, formed by the pyramids, lies at the upper end of the central canal of the spinal cord. The upper angle, formed by the superior peduncles, lies at the lower end of the Sylvian aqueduct. At each of the lateral angles is an opening, called *the foramen of Key and Retzius*, which connects the ventricle with the intermeningeal spaces of the brain. Extending from the upper to the lower angle is a median cleft that forms the dividing line between the lateral halves of the floor.

PLATE 5.



The floor of the fourth ventricle and neighboring structures: 1, Sylvian aqueduct; 2, corpora quadrigemina; 3, striæ acusticæ; 4, superior cerebellar peduncle; 5, inferior cerebellar peduncle; 6, calamus scriptorius; 7, fasciculus gracilis; 8, fasciculus cuneatus; 9, posterior median fissure; 10, clava; 11, tuberculum acusticum.—(Modified from Spalteholz.)

CHAPTER VI.

CONNECTIONS FORMED BY THE AFFERENT CRANIAL NERVES AND THE AFFERENT ROOTS OF THE MIXED NERVES, AFTER REACHING THE CENTRAL NERVOUS SYSTEM.

The Optic Nerve.—The fibers of the optic nerve—which begins in the retina—end mainly in the external geniculate body, though some extend farther back and end in the superior quadrigeminal body and the posterior part of the optic thalamus, these three structures serving as the optic nuclei. Fibers from the nuclei, forming *the optic radiation*, ascend through the posterior part of the internal capsule and thence through the corona radiata to the visual area of the occipital lobe. Mingled with these afferent fibers are efferent fibers which arise in the occipital cortex and end in the nuclei of the oculo-motor, trochlear and abducent nerves, forming a path through which rays of light may reflexly cause movements of the eyeballs.

The Auditory Nerve.—The auditory nerve—which begins in the internal ear—consists of a cochlear and a vestibular division, both of which enter the pons, the cochlear division entering behind the restiform body, and the vestibular division in front of it.

As the cochlear division enters it divides into two branches, one of which ends in *the accessory nucleus*, and the other in *the tuberculum acusticum.* The fibers from the accessory nucleus, running in the trapezium (which they form), cross to the opposite side of the pons, some crossing directly and the others by first winding outward round the restiform body and then re-entering the tegmentum. They end in the trapezoidal nucleus and the superior olive of the opposite side, from which new fibers, running upward in a bundle called *the lateral fillet*, continue the path. The fibers from the tuberculum acusticum run backward and outward across the median raphe and across the opposite half of the floor of the fourth ventricle—where they form *the acoustic striæ*—and then turn upward and join the other fibers in the lateral fillet.

The lateral fillet runs upward through the lateral part of the pons and the isthmus to the final stations in the auditory path. These are the internal geniculate body, the posterior quadrigeminal body and a group of cells called *the superior nucleus of the fillet*. Their fibers, forming *the auditory radiation*, ascend through the posterior end of the internal capsule and thence through the corona radiata, to the auditory area in the temporal lobe.

As the vestibular division enters the pons its fibers bifurcate and form ascending and descending divisions. The descending divisions extend to the lower end of the oblongata and terminate in *the nucleus posterior*, a collection of gray matter derived from the base of the posterior horn. Their further relations are unknown. The ascending divisions join the inferior cerebellar peduncle and pass to the cerebellum, giving off in their course many collaterals to *the nucleus of Deiters* and *the nucleus of Bechterew*, which lie near the lateral angle of the ventricular floor. The fibers from the nucleus of Deiters descend in the spinal cord and form *the vestibulo-spinal tract*. They end in relation with the motor neurons of the voluntary muscles. The fibers from the nucleus of Bechterew take a descending course, but their destination is unknown.

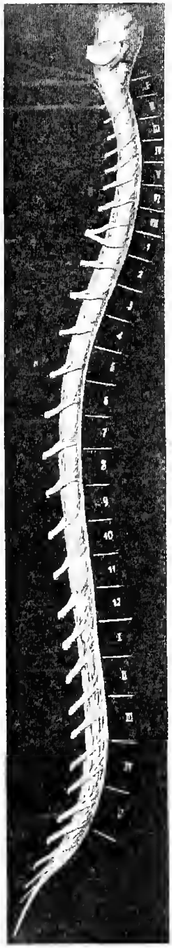
The Afferent Root of the Trifacial Nerve.—The afferent root-fibers of the trifacial nerve arise from cells in the Gasserian ganglion, which lies on the anterior surface of the petrous bone. They enter the pons on its anterior surface and bifurcate, forming ascending and descending divisions. The ascending divisions end in *the trifacial sensory nucleus*, situated in the pons. The descending divisions end mainly in *the nucleus gracilis*, *the nucleus cuneatus* and *the gelatinous substance of Rolando*, though some extend as low as the second or third cervical segment of the spinal cord and end in *the posterior horn* of the spinal gray matter. Through fibers arising in the two nuclei and the Rolandic substance, the path is continued to the cerebrum by way of the fillet, and to the cerebellum by way of the inferior peduncle. The physiological relations of the fibers that descend in the cord are undetermined.

The Afferent Root of the Facial Nerve.—The afferent root-fibers of the facial nerve, which form *the pars intermedia*, arise in the geniculate ganglion, situated in a canal in the petrous bone. They enter the pons on its lateral surface and run downward, terminating in the upper end of the sensory nucleus, which also receives fibers from the ninth and tenth nerves. From the nucleus the path is continued by fibers which pass in the fillet and through the internal capsule to the interior of the hemisphere and thence in part to the body-sense area in the parietal lobe and in part to the gustatory area in the temporal lobe.

The Afferent Roots of the Glosso-pharyngeal and Pneumogastric Nerves.—The afferent root-fibers of the glosso-pharyngeal nerve arise in the jugular and petrosal ganglia, and those of the pneumogastric nerve arise in the root-ganglion and the trunk ganglion. These ganglia are attached to their respective nerves and situated in the jugular foramen. The fibers enter the oblongata between the olive and the restiform body and bifurcate into ascending and descending divisions. The ascending divisions terminate in the column of gray matter that forms their nucleus. The descending divisions, forming a bundle called *the fasciculus solitarius*, run downward along the outer side of the sensory nucleus and terminate in the nucleus gracilis and the gelatinous substance of Rolando. Fibers arising in the various nuclei continue the paths to the cerebrum and the cerebellum. Some of the fibers in the glosso-pharyngeal nerve convey the sense of taste. These form connections by which their impulses reach the gustatory area in the temporal lobe.

Note.—For the central relations of the olfactory nerve, see Part III., Chapter IV.

PLATE 6.



The right side of the spinal cord with the spinal nerves attached.
(Modified from Spalteholz.)

CHAPTER VII.

THE SPINAL CORD

THE spinal cord extends through the vertebral canal from the level of the base of the cranium to the body of the second lumbar vertebra, and from its lower end the *filum terminale* continues down to the coccyx. In the adult the cord proper is about eighteen inches long and a half inch or less in diameter and weighs nearly an ounce. Its surface presents the anterior median fissure in front and the posterior median, postero-intermediate and postero-lateral fissures behind, the median fissures marking the lines of division between the lateral halves of the cord. A minute channel, called the central canal of the spinal cord, runs longitudinally through the interior.

In each half of the cord is a continuous column of gray matter commonly described as consisting of an anterior and a posterior horn. The anterior horn projects a short distance outward and forward. The posterior horn projects outward and backward to the surface, ending at the postero-lateral fissure. In this horn, near its termination, is a small area in which the cells are mingled with fibers of the posterior nerve-roots, and which is known as *substantia gelatinosa.* The anterior horn contains the cells whose fibers form the anterior roots of the spinal nerves, and throughout the entire column are cells whose fibers form tracts in the cord. Of these cells there are some whose fibers travel in the tracts of their own side, others whose fibers cross to the tracts of the opposite side, and still others whose fibers bifurcate and distribute a branch to each side. There are also Golgi cells of the second type, the fibers of which both run and end in the gray matter. The columns of the two sides are united by the anterior and posterior gray commissures.

The white matter in each half of the cord comprises *the anterior column*, bounded by the anterior median fissure and the anterior horn and nerve-root, *the lateral column*, bounded by the anterior horn and nerve-root and the posterior horn, and *the posterior column*, bounded by the posterior horn and the posterior median fissure. The postero-intermediate fissure and a fibrous septum divide the last-named column into an inner part, called *the postero-median column* or the column of Goll, and an outer part, called *the postero-lateral column* or the column of Burdach. About the head of the anterior horn is an area consisting of the adjoining parts of the anterior and lateral columns and often referred to as *the antero-lateral column*. Its limits, however, are not very definitely fixed. The two anterior columns are connected with each other by the white commissure.

On a functional basis the white matter of the cord is divided into tracts, of three general classes. These are *the efferent tracts*, the fibers of which are derived from the brain, *the association tracts*, the fibers of which are derived from the cord, and *the afferent tracts*, the fibers of which are derived in part from the cord and in part from the ganglia of the posterior nerve-roots.

The Efferent Tracts.

The Pyramidal Tracts.—The pyramidal fibers, which connect the motor areas of the cerebrum with the motor neurons of the cranial and spinal nerves, constitute the intercentral paths through which the brain directs the movements of the voluntary muscles. The fibers that make connections with the cranial nerves cross to the opposite side in the isthmus, pons and oblongata, at the levels of the various motor nuclei in which they are destined to end. Of the fibers that reach the spinal nerves, the greater part cross in the pyramidal decussation and then descend in the posterior part of the lateral columns of the cord, where they form *the crossed pyramidal tracts.* The remaining fibers, which form *the direct pyramidal tracts,* run in the anterior columns on the same side as their origin, but pass through the white commissure to the opposite side before terminating. In their course through the brain the pyramidal fibers distribute collaterals to the commissural fibers that connect the two hemispheres of the cerebrum, and to the lenticular and caudate nuclei. In the cord collaterals are given off to the motor neurons along the entire course of the pyramidal tracts.

The Rubro-spinal Tract.—The rubro-spinal tract, also known as the pre-pyramidal tract and Monakow's bundle, occupies a triangular area of the lateral column, in front of the crossed pyramidal tract. Its fibers arise in the red nucleus of the opposite side and end about the motor neurons of the voluntary muscles. Together with the superior cerebellar peduncles, the rubro-spinal tracts constitute the paths by which, as stated previously, each hemisphere of the cerebellum is connected with the motor neurons of the same side of the cord.

The Vestibulo-spinal Tract.—This tract is situated in front of the rubro-spinal tract and extends round the head of the anterior horn. Its fibers arise in Deiter's nucleus (the nucleus of the vestibular division of the auditory nerve) and end in connection with the motor neurons of the voluntary muscles. While its function is not definitely determined, it may be supposed, in view of its anatomical connections, that it forms a path through which vestibular impulses may automatically affect the contraction of the muscles in the maintenance of equilibrium.

The Sulco-marginal Tract.—This runs along the anterior median fissure in the anterior column. Its fibers originate in the anterior quadrigeminal bodies and terminate in the anterior horns. Little is known of their physiology. It is possible, however, that they form connections through which visual impulses may in some way influence muscular contraction.

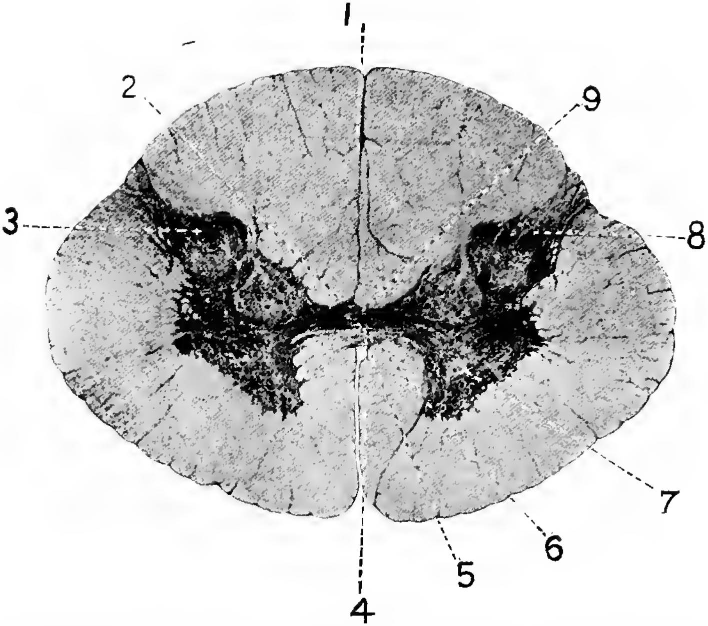
The Anterior Marginal Tract.—This runs along the periphery of the anterior column. Its fibers are thought to arise in the nucleus fastigii of the cerebellum. Their destination is entirely unknown—likewise their physiology.

Helweg's Tract.—This tract is situated at the periphery, near the front of the lateral column. Its fibers arise in the nucleus of the inferior olive, but nothing is known of their terminal relations or of their functions.

The Afferent Tracts.

As the central processes from the spinal ganglia enter the cord, they bifurcate and form ascending and descending divisions. The descending divisions, which are short, pass to the postero-lateral column and in this run downward in an area known as *the comma tract*, so called from its resemblance to the punctuation mark of the same name. They end in the gray matter of the posterior horn. A few of the ascending divisions run upward a short distance in what is known as *the tract of Lissauer*, which lies at the periphery beneath the postero-lateral fissure. These, too, end in the posterior horn. The remaining ascending fibers enter the posterior columns. Of these there are some that end in the adjacent gray matter of the cord, but the main fibers continue upward into the oblongata and end in the nuclei gracilis and cuneatus, from which their subsequent connections are with the cerebrum and the cerebellum. When the long fibers first enter the posterior columns they travel in the postero-lateral column or *the tract of Burdach*, but as they ascend they are gradually crowded inward by fibers entering at higher levels, until, at the upper end of the columns, the fibers from the lumbar and sacral nerves are mainly in the postero-median column or *the tract of Goll.*

PLATE 7.



Cross-section of the spinal cord: 1, posterior median fissure; 2, central canal; 3, substantia gelatinosa; 4, anterior median fissure; 5, anterior white commissure; 6, anterior gray commissure; 7, anterior horn; 8, posterior horn; 9, posterior commissure.—(Modified from Spalteholz.)

Both the ascending and the descending divisions give off collaterals, which, after courses of varying length, enter the gray matter and end about cells of the anterior and the posterior horn. In part from the cells thus connected and in part from cells about which the main fibers from the ganglia end, arise other fibers which form the direct cerebellar tract or *the tract of Flechsig* and the antero-lateral ascending tract or *the tract of Gowers.*

The direct cerebellar tract arises from cells that lie at the base of the posterior horn and form what is known as *the column of Clarke.* This tract begins near the lower end of the cord and runs upward along the margin of the lateral column, directly in front of the posterior horn. On reaching the oblongata it bends backward and enters the inferior cerebellar peduncle, of which it constitutes the greater part. Its fibers, following the course of the peduncle, cross to the opposite side and enter the cerebellum. They end mainly in the middle lobe, but give off numerous collaterals to the hemisphere of their own side, thereby connecting each hemisphere with the afferent nerves of the same side of the cord.

The antero-lateral ascending tract is formed by fibers that arise throughout the entire length of the cord. It runs upward along the margin of the lateral column, in front of the direct cerebellar tract, and appears on the lateral surface of the oblongata. Its fibers continue upward through the oblongata and pons into the isthmus, where they divide and take different courses. Some unite with the fillet and ultimately reach the cortex of the cerebrum. The remainder turn backward, enter the superior cerebellar peduncle and pass to the middle lobe of the cerebellum, where they end.

There are other collaterals which, either directly or through an intermediate neuron, make connections with the anterior root neurons and thus form the arcs for spinal reflexes. As such collaterals arise along the entire course of the fibers, it becomes possible for impulses entering the cord at one segment to cause reflexes in several segments either above or below the level of their entrance.

Concerning the source of the impulses which the different afferent tracts conduct, there is some uncertainty. But experimental study and pathological states have shown that the tracts of Goll, Burdach, Flechsig and Gowers, at least, conduct impulses from the muscles, and that they are consequently essential factors in the co-ordination of muscular movements. That they also have other functions is believed to some extent, but not conclusively determined.

The Association Tracts.

The association tracts adjoin the gray matter in the antero-lateral columns, being often referred to as the fundamental or ground bundles of the cord. They consist of fibers which arise in the gray matter of the cord, and which, after running a distance of one or more segments in the white matter, either up or down, again enter the gray matter and end about other cells, thus connecting the different levels of the cord and associating their activities. They conduct by a system of relays, the impulses passing from one to another of the neurons whose fibers form the tracts. Some of the ascending or afferent association tracts are the principal paths for the conduction of cutaneous impulses, and there is evidence that the impulses which produce the different cutaneous sensations—pressure, pain and temperature—travel in different parts of the tracts. There is further evidence that these impulses, though conducted mainly on the side of the cord that they enter, are conducted to some extent on the opposite side—that is, that their conduction is bilateral.

Reflex Action.

Reflex action is that produced by sensory stimulation of the efferent nerves. It occurs in glands and muscles, and in the glands and the involuntary muscles is the regular mode of activity. In the voluntary muscles three types of reflexes are recognized—namely, the simple reflex, affecting a single muscle, and the co-ordinated and the convulsive reflex, each affecting a number of muscles. Co-ordinated reflexes are purposeful in character and are generally movements which have become more or less habitual by training and experience, as walking, dancing and piano-playing. In such movements the sensory impulses that arise from a given stimulus and enter the cord through a given set of afferent channels, find their way to a fairly constant set of efferent channels and thus produce practically uniform effects on the muscles. Convulsive reflexes are disorderly movements made without purpose. They are possible under intense sensory stimulation, with normal conditions prevailing, but are not common. Their greatest frequency is in pathological conditions in which the irritability of the nerve centers has been greatly increased, as in strychnine poisoning, hydrophobia and uremia. In such conditions even a slight sensory stimulus will often provoke spasms. In these cases, owing to the heightened irritability of the central nervous system, the sensory impulses radiate widely and affect many, or even all, of the efferent neurons, instead of following the usual, habitual path. From the physiological standpoint convulsive reflexes are of interest as indicating an intimate relation between all efferent and all afferent neurons.

The responses from reflex stimulation may be either increased or decreased or entirely suppressed. Within certain limits the brain has an inhibitory influence on the reflex activities of the centers for respiration, micturition and defecation—that is, the activities of these centers may be controlled to a certain extent by the will. The same influence may also be effective in restraining the reflexes of the voluntary muscles. In tickling, for example, an effort of the will may suppress the usual convulsive movements that the stimulus tends to produce. Whether this influence is exerted by the brain through a special set of fibers or by some modification of the activity of the pyramidal fibers, is an unsettled question. It is certain, however, that an inhibitory influence may emanate from the brain to all the motor neurons of the voluntary muscles. A reflex may also be partly or wholly suppressed by simultaneous sensory stimulation in two places. Sneezing, for example, which results from stimulation of the sensory nerves of the nasal fossae, may often be checked by stimulating some of the nerves of the skin; or a reflex movement in one limb may be inhibited by simultaneous sensory stimulation of the other limb.

On the other hand, simultaneous stimulation of the cord from two sources will sometimes result in augmentation of a reflex. If a strong voluntary movement is made simultaneously with a sensory stimulation, the response from the latter is often increased. This result is explained by supposing that the impulses originating in the brain and destined for a definite set of neurons in the spinal cord, overflow, as it were, from their customary channels and exert an influence on the entire cord, with the effect of increasing its irritability. This phenomenon, taken in connection with that in which stimulation from two sources inhibits activity, evidences a fact of importance on the physiological side—namely, that the activity of any part of the cord may have the effect either of increasing or decreasing the irritability of the cord as a whole. It is also a further indication of the intimate relation existing between all parts of the motor apparatus.

Reflex responses are greatly affected by changes in the irritability of the nerve-centers, being increased or decreased by whatever increases or decreases this property. The blood-supply has a marked influence in this respect, and so also have many drugs, such as strychnine, chloroform and opium. A pronounced increase in irritability is manifested in certain pathological states, being especially noticeable in some of the diseases produced by germs.

The Knee-jerk.

This may be produced by a slight blow on the patellar tendon, at a time when the quadriceps muscle is under tension. While it has the appearance of being a reflex movement, it is not regarded as a reflex, in the true sense. It is rather an evidence of the irritability of the quadriceps muscle, by the contraction of which the movement is caused. Since, however, the irritability of the muscle is dependent upon adequate innervation, the movement is also an evidence of the integrity of the afferent and efferent paths between the muscle and the spinal cord, as well as of the condition at the nerve-centers.

The knee-jerk can be obtained in all normal individuals, but varies even with the changing normal states, being abolished during sleep and increased during mental excitation. It is also affected by pathological conditions. For example, if the afferent paths are functionally deficient, as in tabes dorsalis, or the efferent paths, as in chronic anterior myelitis, the blow on the tendon gives little or no response: or, on the other hand, if lateral sclerosis is present, diminishing the inhibitory influence ordinarily exercised by the brain, the response is greatly intensified. Finally, it is increased or decreased by an increase or decrease in the irritability of the cord. It is therefore evident that the knee-jerk may be of valuable service in diagnosis.

The Spinal Nerve-roots.

The anterior roots, which arise from cells in the anterior horn, leave the cord a short distance from the anterior median fissure, and form, at the surface, a vertical series of small bundles, which extends the entire length of the cord. The posterior roots, which consist of the central processes form the cells of the spinal ganglia, enter the cord at the postero-lateral fissure. The roots of the upper cervical nerves are short and horizontal, but below this they gradually increase in length and run more and more obliquely downward, the lowest descending perpendicularly from the end of the cord and forming the *cauda equina*. The union of the two sets of root-fibers forms the trunks of the spinal nerves.

The Spinal Membranes.

In all essential characteristics the membranes of the cord are counterparts of the membranes of the brain, with which they are continuous at the foramen magnum. The dura of the cord, instead of forming the internal periosteum for the vertebræ, is separated from them by the epidural space, which contains areolar tissue and plexuses of veins. The pia of the cord is somewhat less vascular than that of the brain, and a lateral process of the pia forms the *ligamentum denticulatum*, the outer edge of which is attached to the dura between the openings for the spinal nerves. The arachnoid presents no peculiarities of structure, but in the rear it forms a median partition in the subarachnoid space.

The membranes are innervated by the recurrent branches of the spinal nerves.

PART III.

INNERVATION OF THE SKELETAL PARTS OF THE BODY.

CHAPTER I.

GENERAL DISTRIBUTION OF THE SPINAL NERVES.

THE first cervical nerve emerges from the vertebral canal between the occipital bone and the atlas; the coccygeal nerve, through an opening at the lower extremity of the canal, and all the other spinal nerves, through the inter-vertebral foramina. Outside the vertebral column, each nerve gives off a *recurrent branch*, which re-enters the vertebral canal, and then divides into an anterior and a posterior division.

The Anterior Divisions.

In the cervical region the anterior divisions of the upper four nerves form the cervical plexus, which innervates chiefly the skin and muscles of the neck, and those of the lower four nerves, uniting with a part of the first thoracic nerve, form the brachial plexus, which innervates the arm and its related muscles.

The anterior divisions of the first eleven thoracic nerves form intercostal nerves, which course round the chest wall between the internal and external intercostal muscles. The upper six intercostal nerves, as they approach the anterior ends of the external intercostal muscles, pass to the inner surface of the internal intercostal muscles and then run forward to the side of the sternum. Here they return to the surface and end by becoming cutaneous. The lower five intercostal nerves enter the abdominal wall and run forward as far as the rectus muscle, here becoming superficial and being finally distributed to the skin. The twelfth thoracic (subcostal) nerve runs along the lower border of the last rib and thence among the abdominal muscles. The anterior thoracic divisions, as a whole, innervate the intercostal, subcostal and abdominal muscles, the levatores costarum, serrati posteriores and triangularis sterni muscles, and the skin on the lateral and anterior surfaces of the trunk.

The anterior divisions of the first three lumbar nerves, together with a part of the twelfth thoracic and a part of the fourth lumbar nerve, enter the psoas muscle and there form the lumbar plexus, the distribution of which is mainly in the thigh, but to some extent in the genital organs. The remaining lumbar nerves unite with the first, second and third, and a branch of the fourth, sacral nerves and form the sacral plexus, which is distributed in the leg, gluteal region, genital organs and perineum. Another branch of the fourth sacral nerve and a branch of the fifth sacral nerve, form the coccygeal plexus, distributed in the perineum.

The Posterior Divisions.

The posterior divisions, which are smaller than the anterior in all nerves except the first and second cervical, run backward to the dorsal tissues, where all but four—those of the first cervical, fourth and fifth sacral and coccygeal nerves—divide into an internal and an external branch. The internal branches—larger than the external branches from the middle of the thorax upward, but smaller than these in the region below—are distributed mainly to the skin, while the external branches are distributed mainly to muscles. The posterior divisions, as a whole, innervate the skin on the back of the head, neck, trunk and gluteal region, and all the posterior spinal muscles except the serrati posteriores and levatores costarum and those connected with the upper limb.

CHAPTER II.

GENERAL FUNCTIONS OF THE CRANIAL NERVES.

THE **First or Olfactory Nerve,** the **Second or Optic Nerve** and the **Eighth or Auditory Nerve** contain only afferent fibers. The third, fourth, sixth, eleventh and twelfth nerves contain only efferent fibers. But the fifth, seventh, ninth and tenth nerves contain fibers of both classes.

The **Third or Oculo-motor Nerve** supplies efferent (motor) fibers to both voluntary and involuntary muscles, the latter innervating unstriated muscles of the eye.

The **Fourth or Trochlear Nerve,** the **Sixth or Abducent Nerve,** the **Eleventh or Spinal Accessory Nerve** and the **Twelfth or Hypoglossal Nerve** are distributed entirely to voluntary muscles.

The **Fifth or Trifacial Nerve** is the principal sensory nerve of the face. It contains but few efferent fibers, and these innervate only voluntary muscles.

The **Seventh or Facial Nerve** and the **Ninth or Glossopharyngeal Nerve** supply voluntary muscles with motor fibers and blood-vessels with dilator fibers. They also contain some secretory fibers. Among their afferent fibers are those which mediate the sense of taste.

The **Tenth, Vagus or Pneumogastric Nerve** supplies motor fibers to voluntary muscles, motor and inhibitory fibers to viscera, dilator fibers to blood-vessels and secretory fibers to glands. Among its afferent fibers are some that perform special functions in the cardiac and respiratory mechanisms. The pneumogastric nerve is an important factor in a number of the so-called vital processes—digestion, respiration, circulation and the action of the heart. It is also widely distributed, as the characterizing term "vagus" ("wandering") implies, some of its fibers innervating the skin on the back of the ear, and others ramifying as far away as the visceral organs of the abdomen.

CHAPTER III.

INNERVATION OF THE EYE.

The nerves of the eye include the second, third, fourth and sixth cranial nerves, the greater part of the first division of the fifth nerve and some of the terminal branches of its second division.

THE FIRST OR OPHTHALMIC DIVISION OF THE FIFTH NERVE.

The first division of the fifth nerve, arising from the Gasserian ganglion, runs forward through the outer wall of the cavernous sinus, under the fourth nerve, and passes through the sphenoidal fissure into the orbit. Before entering the orbit, it divides into three branches, lachrymal, frontal and nasal.

The lachrymal nerve, entering the orbit at the outer angle of the fissure, runs upward along the upper border of the external rectus muscle to the lachrymal gland, and thence to the upper eyelid. It is distributed to the skin on the outer part of the upper lid, to the outer part of the conjunctiva and to the lachrymal gland.

The frontal nerve, running forward through the orbit on the upper surface of the levator palpebræ muscle, gives off, midway in its course, the supro-trochlear nerve. Then, becoming the supra-orbital nerve, it continues forward and leaves the orbit through the supra-orbital foramen, thence running upward and being distributed over the forehead and front of the scalp. *The supra-trochlear nerve*, running forward and inward over the tendon of the superior oblique muscle, leaves the orbit at its inner angle and becomes cutaneous between the eyebrows, where it ends. It distributes branches to the inner part of the conjunctiva and the upper eyelid.

The basal nerve, entering the orbit between the two divisions of the third nerve, runs forward and inward a short distance and then passes upward through the anterior internal orbital canal into the cranium. Here it runs forward on the cribriform plate of the ethmoid bone, and then, turning downward, descends through the nasal slit into the nasal fossa, where it continues its downward course on the nasal septum, ending in the skin near the end of the nose. Its branches to the eye arise in the orbital fossa. These are the short ciliary nerves, the long ciliary nerves and the infra-trochlear nerve.

The short ciliary nerves, piercing the ciliary ganglion, spread out on its peripheral side and are distributed to the coats of the eyeball.

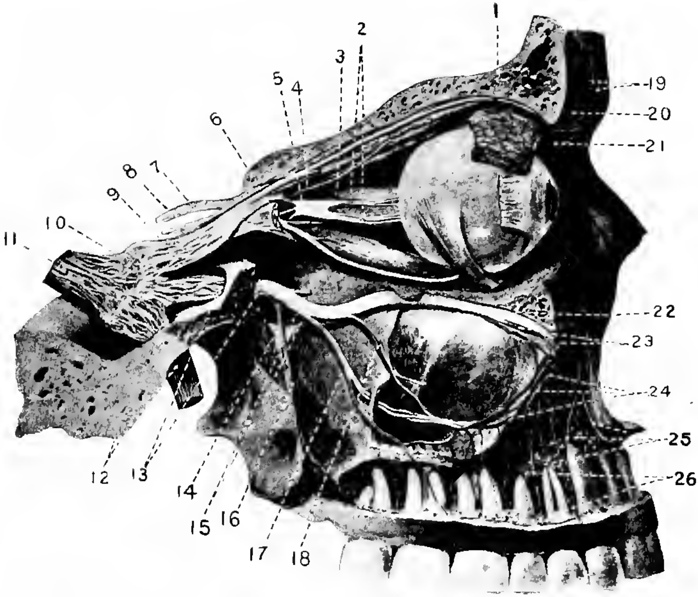
The long ciliary nerves, which arise behind the eyeball, join the inferior group of the short ciliary nerves and pierce the sclerotic. In the coats of the eyeball they continue forward as far as the iris, innervating structures along their course.

The infra-trochlear nerve runs forward under the superior oblique muscle and its tendon, to the inner angle of the eye, distributing branches to the lachrymal sac, conjunctiva and the skin on the inner part of the eyelid.

THE SECOND OR MAXILLARY DIVISION OF THE FIFTH NERVE.

The second division of the fifth nerve, arising from the Gasserian ganglion, leaves the cranium through the foramen rotundum, crosses the spheno-maxillary fossa and passes through the fissure of the same name into the orbit. Here it continues forward, first in the infra-orbital groove and then in the infra-orbital canal, from which it emerges through the infra-orbital foramen into the tissues of the face. Here it

PLATE 8.



Showing the nerves of the eye and the upper part of the mouth: 1, Supra-orbital nerve; 2, short ciliary nerves; 3, optic nerve; 4, upper division of the oculomotor nerve; 5, ciliary ganglion; 6, lower division of the oculomotor nerve; 7, trunk of oculomotor nerve; 8, trochlear nerve; 9, ophthalmic division of trifacial nerve; 10, Gasserian ganglion; 11, trunk of the trifacial nerve; 12, mandibular division of the trifacial nerve; 13, maxillary division of the trifacial nerve; 14, spheno-palatine ganglion; 15, 16, 17, 18, palatine nerves; 19, frontal nerve; 20, supra-orbital nerve; 21, supra-trochlear nerve; 22, infra-orbital nerve; 23, dental nerves; 24, dental plexus; 25, 26, branches of dental nerves.—(Modified from Spalteholz.)

divides into superior labial, lateral nasal and inferior palpebral branches, of which the last-named runs upward to the conjunctiva and the lower lid.

THE THIRD OR OCULO-MOTOR NERVE.

The third nerve, arising from a nucleus in the floor of the aqueduct and passing forward through the posterior longitudinal bundle and the red nucleus, gains the oculo-motor groove on the inner side of the crus cerebri, from which it emerges above the pons. From this point its course is forward through the outer wall of the cavernous sinus to the sphenoidal fissure, at the entrance of which it divides into a superior and an inferior division. The superior division distributes lateral branches to the rectus superior muscle and terminates in the levator palpebræ superioris. The inferior division forms three branches: one to the internal rectus muscle (derived from the sixth nucleus of the opposite side); another to the inferior rectus muscle, and the third to the inferior oblique. From this last branch springs a short offset that ends in the ciliary ganglion and forms part of the pupillo-constrictor path to the iris.

THE FOURTH OR TROCHLEAR NERVE.

The fourth nerve, which arises directly behind the third nerve, crosses the median line and leaves the central axis on the posterior surface of the pons. Winding outward over the superior cerebellar peduncle and forward round the outer side of the crus cerebri, it passes through the outer wall of the cavernous sinus and the inner angle of the sphenoidal fissure into the orbit. Here it runs over the levator palpebræ superioris muscle, to reach and supply the superior oblique.

THE SIXTH OR ABDUCENT NERVE.

The sixth nerve, whose nucleus forms the eminentia teres in the floor of the fourth ventricle, runs forward through the pons and emerges at its lower border, a short distance from the median line. Thence it runs forward through the cavernous sinus and the sphenoidal fissure into the orbit, where it is finally distributed to the external rectus muscle.

Note.—Fibers from the nucleus of the sixth nerve ascend in the posterier longitudinal bundle and cross to the opposite side. Here they join the third nerve and accompany it to the internal rectus muscle. Thus the sixth nerve, which innervates the external rectus of its own side, is in reality the nerve which innervates the internal rectus of the opposite side.

THE OPTIC NERVE.

The optic nerve, arising from cells of the retina, passes back through the optic foramen to the optic groove on the sphenoid bone. In this groove the fibers from the inner half of each retina cross to the opposite side, forming what is known as *the optic chiasm.* Thence both the crossed and the uncrossed fibers, forming *the optic tracts*, pass backward round the outer side of the crura cerebri and end in the external geniculate bodies, the superior quadrigeminal bodies and the posterior part of the optic thalami. From these structures, which constitute the optic nuclei, the path is continued, by way of the optic radiation, to the visual area in the occipital lobe of the cerebrum. In consequence of the decussation of the inner fibers from each retina, each hemisphere of the cerebrum receives visual impulses from the outer half of the retina of its own side and from the inner half of the retina of the opposite side.

Running in the optic chiasm and in the optic tracts is a bundle of fibers which connects the inferior quadrigeminal body and the internal geniculate body, both with each other and with the corresponding structures of the opposite side. It is known as Gudden's commissure. Its functional relations are with the auditory nerves.

CHAPTER IV.

INNERVATION OF THE NASAL FOSSAE.

THE nerves of the nasal fossae are the first cranial nerve and branches of the first and second divisions of the fifth nerve.

The first division of the fifth nerve contributes *the nasal nerve*, already partly described. After entering the fossa it divides into two branches: an internal branch, which supplies the mucous membrane on the front part of the septum, and an external branch, distributed to the front part of the lateral wall.

The branches of the second division supplying the fossa are *the superior nasal* and *the naso-palatine nerves*, both of which reach the fossa by piercing the spheno-palatine ganglion and passing through the spheno-palatine foramen. In the fossa, the naso-palatine nerve, running downward and forward across the vomer and distributing branches to the septum on its way, finally passes through the anterior palatine canal to the roof of the mouth, where it unites, in a plexiform manner, with its fellow nerve of the opposite side. The superior nasal nerves—several small twigs—are distributed to the mucous membrane that covers the upper and hind portion of the superior and middle turbinated bones, and to the corresponding region of the septum.

Note.—The second division also supplies to the fossae a few small branches that arise from the anterior superior dental nerve and the anterior palatine nerve, which for the most part are distributed in the mouth.

THE OLFACTORY END-ORGAN AND THE FIRST OR OLFACTORY NERVE.

In an area covering the upper third of the nasal septum and the surface of the superior turbinated bone, are the cells that constitute the olfactory end-organ. These cells are epithelial-like in character and are mingled with columnar epithelium that serves as support. At the peripheral or free end of each cell are from six to eight fine, ciliary processes; the proximal end is prolonged into a single, slender, non-medullated fiber. The proximal fibers from all the cells are gathered into about twenty small bundles, which ascend through the cribriform plate of the ethmoid bone and arborize about cells of the olfactory nucleus. This nucleus is contained in the olfactory bulb, an oval body, two-fifths of an inch in its long diameter, which lies on the cribriform plate of the ethmoid and is covered above by the olfactory fissure. From the nucleus fibers pass backward in the olfactory groove of the sphenoid bone and the olfactory fissure of the cerebrum, to the anterior perforated space, where they divide into internal, middle and external divisions. From this point the exact course of some of the fibers is imperfectly traced. It is certain, however, that most of them finally reach the olfactory area in the cortex of the cerebrum. It is possible that some fibers decussate in the anterior commissure.

CHAPTER V.

INNERVATION OF THE EXTERNAL PARTS OF THE HEAD.

THE external parts of the head, including the face, scalp and external ear, receive their motor innervation from the facial and trifacial nerves, and their sensory innervation from the trifacial and pneumogastric nerves and the second and third cervical nerves.

INNERVATION FROM THE FIRST AND SECOND DIVISIONS OF THE TRIFACIAL NERVE.

From the first division of the trifacial nerve the branches distributed in these parts are the following:

(1) *The nasal nerve*, which passes downward and supplies the skin on the front and lower part of the nose.

(2) *The infra-trochlear nerve*, which passes downward and supplies the skin on the front and upper part of the nose.

(3) *The supra-trochlear nerve*, which passes inward and upward and supplies the skin of the glabella.

(4) *The supra-orbital nerve*, which runs upward and supplies the forehead and the anterior part of the scalp.

The branches from the second division are the tempero-malar, superior labial and lateral nasal nerves.

The tempero-malar nerve, arising in the spheno-maxillary fossa and passing through the fissure of the same name into the orbit, there divides into a temporal and a malar branch. The temporal branch, coursing upward along the outer wall of the orbit and passing through the temporal canal of the malar bone, turns upward under cover of the temporal muscles and becomes superficial, being distributed in a narrow strip of skin over the anterior part of the temple. The malar branch, running forward and passing through the malar canal of the malar bone, is distributed in the skin of the malar region of the face.

The superior labial and the lateral nasal nerves—terminal branches of the second division—are distributed in the face, in the regions corresponding to their names.

INNERVATION FROM THE THIRD OR MANDIBULAR DIVISION OF THE TRIFACIAL NERVE.

The third division of the trifacial nerve contains both afferent and efferent fibers. The afferent fibers arise in the Gasserian ganglion; the efferent fibers, from a column of cells that begins in the pons and extends upward into the isthmus. These latter fibers emerge from the anterior surface of the pons and run forward to the foramen ovale, through which, in company with the afferent fibers, they leave the cranium. Outside the cranium the two sets of fibers unite and form a single trunk, which almost immediately divides into an anterior and a posterior division.

The trunk, before dividing, gives off *the internal pterygoid nerve*, which supplies the muscle of the same name.

The Anterior Division forms the long buccal nerve, the anterior and posterior deep temporal nerves and the masseteric nerve.

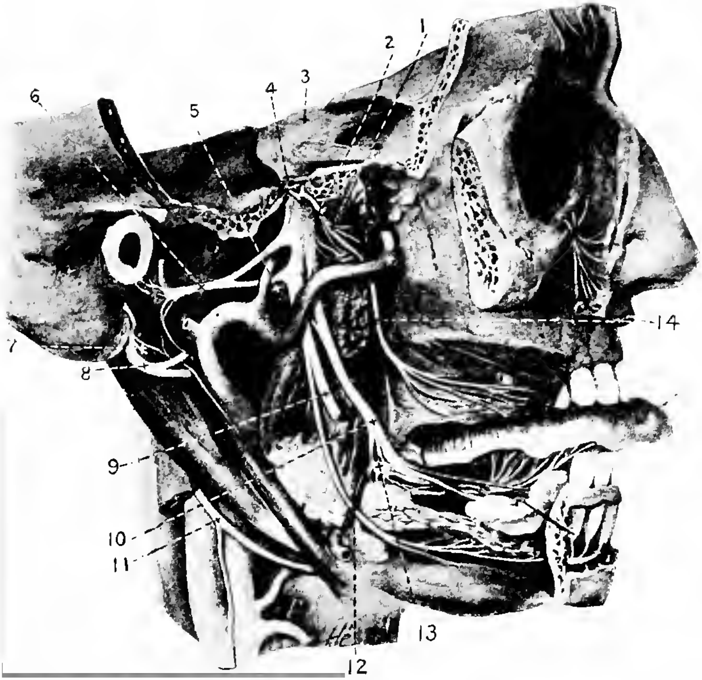
The long buccal nerve emerges between the heads of the external pterygoid muscle, which it supplies through a few small twigs, and then runs forward between the masseter and buccinator muscles, distributing branches in the skin of the cheek.

The anterior and the posterior deep temporal nerves, emerging over the upper border of the external pterygoid muscle, run upward and innervate the temporal muscles.

The masseteric nerve, also emerging over the upper border of the external pterygoid muscle, turns downward and innervates the masseter muscle.

The Posterior Division forms three main branches, the

PLATE 9.



Mandibular division of the trifacial nerve: 1, external pterygoid nerve; 2, buccinator nerve; 3, Gasserian ganglion; 4, mandibular trunk; 5, chorda tympani; 6, auriculo-temporal nerve; 7, branch to digastric muscle; 8, facial nerve; 9, inferior dental nerve; 10, lingual nerve; 11, hypoglossal nerve; 12, mylohyoid nerve; 13, submaxillary ganglion; 14, buccinator nerve.—(Modified from Spalteholz.)

lingual nerve (of the tongue), the auriculo-temporal nerve and the inferior dental nerve.

The auriculo-temporal nerve ascends in front of the external ear and divides into terminal branches in the skin of the temple. It also distributes lateral branches to the tympanum, the external auditory meatus and the anterior border of the pinna, and to the parotid gland and the skin of the face.

The inferior dental nerve, which runs through the inferior dental canal, leaves the canal at the mental foramen and distributes its radiating terminal branches in the tissues of the chin and the mucous membrane of the lower lip.

INNERVATION FROM THE CERVICAL NERVES.

The Great Auricular Nerve (2. 3. C.), passing to the hind border of the sterno-mastoid muscle and running upward across it, divides into a facial, a mastoid and an auricular branch. The facial branch is distributed to the skin in the parotid and buccal regions of the face; the mastoid branch, to the mastoid region of the scalp; and the auricular branch, to the skin on the lower part of the back of the pinna.

The Small Occipital Nerve (2. C.) passes to the hind border of the sterno-mastoid muscle and then upward to the level of the mastoid process, where it divides into an auricular, a mastoid and an occipital branch. The auricular branch is distributed to the skin on the upper part of the back of the pinna; and the mastoid and occipital branches are distributed in the mastoid and occipital regions of the scalp.

The Great Occipital Nerve, consisting of the internal branch of the posterior primary division of the second cervical nerve, is distributed in the occipital and parietal regions of the scalp.

The Third Occipital Nerve, consisting of the internal branch of the posterior primary division of the third cervical nerve, is distributed to the scalp in the mid-occipital region.

INNERVATION FROM THE PNEUMOGASTRIC NERVE.

The Nerve of Arnold, arising from the tenth nerve at its root-ganglion and running back to the jugular fossa, passes through Arnold's foramen into a canal in the petrous bone. Here coursing at first backward and then downward, it emerges from the petrous bone through the auricular fissure and divides into two branches, one of which is distributed to the external auditory canal and to the skin on the lower part of the back of the pinna. The remaining branch joins the posterior auricular nerve.

INNERVATION FROM THE FACIAL NERVE.

The efferent portion of the facial nerve, arising from a nucleus in the pons, pursues a circuitous route through the substance of the pons and emerges at its lower border outside the olive. Turning outward it passes through the internal auditory meatus and enters the aqueductus Fallopii. In this it runs outward to the inner wall of the tympanum and then backward a short distance in the substance of the wall. Finally, making a sharp turn downward behind the posterior wall of the tympanum, it passes through the stylo-mastoid foramen to the under surface of the cranium and enters the parotid gland, in which it divides into a tempero-facial and a cervico-facial division. The tempero-facial division further divides into temporal, malar and infra-orbital branches, and the cervico-facial division, into buccal, supra-mandibular and infra-mandibular branches, all of which, except the infra-mandibular branch, are distributed to facial muscles, each branch in the region corresponding to its name.

From the trunk of the nerve, before its division, arises *the posterior auricular nerve*, which runs horizontally backward and supplies the occipitalis muscle of the scalp. This nerve also gives off lateral branches that pass upward and innervate the muscles of the external ear.

CHAPTER VI.

INNERVATION OF THE MOUTH.

THE mouth derives its innervation from the trifacial, facial, glosso-pharyngeal and hypoglossal nerves.

INNERVATION FROM THE SECOND DIVISION OF THE TRIFACIAL NERVE.

The second division of the trifacial nerve distributes branches in the mouth, as follows :

(1) *The posterior superior dental nerves* (generally two in number), arising in the spheno-maxillary fossa and descending on the hind surface of the maxilla, give off twigs to the gums and buccal mucous membrane, and then, entering the posterior dental canals, supply the molar teeth.

(2) *The middle superior dental nerve*, arising in the hind part of the infra-orbital canal, descends in the outer wall of the antrum and supplies the bicuspid teeth.

(3) *The anterior superior dental nerve*, arising in the front part of the infra-orbital canal, descends in the wall of the antrum and supplies the incisor teeth.

(4) *The anterior palatine nerve*, piercing the spheno-palatine ganglion and descending through the posterior palatine canal, runs forward on the hard palate, supplying the gums and the roof of the mouth.

(5) *The naso-palatine nerve*, after reaching the roof of the mouth, is distributed to the mucous membrane behind the incisor teeth.

(6) A branch given off by *the long buccal nerve* is distributed in the buccal mucous membrane.

INNERVATION FROM THE THIRD DIVISION OF THE TRIFACIAL NERVE.

From the third division the branches distributed in the mouth are the inferior dental nerve and the lingual nerve.

The inferior dental nerve supplies all the lower teeth and distributes some fibers to the gums.

The lingual nerve runs downward and forward on the internal pterygoid muscle to the inner side of the jaw and then forward between the mylohyoid and hyoglossus muscles to the tip of the tongue. It supplies the anterior two-thirds of the tongue and the adjacent parts of the gums.

INNERVATION FROM THE GLOSSO-PHARYNGEAL NERVE.

The glosso-pharyngeal nerve contains both afferent and efferent fibers. The afferent fibers arise from cells in the jugular and petrosal ganglia, situated in the jugular fossa and attached to the trunk of the nerve. The efferent fibers arise from cells in the nucles ambiguus in the oblongata. The two sets of fibers unite in the substance of the oblongata and appear in a single bundle on its lateral surface, between the restiform body and the lateral tract. From its superficial origin the nerve runs outward and leaves the cranium through the jugular foramen. Descending a short distance between the internal carotid artery and the internal jugular vein, it curves under the styloid process and passes to the under surface of the hyoglossus muscle, where it divides into terminal branches, of which those known as *the lingual nerves* are distributed over the posterior third of the dorsum of the tongue and the posterior half of its sides. These nerves contain some of the fibers that convey sensations of taste.

INNERVATION FROM THE HYPOGLOSSAL NERVE.

The hypoglossal nerve, arising from a long column of cells in the oblongata and becoming superficial between the olive and the anterior pyramid, runs outward and leaves the cranium through the anterior condylar foramen. From the under surface of the cranium it runs at first downward, as far as the lower border of the digastric muscle, and then forward among the lingual muscles, as far as the tip of the tongue, distributing branches to all the intrinsic tongue muscles. It supplies the entire motor innervation of the tongue.

INNERVATION FROM THE FACIAL NERVE.

The Chorda Tympani Nerve contains both efferent and afferent fibers, its efferent fibers being derived from the facial nucleus, and its afferent fibers from the geniculate ganglion, which is attached to the facial nerve at its backward bend in the petrous bone. Leaving the facial nerve at the lower end of the Fallopian aqueduct, it enters the back part of the tympanum, crosses the tympanic cavity and passes out of the cranium through a canal at the inner side of the Glasserian fissure, thence running downward and forward and joining the lingual nerve, with which the afferent fibers continue to the anterior two-thirds of the tongue, being distributed for the most part to the taste-buds. The efferent fibers leave the lingual nerve and end in sympathetic ganglia.

CHAPTER VII.

INNERVATION OF THE INTERNAL PARTS OF THE EAR.

THE nerves which contribute to the innervation of these parts are the trifacial, facial, glossopharyngeal and auditory.

The trifacial nerve, through a small branch from its third division, supplies the *tensor tympani muscle;* and the facial nerve, through a branch arising in the aqueduct, supplies the *stapedius muscle.*

The Tympanic Nerve, arising from the glossopharyngeal nerve close under the base of the cranium, passes through a foramen that is situated between the carotid canal and the jugular fossa, and thus reaches the tympanum. Here it divides into branches and forms *the tympanic plexus,* from which fibers are distributed to the mastoid cells, fenestra rotunda, fenestra ovalis and Eustachian tube.

THE AUDITORY NERVE.

The auditory nerve consists of two divisions, the cochlear division or the nerve of hearing, and the vestibular division or the nerve of equilibrium. The cochlear division arises in the spiral ganglion of the cochlea, and the vestibular division in the vestibular ganglion of the vestibule. The two divisions, running together through the auditory canal to the lower border of the pons, here separate and pursue different courses in reaching their nuclei, the vestibular division entering the pons in front of the restiform body, and the cochlear division entering behind it. The cochlear division ends in the accessory nucleus and the tuberculum acusticum, from which the path is continued to the auditory area of the cerebrum. The vestibular division ends partly in the nucleus posterior and partly in the cerebellum, the fibers to the cerebellum giving off collaterals to the nucleus of Deiters, whose axis-cylinder processes descend in the vestibulo-spinal tract and establish connection between the end-organ of equilibrium and the anterior horns of the cord.

CHAPTER VIII.

INNERVATION OF THE SOFT PALATE AND TONSILS AND THE PHARYNX AND LARYNX.

The nerves contributing to the innervation of these parts are the trifacial, glosso-pharyngeal, pneumogastric and spinal accessory.

COURSE OF THE PNEUMOGASTRIC AND SPINAL ACCESSORY NERVES.

The Pneumogastric Nerve contains both afferent and efferent fibers, the afferent fibers arising in the trunk-ganglion and the root-ganglion, in the jugular foramen, and the efferent fibers in the nucleus ambiguus, in the oblongata. Becoming superficial on the side of the oblongata, between the restiform body and the lateral tract, the two sets of fibers, at first in from ten to fifteen fine strands, soon unite into a single bundle and leave the cranium through the jugular foramen. From the under surface of the cranium the trunk of the nerve descends in the sheath with the internal carotid artery and the internal jugular vein, and lower down with the same vein and the common carotid artery. At the level of the clavicle the right and left nerves take different courses.

The right nerve, entering the thorax between the subclavian artery and the brachio-cephalic vein, bends backward to the right side of the trachea and then descends to the posterior surface of the root of the right lung, where it breaks up and forms the posterior pulmonary plexus. Thence, as two cords, it passes to the right side of the œsophagus, where it again breaks up and joins with the left nerve in forming the œsophageal plexus. From here it runs along the posterior surface of the œsophagus and passes through the œsophageal opening of the diaphragm into the abdomen, being distributed for the most part on the posterior surface of the stomach.

The left nerve, after forming a plexus on the posterior surface of the root of the left lung, descends on the anterior surface of the œsophagus and is distributed for the most part on the anterior surface of the stomach. In other respects it behaves like the right nerve.

The Spinal Accessory Nerve contains both cranial and spinal fibers, the cranial fibers arising from the nucleus ambiguus in the oblongata, and the spinal fibers from the upper six or seven cervical segments of the cord. The cranial fibers, emerging from the lateral surface of the oblongata, pass to the jugular foramen and there unite with the pneumogastric nerve, with which they are subsequently distributed. The spinal fibers ascend on the side of the cord and pass through the foramen magnum into the cranium. Here joining the cranial fibers, they leave the cranium through the jugular foramen and are then distributed, their destination being the sterno-mastoid and trapezius muscles.

INNERVATION FROM THE TRIFACIAL NERVE.

(1) *The posterior palatine nerve,* arising from the maxillary division and piercing the spheno-palatine ganglion, descends in an accessory palatine canal and distributes its fibers to the soft palate, tonsil and uvula.

(2) *The external palatine nerve,* arising from the maxillary division and piercing the spheno-palatine ganglion, descends in another accessory palatine canal and distributes its fibers to the soft palate and tonsil.

(3) *The pharyngeal nerve,* arising from the maxillary division and piercing the spheno-palatine ganglion, runs back through the pterygo-palatine canal and distributes fibers to the naso-pharynx and the Eustachian tube.

(4) *A small efferent nerve,* arising from the mandibular divi-

sion and piercing the otic ganglion, innervates the tensor palati muscle.

INNERVATION FROM THE GLOSSO-PHARYNGEAL NERVE.

(1) *Two or three tonsillar nerves*, ascending under the hyoglossus muscle to the tonsil, here from a plexus, called the *circulus tonsillaris*, from which the fibers are distributed to the tonsil and soft palate.

(2) *Two or three pharyngeal nerves*, leaving the main nerve below the petrous ganglion, descend over the internal carotid artery to the back of the pharynx, where they join with nerves of pneumogastric origin in forming *the pharyngeal plexus.* These nerves contain only afferent fibers.

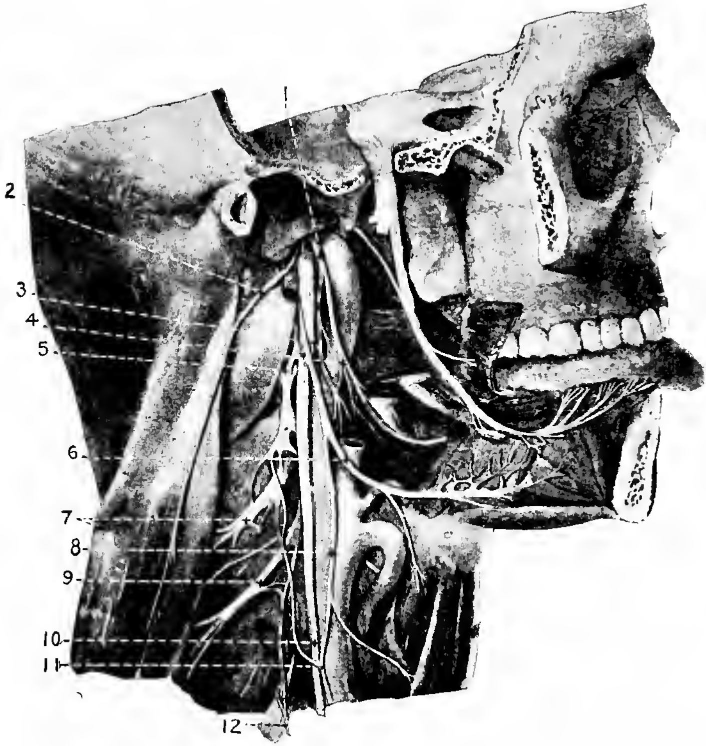
INNERVATION FROM THE PNEUMOGASTRIC NERVE.

(1) *The pharyngeal nerve*, leaving the main nerve at the trunk-ganglion, runs downward to the back of the pharynx and joins the pharyngeal plexus. It consists for the most part of efferent fibers derived from the spinal accessory nerve.

(2) *The superior laryngeal nerve*, also leaving the main nerve at the trunk-ganglion, runs downward to the region of the larynx and there divides into an internal and an external branch. The internal branch, passing through the thyrohyoid membrane into the larynx, is distributed to the mucous membrane of the interior of the larynx and of the epiglottis. The external branch, descending under the sterno-thyroid muscle, ends in and innervates the crico-thyroid muscle. It also supplies the inferior constrictor muscle of the pharynx and distributes some fibers to the pharyngeal plexus and the laryngeal mucous membrane. This nerve consists of afferent fibers of pneumogastric origin and of efferent fibers derived from the spinal accessory nerve.

(3) *The inferior or recurrent laryngeal nerve*, on the right side of the body, leaves the main nerve at the level of the lower border of the subclavian artery. Passing back under

PLATE 10.



Deep nerves of the upper cervical region ; 1, glosso-pharyngeal nerve ; 2, branch of spinal accessory nerve ; 3, pharyngeal branch of vagus nerve ; 4, pharyngeal branch of glosso-pharyngeal nerve ; 5, second cervical nerve ; 6, hypoglossal nerve ; 7, third cervical nerve ; 8, descendens hypoglossi ; 9, fourth cervical nerve ; 10, trunk of vagus nerve ; 11, ansa hypoglossi ; 12, phrenic nerve.—(Modified from Spalteholz.)

this vessel, it runs upward and inward to the groove between the trachea and oesophagus. The left recurrent nerve, leaving the main nerve in front of the aortic arch, runs back beneath it and enters the groove between the trachea and oesophagus on the left side. In these grooves the two nerves course upward under the inferior constrictor of the pharynx and finally reach the inner surface of the ala of the thyroid cartilage of the larynx. In this position each nerve forms its terminal divisions, its branches being distributed to the laryngeal mucous membrane and to all the laryngeal muscles except the crico-thyroid.

DISTRIBUTION OF THE PHARYNGEAL PLEXUS.

The pharyngeal plexus is distributed to the muscles and mucous membrane of the pharynx and to all the palatal muscles except the tensor.

CHAPTER IX.

INNERVATION OF THE CERVICAL REGION.

THE innervation of the cervical region is derived to a slight extent from some of the cranial nerves, but for the most part from the upper four cervical nerves, by way of the cervical plexus.

INNERVATION FROM CRANIAL NERVES.

(1) *The mylohyoid nerve,* springing from the inferior dental nerve before it enters the inferior dental canal, runs forward in the mylohyoid groove of the inferior maxilla and supplies the mylohyoid muscle and the anterior belly of the digastric.

(2) *The stylo-hyoid nerve,* springing from the facial nerve before its first division, supplies the stylo-hyoid muscle and the posterior belly of the digastric.

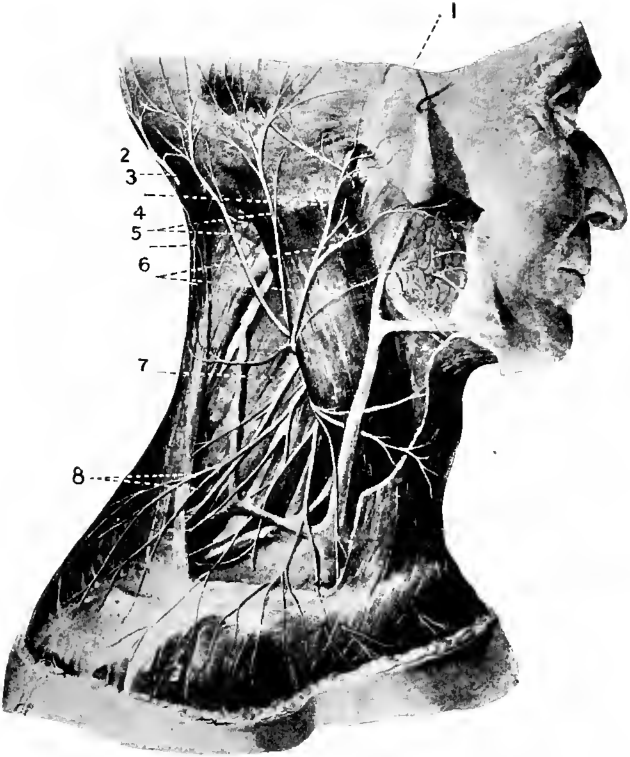
(3) *The infra-mandibular nerve,* springing from the cervico-facial nerve in the parotid gland, runs downward behind the angle of the inferior maxilla and supplies the platysma, being distributed on its inner surface.

(4) *The spinal accessory nerve* distributes a part of its spinal fibers to the sterno-mastoid muscle. The remainder pass to the under surface of the trapezius muscle and there join with branches of the third and fourth cervical nerves in forming the subtrapezial plexus, by which the trapezius is supplied.

INNERVATION FROM THE CERVICAL PLEXUS.

(1) Spinal fibers arising in the first and second cervical nerves join the hypoglossal nerve close under the base of the cranium. A few of these fibers run forward with the hypoglossal and supply the genio-hyoid and thyro-hyoid muscles.

PLATE 11.



The cervical plexus: 1, posterior auricular nerve; 2, great occipital nerve; 3, 6, great auricular nerve; 4, small occipital nerve; 5, third occipital nerve; 7, branch of spinal accessory nerve; 8, superficial cervical nerve.—(Modified from Spalteholz.)

The greater part soon branch off as the *descendens hypoglossi.* This runs down beneath the sterno-mastoid muscle to about the level of the cricoid cartilage and there meets the *ramus cervicalis descendens,* from the second and third cervical nerves, the two descending branches forming the *ansa hypoglossi.* From the *descendens hypoglossi* fibers are distributed to the anterior belly of the omohyoid, and from the *ansa hypoglossi,* to the sterno-hyoid, sterno-thyroid and the posterior belly of the omohyoid.

(2) **The Superficial Cervical Nerve** (2. 3. C.) winds round the hind border of the sterno-mastoid muscle and distributes cutaneous branches over the front of the neck from the chin to the sternum.

(3) **The Descending Cutaneous Nerve** (3. 4. C.), running downward to the middle of the hind border of the sterno-mastoid muscle, here becomes superficial and divides into sternal, clavicular and acromial branches, each of which is distributed to the skin in the region corresponding to its name.

Note.—The posterior parts of the neck are innervated by the posterior divisions of all the cervical nerves; the recti capitis and scaleni muscles, by the anterior divisions of the upper four nerves.

CHAPTER X.

INNERVATION OF THE SHOULDER AND ARM.

THE shoulder and arm and their related muscles receive their innervation by way of the brachial plexus, formed by the lower four cervical and first thoracic nerves.

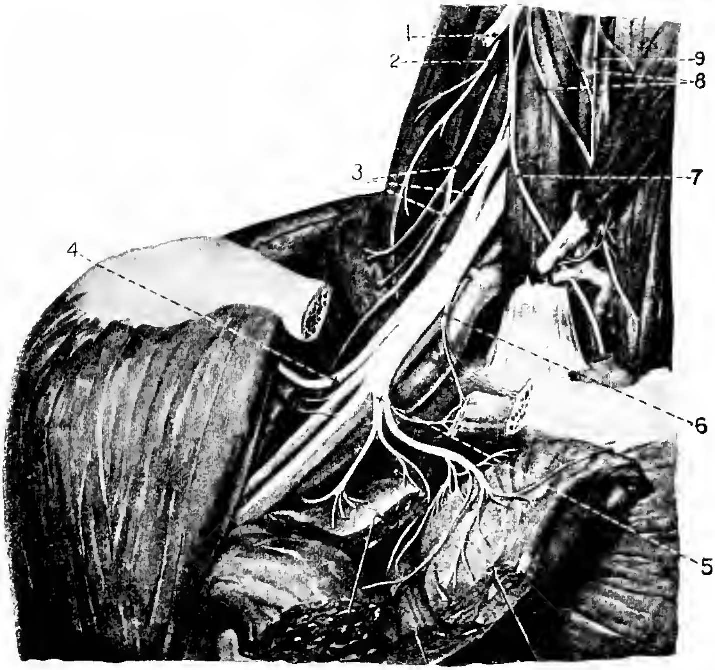
FORMATION OF THE BRACHIAL PLEXUS.

The cervical nerves that enter the plexus descend on the anterior surface of the scalenus medius muscle. Here the fifth and sixth nerves unite and form *the upper trunk*, the seventh nerve becomes *the middle trunk*, and the first thoracic nerve, passing upward over the first rib, unites with the eighth cervical nerve, the union of the two nerves forming *the lower trunk*. The three trunks run downward and outward to the subclavian triangle, where each divides into an anterior and posterior division. The anterior division of the lower trunk forms *the inner cord;* the anterior divisions of the upper and middle trunks unite and form *the outer cord;* and the posterior divisions of the three trunks unite and form *the posterior cord*. The three cords accompany the axillary artery. Behind the pectoralis minor muscle the inner cord lies at the inner side of the artery, the outer cord at its outer side, and the posterior cord behind it. In these positions each of the cords divides into its terminal divisions.

LATERAL BRANCHES OF THE PLEXUS.

The Rhomboid Nerve (5. C.), leaving the main nerve near the vertebral column, runs downward on the inner surface of the levator scapulae muscle and along the inner

PLATE 12.



Showing the brachial plexus and its principal lateral branches: 1, fourth cervical nerve; 2, subscapular nerve; 3, posterior thoracic nerve; 4, suprascapular nerve; 5, anterior thoracic nerve; 6, subclavian nerve; 7, phrenic nerve; 8, ansa hypoglossi; 9, descendens hypoglossi.—(Modified from Spalteholz.)

border of the scapula and supplies both rhomboid muscles. It also distributes small branches to the levator scapulae.

The Supra-scapular Nerve (5. C.), arising from the upper trunk and running downward and outward under the trapezius muscle, passes through the suprascapular notch and then divides into two branches, one of which supplies the supraspinatus muscle, and the other, winding round through the great scapular notch, supplies the infraspinatus muscle.

The Upper Subscapular Nerve (5. 6. C.), arising from the posterior cord, runs backward over the first rib and supplies the upper part of the subscapular muscle.

The Lower Subscapular Nerve (5. 6. C.), arising from the posterior cord, runs backward and then downward and supplies the lower part of the subscapular muscle and the teres major.

The Long Subscapular Nerve (7. C.), arising from the posterior cord, descends on the posterior wall of the chest and supplies the latissimus dorsi.

The Posterior Thoracic Nerve (5. 6. 7. C.), formed near the vertebral column, runs downward behind the plexus and the axillary artery and thence downward on the outer side of the chest wall, being finally distributed in the serratus magnus muscle.

The External Anterior Thoracic Nerve (6. 7. C.), arising from the outer cord, descends on the front of the chest wall and supplies the pectoralis major muscle.

The Internal Anterior Thoracic Nerve (8. C. 1. Th), arising from the inner cord, descends on the front of the chest wall and distributes branches both to the pectoralis major and to the pectoralis minor.

The Subclavian Nerve (5. C.), arising from the upper trunk, descends in front of the subclavian artery and supplies the subclavian muscle.

THE POSTERIOR CORD.

The posterior cord divides into the circumflex and musculo-spiral nerves.

The Circumflex Nerve (5. 6. C.) passes back under the lower border of the teres minor muscle and between the long head of the triceps muscle and the neck of the humerus and then divides into an anterior and a posterior branch. The anterior branch winds round the humerus and supplies the anterior part of the deltoid muscle. The posterior branch supplies the teres minor muscle and the posterior part of the deltoid. Both branches also distribute cutaneous fibers over the upper and outer part of the arm.

The Musculo-spiral Nerve (6. 7. 8. C.), winding outward round the humerus and then coursing in the spiral groove, reaches the outer side of the arm at a point between the lower end of the brachialis muscle and the upper end of the brachio-radialis. Here it divides into the posterior interosseous and radial nerves.

The posterior interosseous nerve, running downward between the brachialis and extensor carpi radialis longus muscles, enters the supinator muscle and winds round the radius. Emerging from the supinator it divides into several branches. One of its branches runs downward as far as the wrist and supplies the carpal joints ; the other branches are distributed to the supinator and all the neighboring extensor muscles except the extensor carpi radialis longus.

The radial nerve runs downward under the brachio-radialis muscle to the lower third of the forearm, where it turns backward under the tendon of the muscle and divides. Its branches, continuing downward to the hand, are there distributed to the skin on the radial half of the dorsum and on the back of the first two and a half digits as far down as the last phalanges.

A few branches arise from the musculo-spiral nerve before it divides. These are as follows :

(1) *The internal cutaneous nerve*, arising in the axilla, is distributed to a strip of skin on the inner side of the arm.

(2) *The external cutaneous nerves*, upper and lower, arising farther down, are also distributed to the skin, the one over the lower and outer part of the biceps, and the other on the back of the forearm from the elbow to the wrist.

(3) Muscular branches, arising as the nerve reaches the back of the humerus, supply the three heads of the triceps and the anconeus.

(4) Muscular branches arising just before the nerve divides, supply the brachialis, the brachio-radialis and the extensor carpi radialis longus.

THE OUTER CORD.

The outer cord divides into the musculo-cutaneous nerve and the outer head of the median nerve.

The Musculo-cutaneous Nerve (5. 6. C.), perforating the coraco-brachialis muscle and then running downward and outward between the brachialis and the biceps, comes to the surface at the outer border of the biceps, above the bend of the elbow. Thence it continues downward in a superficial position into the forearm, where it divides into an anterior and a posterior division. Before dividing it supplies the muscles through and between which it passes. Its terminal divisions are distributed to the skin on the radial side of the forearm, from the elbow to the wrist.

THE INNER CORD.

The inner cord divides into the small internal cutaneous, internal cutaneous and ulnar nerves and the inner head of the median nerve.

The Small Internal Cutaneous Nerve (1. Th.) descends on the inner side of the arm to its middle and then turns backward to supply a narrow strip of skin on the lower third of the arm.

The Internal Cutaneous Nerve (8. C. 1. Th.) descends on the inner side of the arm to its lower third and then divides into an anterior and a posterior division. These continue downward and supply the skin on the ulnar half of the forearm, from the elbow to the wrist.

The Ulnar Nerve (8. C. 1. Th.), descending first with the brachial artery and then with the inferior profunda, reaches the elbow. Here it passes between the external condyle and the olecranon process and between the two heads of the flexor carpi ulnaris muscle, to reach the under surface of the flexor profundus, along which it courses to the lower third of the forearm. Thence, in company with the ulnar artery, it passes over the annular ligament into the palm, where it divides into a deep and a superficial division.

The deep division is entirely distributed to these muscles: the abductor pollicis, the inner head of the flexor brevis pollicis, the flexor brevis minimi digiti, the opponens minimi digiti, the abductor minimi digiti, the outer two lumbricales and the interossei.

The superficial division is entirely cutaneous. It supplies the palmar surface of the outer one and a half fingers and the dorsum of their last phalanges.

The ulnar nerve also gives off branches in its course through the arm. These are as follows:

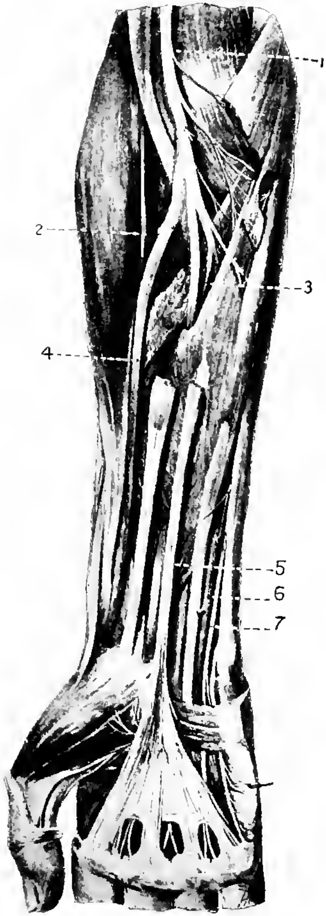
(1) A few small branches, arising near the elbow, supply the elbow joint.

(2) Two muscular branches, arising below the elbow, supply the flexor carpi ulnaris and the outer part of the flexor profundus.

(3) *The palmar cutaneous nerve*, arising near the middle of the forearm and descending with the ulnar artery, supplies the skin on the ulnar half of the palm.

(4) *The dorsal cutaneous nerve*, arising about two inches above the wrist, turns backward under the flexor carpi ulnaris muscle and then descends to the back of the hand. It supplies the ulnar half of the dorsum of the hand, and the dor-

PLATE 13.



Nerves of the front of the forearm: 1, 5, median nerve; 2, radial nerve; 3, anterior interosseous nerve; 4, radial artery; 6, ulnar nerve; 7, ulnar artery.—(Modified from Spalteholz.)

sum of the outer one and a half fingers, as far as their ungual phalanges.

THE MEDIAN NERVE.

The median nerve (6. 7. 8. C. 1. Th.) is formed by the union of two short branches, one from the inner, and one from the outer cord. It descends with the brachial artery to the elbow and there passes between the heads of the pronator teres muscle. Thence coursing through the middle of the forearm, between the flexor sublimis and flexor profundus muscles, it runs under the annular ligament into the palm, where it divides into an internal and an external division.

The internal division forms two branches, one to each of the second and third finger clefts. Each branch divides into two smaller digital branches, which course along the sides of the contiguous fingers. They supply these fingers on their palmar surface and the dorsum of their ungual phalanges. They also supply the outer two lumbrical muscles.

The external division also forms two branches. One branch, passing to the outer side of the thumb, supplies the abductor pollicis, the outer head of the flexor brevis pollicis, the flexor ossis metacarpi pollicis and the neighboring skin. The other branch breaks up into collaterals that supply the skin on the inner side of the thumb and the outer side of the index finger.

In the arm the median nerve gives off branches as follows:

(1) A few branches, arising at the elbow, supply the pronator teres, palmaris longus, flexor carpi radialis and flexor sublimis digitorum muscles and the elbow joint.

(2) *The anterior interosseous nerve*, which arises a little below the elbow and descends on the interosseous membrane, distributes branches to the inner part of the flexor profundus and the flexor longus pollicis, and then, passing under the pronator quadratus, supplies that muscle and the wrist joint.

(3) *The palmar cutaneous nerve*, arising above the annular ligament and descending to the hand, is distributed to the skin on the radial half of the palm.

CHAPTER XI.

INNERVATION OF THE HIP AND LEG.

THE innervation of these parts is derived from the five lumbar nerves and the first three sacral nerves, by way of the lumbar and sacral plexuses.

INNERVATION THROUGH THE LUMBAR PLEXUS.

The Ilio-inguinal Nerve (1. L.), running outward parallel with the iliac crest and passing through the inguinal canal to the external abdominal ring, here divides into several branches, some of which supply the skin on the upper and inner part of the thigh.

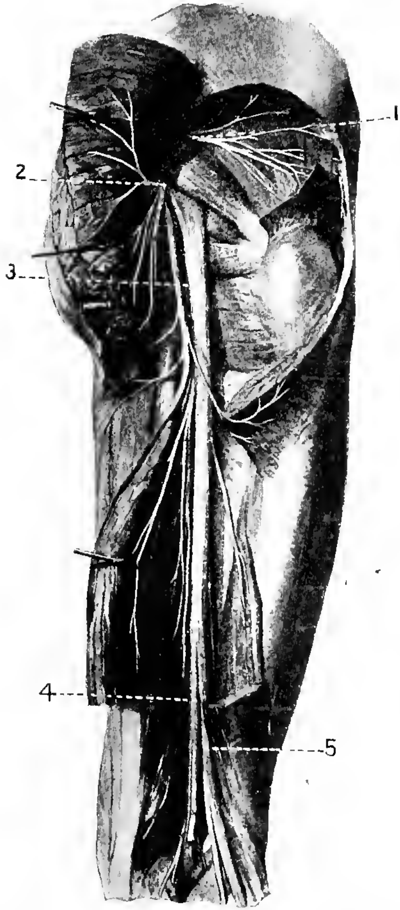
The Ilio-hypogastric Nerve (1. L.), running parallel with the iliac crest, divides into two branches, one of which, *the iliac nerve*, supplies the skin between the iliac crest and the great trochanter.

The Genito-crural Nerve (1. 2. L.) descends over the anterior surface of the psoas muscle until near the bifurcation of the common iliac artery, where it divides into a genital and a crural branch. The crural branch, passing under the inguinal ligament, supplies the skin on the front and upper part of the thigh.

The External Cutaneous Nerve (2. 3. L.), piercing the psoas muscle and passing over the iliacus to a point below the anterior superior iliac spine, runs thence under the inguinal ligament and supplies the skin on the outer side of the thigh.

The Anterior Crural Nerve (2. 3. 4. L.), descending along the outer border of the psoas muscle, distributes lateral

PLATE 14.



Nerves of the back of the thigh: 1, superior gluteal nerve; 2, inferior gluteal nerve; 3, sciatic nerve; 4, popliteal nerve; 5, peroneal nerve.—(Modified from Spalteholz)

branches to the iliacus muscle, and then, passing under the inguinal ligament into the thigh, divides into terminal branches, as follows:

(1) Muscular branches, arising soon after the nerve enters the thigh, supply the rectus femoris, the vastus internus, the vastus externus, the vastus intermedius and the pectineus.

(2) *The middle cutaneous nerve*, consisting of two branches, supplies the skin on the front of the thigh. One of its branches also perforates and supplies the sartorius muscle.

(3) *The internal cutaneous nerve* descends with the femoral artery and supplies the skin on the inner side of the thigh.

(4) *The internal saphenous nerve*, descending through Hunter's canal and then with the internal saphenous vein, supplies the skin on the inner side of the leg below the knee, and on the inner side of the foot as far as the ball of the great toe.

The Obturator Nerve (2. 3. 4. L.) follows the inner border of the psoas muscle to the pelvic brim and then passes to the obturator foramen, through which it leaves the pelvis in two divisions. It supplies the adductor magnus, the adductor longus, the adductor brevis, the adductor gracilis and the obturator externus, and distributes some branches to the hip joint.

The Patellar Plexus, formed by branches of the external, middle and internal cutaneous nerves, is distributed to the skin about the patella.

The Subsartorial Plexus, formed by branches of the internal cutaneous, internal saphenous and obturator nerves, is situated beneath the sartorius muscle in the lower third of the thigh. Its fibers are distributed to surrounding structures.

INNERVATION THROUGH THE SACRAL PLEXUS.

The Superior Gluteal Nerve (4. 5. L. 1. S.), leaving the pelvis through the great sacro-sciatic foramen and passing above the pyriformis muscle, runs outward and upward and supplies the gluteus medius, gluteus minimus and tensor vaginae femoris muscles.

The Inferior Gluteal Nerve (4. 5. L. 1. S.), leaving the pelvis through the great sacro-sciatic foramen but passing under the pyriformis muscle, runs outward and downward and supplies the gluteus maximus muscle.

Note.—Closely related to the gluteal nerves in origin are three small nerves that supply the quadratus femoris, gemellus superior, obturator internus and pyriformis muscles.

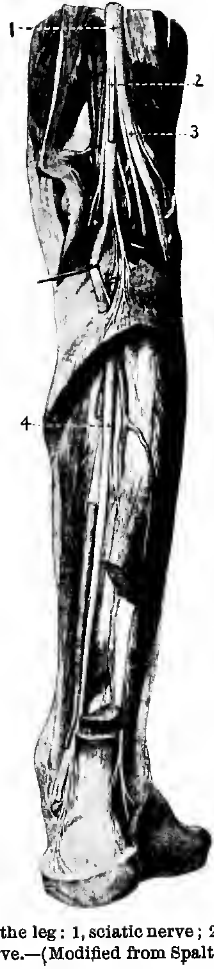
The Perforating Cutaneous Nerve, perforating the great sacro-sciatic ligament, is distributed to the skin over the lower and inner part of the gluteus maximus muscle.

The Small Sciatic Nerve (1. 2. 3. S.), entering the thigh under the pyriformis muscle, is distributed to the skin on the lower part of the buttock, and on the back of the thigh as far down as the knee. *The long pudendal nerve,* a branch of the small sciatic, is distributed to the skin on the upper and inner part of the thigh.

The Great Sciatic Nerve (4. 5. L. 1. 2. 3. S.), entering the thigh under the pyriformis muscle and descending on the adductor magnus muscle for a variable distance below the middle of the thigh, divides into the popliteal and peroneal nerves. Before dividing it distributes lateral branches to the biceps flexor cruris, semimembranosus, semitendinosus and adductor magnus muscles.

The Popliteal Nerve (4. 5. L. 1. S.), which extends to the lower end of the popliteal space, supplies the soleus, gastrocnemius, popliteus and plantaris muscles and the knee- and tibio-fibular joints. It also gives off a cutaneous branch, *the tibial communicating nerve,* which descends on the back of the calf and joins *the fibular communicating nerve,* a branch of the peroneal, the union of the two branches forming *the short saphenous nerve,* which accompanies the vein of the same name and passes along the side of the heel and foot to the little toe, distributing branches to the skin in the region through which it travels.

PLATE 15.



Deep nerves of the back of the leg: 1, sciatic nerve; 2, popliteal nerve; 3, peroneal nerve; 4, posterior tibial nerve.—(Modified from Spalteholz.)

The Posterior Tibial Nerve (4. 5. L. 1. 2. S.)—a continuation of the popliteal nerve—descends through the calf to a point between the os calcis and the internal malleolus and then divides into the internal and external plantar nerves. Before forming its terminal divisions it gives off lateral branches to the soleus, tibialis posterior, flexor longus hallucis and flexor longus digitorum muscles, and a cutaneous branch, *the calcaneo-plantar nerve*, that supplies the inner and under surface of the heel.

The Internal Plantar Nerve distributes branches as follows : muscular branches to the adductor hallucis, flexor brevis hallucis, flexor brevis digitorum and the inner two lumbricales ; articular branches to some of the joints of the foot, and cutaneous branches to the inner part of the sole, the under surface of the first three and a half toes and the dorsum of their ungual phalanges.

The External Plantar Nerve distributes branches as follows : muscular branches to the flexor accessorius, flexor brevis minimi digiti, adductor obliquus hallucis, adductor transversus hallucis, interossei and the outer two lumbricales ; articular branches to some of the joints of the foot, and cutaneous branches to the outer part of the sole, the under surface of the outer one and a half toes and the dorsum of their ungual phalanges.

The Peroneal Nerve (4. 5. L. 1. 2. S.) runs downward and outward to the upper end of the peroneus longus muscle and there divides into the musculo-cutaneous and anterior tibial nerves. Before dividing it gives off articular branches to the knee joint, and a cutaneous branch, *the lateral cutaneous nerve*, which supplies the upper two-thirds of the outer side of the leg.

The Musculo-cutaneous Nerve descends under the peroneal muscles and distributes branches to the peroneus longus and the peroneus brevis. Near the lower fourth of the leg it becomes superficial and divides into terminal branches, which are distributed to the skin on the lower fourth of the leg and the dorsum of the foot.

The Anterior Tibial Nerve descends on the interosseus membrane with the anterior tibial artery and passes under the annular ligament, from which it emerges in an internal and an external division. In the leg it distributes branches to the tibialis anterior, extensor longus digitorum, extensor proprius hallucis and peroneus tertius muscles and to the ankle joint. The internal division runs to the cleft between the first two toes and distributes digital branches to the skin on their contiguous surfaces. The external division supplies the extensor brevis digitorum muscle.

CHAPTER XII.

INNERVATION OF THE EXTERNAL GENITAL ORGANS AND THE PERINEUM.

THESE parts derive their innervation from the first and second lumbar nerves, and from the sacral and coccygeal nerves, by way of the sacral and coccygeal plexuses.

The Ilio-inguinal Nerve (1. L.), as it leaves the external abdominal ring, gives off branches that are distributed to either the scrotum or the labium majus, according to sex.

The Genito-crural Nerve (1. 2. L.), through its genital branch, supplies the cremaster muscle. In the female it accompanies and supplies the round ligament.

The Inferior Pudendal Nerve (1. 2. 3. S.), a branch of the small sciatic, emerging under the gluteus maximus muscle and winding inward round the thigh, contributes further innervation to either the scrotum or the labium majus.

The Pudic Nerve (2. 3. 4. S.), leaving the pelvis through the great sacro-sciatic foramen and running forward in the outer wall of the ischio-rectal fossa, divides into the perineal nerve and the dorsal nerve of the penis.

The perineal nerve divides into a deep and a superficial division. The deep division is distributed to the ischio-cavernosus, bulbo-cavernosus, transversus perinei, levator ani and sphincter ani externus muscles, and to the corpus spongiosum and the mucous membrane of the urethra. The superficial division divides into an internal and an external branch. The internal branch pierces the transverse perineal muscle and then runs forward on the inner side of the perineal vessels. The external branch crosses the transverse muscle and runs forward on the outer side of the perineal vessels. Both branches are distributed to either the scrotum or the labium majus and to the skin of the perineum.

The dorsal nerve of the penis, running forward between the layers of the triangular ligament, finally pierces the outer layer and continues forward along the dorsum of the penis as far as the glans. It supplies the corpus cavernosum and the constrictor urethrae muscle. The corresponding nerve in the female is distributed to the clitoris.

The Coccygeal Plexus, formed by the coccygeal nerve and branches of the fourth and fifth sacral nerves, is distributed to the levator ani, coccygeus and sphincter ani externus muscles and to the skin about the anus.

CHAPTER XIII.

INNERVATION OF THE RESPIRATORY MECHANISMS.

The Inspiratory Nerves and Muscles.

THE inspiratory or active phase of respiration involves the activity of a number of motor nerves, among the most important of which is the phrenic, supplying the diaphragm.

The Phrenic Nerve, arising from the fourth and fifth cervical segments of the cord, descends over the anterior scalenus muscle and beneath the supracapsular artery and then passes behind the subclavian vein into the thorax. From this point the right nerve descends along the outer side of the pericardium to the front of the right lung and thence between the lung and thoracic wall to the diaphragm. The left nerve crosses the aortic arch and the pericardium to the front of the left lung, whence its course is similar to that of the right nerve. Both nerves pierce the diaphragm and are distributed on its lower surface.

The diaphragm also receives a few branches from the lower intercostal nerves, but they are of far less importance than the phrenics.

The other motor nerves concerned in inspiration, together with the inspiratory muscles which they innervate, are the following: *The intercostal nerves*, supplying the external intercostal muscles, the intercartilaginous portion of the internal intercostals and the serratus posterior; *the cervical plexus*, supplying the anterior, medius and posterior scaleni; *the brachial plexus*, supplying the pectoralis minor; *the spinal accessory nerve*, supplying the sterno-cleido-mastoid; *the facial nerve*, supplying the elevators of the wings of the anterior nares; and *the pneumogastric nerve*, supplying the posterior crico-arytenoid muscle of the larynx.

Action of the Inspiratory Muscles.

Contraction of the diaphragm causes its convex upper surface—which, when the muscle is at rest, invades the thorax—to become flattened and the muscle to descend, the effect of which on the thoracic side is enlargement of the chest in its vertical diameter. On the abdominal side it produces an increase of pressure, which is transmitted through the viscera and causes protrusion of the abdominal wall, as is evidenced in what is known as the abdominal or diaphragmatic type of breathing. Contraction of the muscles about the chest and in the neck elevates the ribs and enlarges the chest in circumference. With the expansion of the chest, due to the contraction of the inspiratory muscles, the air enters the lungs under the pressure of the outside atmosphere, and this constitutes the inspiratory phase of respiration.

Contraction of the elevators of the wings of the nose dilates the anterior nares, and contraction of the posterior crico-arytenoid muscle dilates the glottis, thus in both cases making freer passage for the entering current of air.

In the usual inspirations, such as are made without conscious effort, only the diaghragm and the levatores costarum are active, but in labored or difficult breathing any or all of the other inspiratory muscles may come into play, depending upon the force and amplitude of the inspiratory movements.

The Expiratory Nerves and Muscles.

The ordinary type of expiration, such as occurs in normal breathing, is a purely passive process, the lungs, after being expanded by an inspiration, collapsing under such physical influences as their own elasticity and the weight of the chest walls. Expiration, however, occasionally becomes an active process, and then involves contraction of the interosseous portion of the internal intercostal muscles and of the triangularis sterni, serratus posterior inferior and abdominal muscles, all supplied by the *intercostal nerves*, and contraction of the quadratus lumborum muscle, supplied by the *lumbar nerves.*

Action of the Expiratory Muscles.

Contraction of the abdominal muscles causes pressure on the abdominal viscera. If the glottis is simultaneously dilated, allowing the air to escape from the lungs, the pressure is exerted upon the diaphragm, pushing it upward into the thorax and thus diminishing the size of the chest cavity. If, however, the glottis is kept closed, retaining the air in the lungs, the diaphragm becomes immovable, and the pressure is then exerted upon the pelvic viscera—an effect that has an important bearing upon all straining movements in which the action of the pelvic organs is involved.

Contraction of the other expiratory muscles pulls the ribs downward, the effect of which on the thorax is to further diminish its size by reducing its lateral and antero-posterior diameters.

Functions and Properties of the Respiratory Center.

Both the inspiratory and the expiratory muscles belong in the skeletal group and are under voluntary control, but in respiration their movements are directed and co-ordinated by the respiratory center in the medulla. This center comprises two functionally distinct groups of cells, one of which, acting in inspiration, may be termed the *inspiratory center*, and the other, acting in expiration, the *expiratory center.*

Expiration being normally passive and inspiration always active, it is evident that the inspiratory center exerts the greater influence in respiratory control. This center is rhythmical in its action and also possesses the peculiar property of being automatic. Its automatic activity is the result of chemical changes that take place in its cells, due to the presence of carbon dioxid in its blood-supply. The rhythm of its action is maintained by afferent fibers contained in the pneumogastric nerves and distributed to the air-vesicles of the lungs. When the lungs are expanded by an inspiration, these fibers are mechanically stimulated by the expansion and their impulses have an inhibitory effect on the inspiratory center, cutting short the inspiration and causing expiration, after which the center again discharges, under the influence of its normal chemical stimulus. These fibers are the chief factors in maintaining the normal rate of respiration.

The pneumogastric nerves supply the lungs with another set of afferent fibers, which have an accelerating effect on the inspiratory center. Concerning the extent to which these fibers are involved in ordinary respiration and the circumstances under which they are stimulated, there is no universal agreement. The most generally accepted belief is that they are stimulated by collapse of the lungs at the end of expiration and thus hasten the resumption of the inspiratory movements. There is no evidence, however, that they have any important part in the maintenance of the respiratory rate.

The expiratory center is active only when expiration becomes an active process. This center, unlike the inspiratory center, is not automatic, but is normally stimulated either by impulses received through various afferent paths or by impulses received through intercentral fibers from the cerebral cortex.

Modifications of the Respiratory Movements.

The activity of the respiratory center, and consequently the respiratory movements, may be modified reflexly in different ways, by stimulation of sensory fibers in various parts of the body. Strong stimulation of the cutaneous fibers may produce either an increase or a decrease in both the rate and amplitude, or temporarily inhibit all respiratory movements. Complete inhibition may also be obtained by stimulation of the splanchnic nerves or by stimulation of the glosso-pharyngeal fibers supplying the mucous membrane of the pharynx. Certain forms of stimuli acting on the trifacial fibers that supply the mucous membrane of the nose, will so excite the expiratory center as to produce the type of expiration that occurs in *sneezing*. When the pneumogastric fibers supplying the interior of the larynx, the trachea or the bronchi are stimulated, as by mucous or foreign bodies, the effect is transmitted to the expiratory center and the forced expirations of *coughing* ensue. Stimulation of the pneumogastric fibers supplying the lining membrane of the stomach, may either excite the expiratory movements of coughing or cause the sudden and involuntary contractions of the diaphragm that occur in the inspiratory movements of *hiccoughing*.

Respiration may also be affected by emotional states, through the efferent paths extending from the cortex of the cerebrum to the respiratory center of the medulla. Emotions may either increase or decrease both phases of respiration, or cause the inspiratory movements of *sighing* and *sobbing* and the expiratory movements of *laughing*.

Finally, respiratory movements may be increased, decreased or entirely suspended by voluntary control. But in complete voluntary suspension of respiration the accumulation of carbon dioxid in the blood so increases the irritability of the respiratory center that it eventually overcomes the voluntary inhibition and respiration is resumed. Whether the voluntary control of respiration is effected entirely through the pyramidal fibers that make connections with the efferent neurons of the respiratory muscles, or to some extent through the intercentral fibers that connect the cerebral cortex with the respiratory center, is not known.

Note.—For the efferent innervation of the bronchi, see page 141.

PART IV.

THE SYMPATHETIC NERVES AND THE INNERVATION OF THE BLOOD-VESSELS AND VISCERA.

CHAPTER I.

FORMATION AND RELATIONS OF THE SYMPATHETIC SYSTEM.

THE so-called sympathetic nervous system comprises the outlying efferent neurons through which impulses from the central nervous system finally reach the involuntary muscles and glands. Though situated entirely in the periphery, these neurons are connected with the anterior horns of a part of the spinal cord, and with the oculo-motor, facial, glosso-pharyngeal and pneumogastric nuclei. Their cell-bodies are collected into ganglia, which are found in the region of the head, along the vertebral column, in the prevertebral plexuses and in the tissues of the viscera. There is also a large number of small nerve-cells in the walls of the alimentary tract, forming what are known as *the plexuses of Meissner and Auerbach*, which may, or may not, be associated with the sympathetic system, their function not being satisfactorily determined.

Every efferent nerve path to the cell of an involuntary muscle or gland consists of two distinct but connected neurons. The fiber of the first neuron, arising in the brain or spinal cord, passes out in a cranial or a spinal nerve and ends about the dendrites of the second neuron, in one of the sympathetic ganglia. The fiber of the second neuron completes the path. The first fiber is generally medullated or white and termed *preganglionic;* the second fiber is generally non-medullated or gray and termed *postganglionic*, these terms signifying the position of the fibers in relation to the ganglia.

THE VERTEBRAL GANGLIA.

The vertebral ganglia lie in two chains along the front of the vertebral column, from the second cervical vertebra to the coccyx. The ganglia of each side are connected with one another by a cord of nerve-fibers, the cords and the ganglia forming *the sympathetic trunks.* Each trunk generally contains from 20 to 23 ganglia, consisting of three cervical, eleven or twelve thoracic, four lumbar, four sacral and one coccygeal, the last being common to both trunks and known as the *ganglion impar.*

The preganglionic fibers that connect the vertebral ganglia with the cord leave the cord in the thoracic and the first two lumbar nerves—occasionally, also, in the next two nerves below. As each of these nerves reaches the outside of the vertebral column, its preganglionic fibers, branching off in a *white ramus communicans*, pass to the nearest vertebral ganglion. Some of the fibers end in the first ganglion that they enter; others, passing through the first ganglion, ascend or descend in the sympathetic trunk and end in a higher or a lower ganglion; and still others, after passing through one or more vertebral ganglia, continue as preganglionic fibers and end in some ganglion of a prevertebral plexus. These last fibers are known as *the rami efferentes* of the ganglia that they traverse, and they always run in visceral nerves.

The white rami communicantes, in addition to their efferent fibers, also contain sensory fibers of the viscera. These fibers arise in the ganglia of the posterior nerve-roots, pass through the white rami and the vertebral ganglia, and then run in the visceral nerves to their destination in the viscera.

The postganglionic fibers of the vertebral ganglia form *gray rami communicantes*, and sometimes, also, *rami efferentes.* The rami efferentes generally enter prevertebral plexuses and are thence distributed directly to blood-vessels or viscera. The gray rami communicantes are small bundles that pass from each ganglion to the skeletal parts of one or more of the neighboring spinal nerves. The majority of the fibers in each gray ramus accompany the peripheral branches of the nerve, particularly the cutaneous branches, being finally distributed to the blood-vessels of the muscles and skin, the erector muscles of the hair and the sweat glands. Some of the fibers, however, instead of running peripherally, pass back along the posterior nerve-root and re-enter the vertebral canal, to suppy the blood-vessels of the spinal cord and its membranes. The remaining fibers leave the gray ramus before its junction with the nerve, some to accompany the recurrent branch of the nerve to the vertebral canal, and the others to follow and innervate the intercostal and lumbar arteries. The gray rami, as a whole, contain vaso-constrictor, vaso-dilator, pilo-motor and secretory fibers.

The Superior Cervical Ganglion.

The superior cervical ganglion, varying from an inch to an inch and a half in length, lies on the front of the transverse processes of the second and third cervical vertebrae, with the internal carotid artery in front and the pneumogastric nerve behind. The preganglionic fibers that connect it with the spinal cord, leave the cord in the first five or six thoracic nerves, pass through the white rami to the sympathetic trunk, and thence upward in the trunk, to end about the cells of the ganglion. Its postganglionic fibers form a gray ramus for each of the first four cervical nerves. It distributes *rami efferentes*, as follows :

(1) Three branches, joining respectively the glosso-pharyngeal, pneumogastric and hypoglossal nerves, accompany these nerves to parts in which they are distributed.

(2) *Two or three pharyngeal branches*, descending to the back of the pharynx, join the pharyngeal plexus.

(3) *The internal carotid branc* ascending along the inner side of the internal carotid artery to the carotid canal, there

divides into an inner and an outer division. *The inner division,* continuing along the inner side of the artery to the cavernous sinus, there breaks up and forms *the cavernous plexus,* the fibers from which are distributed to the third and fourth cranial nerves, the ciliary ganglion and the pituitary body. *The outer division,* while still in the carotid canal, forms *the carotid plexus* about the artery. From this spring *the great deep petrosal nerve,* which passes through the Vidian canal to the spheno-palatine ganglion, and *the small deep petrosal nerve,* which runs with the tympanic nerve to the tympanic plexus in the petrous bone. It also gives off branches that join the abducent and trifacial nerves, the latter at the Gasserian ganglion.

(4) *The external carotid branch,* running with the external carotid artery, forms on the facial artery a plexus from which fibers pass to the sublingual and submaxillary ganglia, and on the middle meningeal artery another plexus from which fibers pass to the otic ganglion.

(5) *Two or three superior cardiac branches,* descending behind the carotid sheath, enter the thorax and join the cardiac plexus.

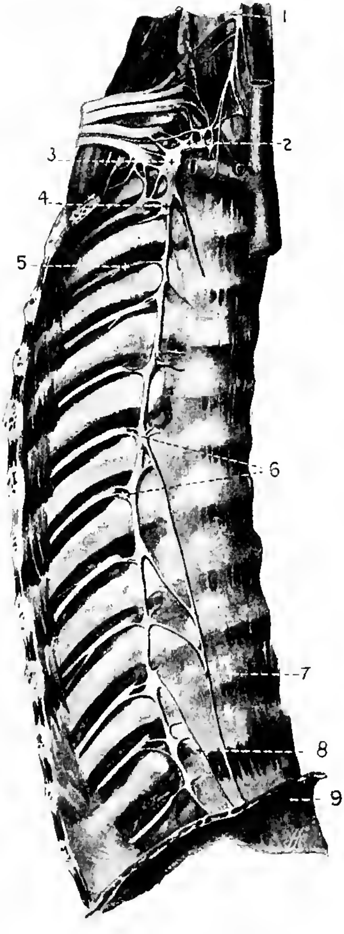
The Middle Cervical Ganglion.

The middle cervical ganglion lies on the front of the sixth or seventh cervical vertebra. The fibers that connect it with the cord, leave the cord in the upper five or six thoracic nerves and reach the ganglion by way of the white rami communicantes and the sympathetic trunk. Its postganglionic fibers form a gray ramus for each of the fifth and sixth cervical nerves and a ramus efferens that terminates in the thyroid gland. *A middle cardiac branch* joins the cardiac plexus.

The Inferior Cervical Ganglion.

The inferior cervical ganglion lies above the neck of the

PLATE 16.



The right sympathetic trunk: 1, middle cervical ganglion; 2, inferior cervical ganglion; 3, first thoracic ganglion; 4, second thoracic ganglion; 5, intercostal nerve; 6, rami communicantes; 7, greater splanchnic nerve; 9, the diaphragm.—(Modified from Spalteholz.)

first rib, covered by the vertebral artery. The preganglionic fibers connecting it with the spinal cord leave the cord in the upper six or seven thoracic nerves and reach the ganglion by way of the white rami and the sympathetic trunk. Its postganglionic fibers form a gray ramus for each of the seventh and eighth cervical nerves, and rami efferentes, as follows: (a) branches distributed to neighboring blood-vessels; (b) *the inferior cardiac branch*, which forms one of the accelerator nerves of the heart and ends in the cardiac plexus, and (c) branches that unite in a plexiform manner with branches of the first thoracic ganglion and accompany the vertebral artery into the cranium.

The Thoracic Ganglia.

The first thoracic ganglion lies under the head of the first rib; the twelfth, on the side of the twelfth thoracic vertebra; and the intervening ganglia, on the heads of the ribs. Each of these ganglia is connected with the spinal cord by a white ramus communicans, and each distributes a gray ramus to one of the thoracic nerves. The first ganglion gives off to the cardiac plexus a ramus efferens that forms an accelerator nerve of the heart. The second, third and fourth ganglia distribute rami efferentes to the pulmonary plexus, and the upper five ganglia distribute other rami efferentes to the plexus about the aorta. The lower six or seven ganglia give off rami efferentes that form the great splanchnic, small splanchnic and least splanchnic nerves.

The great splanchnic nerve is formed on the side of the vertebral column by the union of rami efferentes of the ganglia from the fifth or sixth to the ninth or tenth. *The small splanchnic nerve* is formed by the union of rami efferentes from the ninth and tenth ganglia, and sometimes, also, from the eleventh. *The least splanchnic nerve* is a ramus efferens of the twelfth ganglion. All these nerves pass through the diaphragm into the abdomen and join prevertebral plexuses. Their efferent fibers end about sympathetic cells.

The Lumbar Ganglia.

The lumbar ganglia lie on the front of the bodies of the lumbar vertebrae. The first and second ganglia are each connected with the spinal cord by the white ramus communicans of the corresponding lumbar nerve. But the third and fourth ganglia are connected by fibers that arise at higher levels and pass to the ganglia by way of the sympathetic trunk, there being, as a rule, no white rami below the second lumbar nerve. The postganglionic fibers of the lumbar ganglia form a gray ramus communicans for each of the lumbar nerves. Their rami efferentes, containing preganglionic fibers, join the neighboring prevertebral plexuses.

The Sacral Ganglia.

The sacral ganglia are situated on the front of the sacrum along the inner side of the anterior sacral foramina. They distribute a gray ramus to each of the sacral nerves and rami efferentes to the neighboring plexuses. But white rami in this region are wanting, the preganglionic connection of the ganglia being derived through nerves at a higher level, by way of the sympathetic trunk. The second, third and fourth sacral nerves, however, contain preganglionic fibers, and these unite to form *the nervus erigens.* This enters the pelvic plexus and ends by arborization in pelvic ganglia, without making any connection with the sympathetic trunk. It contains viscero-motor, viscero-inhibitory and vaso-dilator fibers.

Below the sacrum the two sympathetic trunks unite in the ganglion impar, which is also connected with the coccygeal nerves.

THE GANGLIA OF THE HEAD REGION.

The sympathetic system, continuing upward into the head, is here represented by the ciliary, spheno-palatine, otic, sublingual and submaxillary ganglia. These ganglia are each traversed by fibers of the trifacial nerve, as shown in previous chapters, and by the sympathetic fibers that reach them through the carotid branches of the superior cervical ganglion, both sets of fibers, after passing through the ganglia, being distributed from their peripheral side.

The Ophthalmic, Ciliary or Lenticular Ganglion is a small quadrangular body, about one-twelfth of an inch in its long diameter, lying in the back of the orbital fossa, between the optic nerve and the external rectus muscle. The preganglionic fibers that connect it with the central nervous system arise in the oculo-motor nucleus, pass through the oculo-motor nerve and its branch to the inferior oblique muscle of the eyeball, and then branch off as a short bundle and pass to the ganglion. Its postganglionic fibers run in the short ciliary nerves and supply the ciliary muscle and the sphincter muscle of the iris.

The Spheno-palatine or Meckel's Ganglion is a small triangular body, about one-fifth of an inch long, lying under the superior maxillary nerve in the fat of the spheno-maxillary fossa. Its central connections are with the facial nucleus. The preganglionic fibers run in the facial nerve as far as the geniculate ganglion, and then branch off in *the great superficial petrosal nerve,* in which they complete their course. This nerve, leaving the petrous bone through a foramen on its anterior surface, runs thence through the foramen lacerum medium to the under surface of the cranium, where it turns forward and passes to the ganglion by way of the Vidian canal. The fibers arising in the ganglion accompany branches of the superior maxillary nerve and are distributed to blood-vessels.

The Otic Ganglion is a small oval body, about one-sixth of an inch in its long diameter, lying under the base of the cranium near the foramen ovale, with the Eustachian tube on its inner side. Its central connections are with the glosso-pharyngeal nucleus. The preganglionic fibers pass with the tympanic nerve into the petrous bone and there divide into two divisions, one of which joins the great superficial petrosal nerve, and the other, uniting with *the small superficial petrosal nerve*, runs with this to the otic ganglion. The course of the small superficial petrosal nerve is from the geniculate ganglion through a foramen on the anterior surface of the petrous bone, and thence out of the cranium between the petrous bone and the great wing of the sphenoid. Beneath the cranium it passes to the otic ganglion, where the glossopharyngeal fibers end. The fibers from the ganglion are distributed mainly with the mandibular division of the trifacial nerve, their destination being the blood-vessels of the parts which this division supplies, and the parotid and orbital glands. They are both vaso-dilator and secretory in function.

The Sublingual Ganglion is a small body about the size of a pin-head, situated in the floor of the mouth, with the lingual nerve above and Wharton's duct below. **The Submaxillary Ganglion** is a still more minute body, lying in the hilum of the submaxillary gland. The fibers that connect these ganglia with the central nervous system, arise in the nucleus of the facial nerve and reach the ganglia by way of the facial and chorda tympani nerves. The fibers from the submaxillary ganglion are distributed to the submaxillary gland and its blood-vessels. The fibers from the sublingual ganglion join the lingual nerve and with this are distributed to the sublingual gland and its blood-vessels and to the anterior two-thirds of the tongue. The fibers from both ganglia are in part vaso-dilator and in part secretory.

THE PREVERTEBRAL PLEXUSES.

These are the plexuses through which the cerebro-spinal nerves are distributed to the visceral organs and their blood-vessels. The main prevertebral plexuses are the cardiac, pulmonary, solar, hypogastric and pelvic.

The Cardiac Plexus, lying in the concavity of the aortic arch and in the bifurcation of the trachea, is formed by branches of the pneumogastric nerves and *rami efferentes* of the cervical and first thoracic ganglia. It contains the ganglion of Wrisberg and other small ganglia and gives rise to *the right and left coronary plexuses,* which accompany the corresponding arteries of the heart. The efferent fibers that enter it are derived from the pneumogastric nerves and the inferior cervical and stellate ganglia.

The Pulmonary Plexuses are two in number for each lung—the anterior, lying in front of the bronchus, and the posterior, lying behind the root of the lung. They are formed by pneumogastric fibers and by rami efferentes of the second, third and fourth thoracic ganglia. Their branches are distributed to the bronchi and the pulmonary blood-vessels.

The Solar or Epigastric Plexus, lying in front of the upper two lumbar vertebrae, behind the stomach and between the upper ends of the kidneys, consists of two lateral parts connected by fibers extending across the aorta and surrounding the origin of the coeliac axis. It is formed by pneumogastric fibers and the great splanchnic and small splanchnic nerves. Its principal ganglia are *the semi-lunar* and *the aortico-renal,* in each half of the plexus, and *the superior mesenteric,* in the right half only. Arising from it are the phrenic, hepatic, coronary, superior mesenteric, splenic and aortic plexuses, which accompany the blood-vessels of the corresponding names.

The aortic plexus, beginning with fibers from the lower end of the solar plexus, is re-enforced by rami efferentes from the upper lumbar ganglia. As two lateral cords connected by intervening fibers, it descends on the aorta as far as the front of the fifth lumbar vertebra and there ends in the hypogastric plexus. Its main branch forms *the inferior mesenteric plexus*, which follows the course of the inferior mesenteric artery and holds in its meshes *the inferior mesenteric ganglion.* Its other branches unite with branches of the solar plexus and with the least splanchnic nerve, the union forming *the renal and supra-renal plexuses.* These follow the course of the renal and supra-renal arteries and distribute fibers to the kidney and supra-renal body and the ureter and spermatic cord.

The Hypogastric Plexus is a strong meshwork of fibers derived from the aortic plexus and the lower lumbar ganglia. It serves principally as a connecting link between the plexuses of the abdomen and the pelvis.

The Pelvic Plexus begins with two lateral groups of fibers derived from the lower end of the hypogastric plexus. These descend on each side of the rectum and bladder in the male, and of the rectum, bladder and vagina in the female. On reaching the pelvis they are augmented by the nervus erigens and by rami efferentes from the sacral ganglia. This plexus contains many small collections of sympathetic nerve-cells, the preganglionic connections of which are with the lumbar and sacral segments of the spinal cord. Its secondary plexuses are the hemorrhoidal and vesical (in both sexes), the prostatic (in the male), and the uterine and vaginal (in the female).

The hemorrhoidal plexus descends on the middle hemorrhoidal artery, where fibers descending from the inferior mesenteric plexus join it. It supplies the walls and blood-vessels of the rectum and the internal sphincter of the anus.

The vesical plexus extends over the base and sides of the bladder. Its branches are distributed to the bladder walls and blood-vessels, and, in the male, to the vasa deferentia and the seminal vesicles.

The prostatic plexus lies between the prostate gland and the levator ani muscle. It supplies the gland and contributes somewhat to the innervation of the seminal vesicles and the corpus cavernosum.

The uterine plexus accompanies the broad ligament, being distributed to the uterus, ovaries and Fallopian tubes.

The vaginal plexus lies in the walls of the vagina. It supplies the blood-vessels, mucous membrane and muscles of the vagina and distributes some fibers to the clitoris. Among its efferent fibers are some that are under voluntary control.

CHAPTER II.

INNERVATION OF THE BLOOD-VESSELS.

The vaso-constrictor nerves (preganglonic fibers) for the whole body have their cells of origin in the spinal cord and leave the cord in the thoracic and first two lumbar nerves. The vaso-dilator nerves (preganglionic fibers) are of both spinal and cranial origin. The spinal dilator fibers leave the cord in the thoracic and first two lumbar nerves and in the second, third and fourth sacral nerves. The cranial dilator fibers arise in the facial, glossopharyngeal and pneumogastric nuclei and leave the brain in the facial, glossopharyngeal and pneumogastric nerves. The vaso-motor nerves, both constrictor and dilator, of thoracic and lumbar origin, pass through *the white rami communicantes* to the sympathetic trunks. Those destined for skeletal parts of the body and for all structures in the head, end by arborization in vertebral ganglia. Those destined for visceral organs—with two exceptions—pass through the vertebral ganglia and end by arborization in prevertebral ganglia. The sacral dilator nerves make no connection with the sympathetic trunks but pass directly to prevertebral ganglia in the pelvis.

VASO-MOTOR NERVES OF THE HEAD REGION.

The vaso-constrictor nerves of the head region leave the cord in the upper five or six thoracic nerves and reach their destination as postganglionic fibers from the superior cervical ganglion, being distributed with both cranial and cervical nerves.

The vaso-dilator nerves arise in the upper five or six thoracic nerves and in the facial and glossopharyngeal nerves. The dilator fibers of spinal origin pass to the superior cervical ganglion, and from this, as postganglionic fibers, their course is continued to the cheeks, lips, gums, palate and nasal fossæ and to the scalp and external ear. Of the facial fibers a part pass to *the spheno-palatine ganglion.* From this the postganglionic fibers are distributed with the trifacial fibers by which the ganglion is traversed, i. e., in the mucous membrane of the upper lip, the upper part of the mouth, the soft palate, the tonsils, the nasal fossæ and the upper part of the pharynx. Other facial fibers pass to *the sublingual ganglion,* from which the postganglionic fibers are distributed in the sublingual gland and in the mucous membrane of the anterior two-thirds of the tongue. The remaining facial fibers pass to *the submaxillary ganglion,* and from this the postganglionic fibers are distributed in the gland of the same name. The glossopharyngeal fibers pass to *the otic ganglion,* from which the postganglionic fibers are distributed with the mandibular division of the trifacial nerve, their destination being the skin of the temples, the skin and mucous membrane of the cheeks, the lower lip and lower gums, the posterior third of the tongue and the parotid and orbital glands.

VASO-MOTOR NERVES OF THE NECK, TRUNK AND LIMBS.

The vaso-motor nerves, both constrictor and dilator, for the cervical region leave the cord in the upper five or six thoracic nerves and pass mainly to the superior cervical ganglion, though some end in the two ganglia below. From these ganglia postganglionic fibers accompany the cervical nerves to the muscles and skin of the neck.

The vaso-motor nerves, both constrictor and dilator, for the upper limb leave the cord in the upper five or six thoracic nerves and pass to the first thoracic ganglion, from which, as postganglionic fibers, they are distributed with the terminal branches of the brachial plexus.

The vaso-motor nerves, both constrictor and dilator, for the lower limb leave the cord in the lower thoracic and the first two lumbar nerves and pass to the lower lumbar and the upper sacral ganglia, from which, as postganglionic fibers, their course is continued in branches of the lumbar and sacral plexuses.

The vaso-motor nerves, both constrictor and dilator, for the trunk arise throughout the entire vaso-motor area of the cord and pass to all the vertebral ganglia below the superior cervical. Thence, as postganglionic fibers, they accompany all the spinal nerves that are distributed in the trunk.

VASO-MOTOR NERVES OF THE TONSILS, PHARYNX AND LARYNX.

The vaso-constrictor nerves for these parts leave the cord in the upper five or six thoracic nerves and are distributed as postganglionic fibers from the superior cervical ganglion. The vaso-dilator nerves are derived to some extent from the facial nerve, as previously stated. But their main source is *the nucleus ambiguus*, from which they emerge in either the glossopharyngeal or the pneumogastric nerve. Their cell stations are in or near the parts to which as postganglionic fibers they are eventually distributed.

VASO-MOTOR NERVES OF THE SPINAL CORD.

The vaso-motor nerves, both constrictor and dilator, for the spinal cord and its membranes leave the cord in the thoracic and the first two lumbar nerves and pass to the vertebral ganglia. Thence, as postganglionic fibers, they enter the gray rami communicantes and pass to the vertebral canal, some passing by way of the posterior roots of the spinal nerves, and the remainder by way of their recurrent branches.

VASO-MOTOR NERVES OF THE BRAIN.

The blood-supply of the brain is regulated, to a considerable extent, by vaso-motor activity in other parts of the body. Mental activity is accompanied by a vaso-constriction in the skin and abdomen, the result of which is less blood in these regions and more blood in the brain. A lessening or cessation of mental activity is accompanied by a vascular relaxation in the skin and abdomen, and in this case the result is more blood in these regions and less blood in the brain. The anatomical relations by which this adjustment of the cerebral circulation is effected are uncertain, though it is probably brought about through fibers extending from the cortex of the cerebrum to the vaso-constrictor center.

Besides this indirect or reflex control of the cerebral circulation, there is evidence that the brain is also supplied with both vaso-constrictor and vaso-dilator nerves which arise in the second, third and fourth thoracic nerves and reach the brain by way of the superior cervical ganglion and its internal carotid branches. To what relative extent these nerves are factors in regulating the brain circulation, has not been finally determined.

VASO-MOTOR NERVES OF THE HEART.

Vaso-motor nerves of the heart have not been conclusively demonstrated, but such evidence as there is points to the following: That constrictor nerves are received by way of the upper two or three thoracic nerves and either the first thoracic or the inferior cervical ganglion, and that dilator nerves are derived through the pneumogastric nerves and ganglia located in the region of the heart.

VASO-MOTOR NERVES OF THE LUNGS.

These nerves, too, are a matter of some uncertainty, but, so far as they have been investigated, the evidence is that both constrictor and dilator nerves leave the cord in the thoracic nerves, from the third to the seventh, and pass to the second, third and fourth thoracic ganglia, being thence distributed, as postganglionic fibers, to the bronchial arteries. The pulmonary arteries have no vaso-motor nerves, so far as known.

VASO-MOTOR NERVES OF THE ABDOMINAL ORGANS.

The vaso-constrictor nerves for the stomach, liver, spleen and pancreas, and for the intestine down to the sigmoid colon, arise in the spinal nerves, from the fourth or fifth thoracic to the second lumbar, and pass to the semi-lunar, aortico-renal, superior mesenteric and inferior mesenteric ganglia, from which, as postganglionic fibers, they are distributed by way of the solar plexus and its branches. The vaso-dilator nerves for the descending colon and the left half of the transverse colon arise in the spinal nerves, from the sixth thoracic to the second lumbar, and reach their destination by way of the inferior mesenteric ganglion and the inferior mesenteric plexus. The vaso-dilator nerves for the remaining organs here considered arise in the pneumogastric nerves and pass to the various blood-vessels as postganglionic fibers from ganglia of the solar plexus.

The kidneys and the supra-renal bodies receive both vaso-constrictor and vaso-dilator nerves from the spinal cord. They leave the cord, for the most part, in the eleventh and twelfth thoracic and the first two lumbar nerves and end mainly in the aortico-renal ganglion. Thence, as postganglionic fibers, they follow the course of the renal and the supra-renal blood-vessels.

VASO-MOTOR NERVES OF THE SIGMOID COLON AND RECTUM.

The vaso-constrictor nerves for these parts of the intestine leave the cord in the tenth, eleventh and twelfth thoracic and the first two lumbar nerves and pass to the inferior mesenteric ganglion, from which postganglionic fibers, forming *the* *hypogastric nerve*, continue the path. The vaso-dilator nerves arise in the second, third and fourth sacral nerves and pass to pelvic ganglia, from which, as postganglionic fibers, they are distributed in branches of the pelvic plexus.

VASO-MOTOR NERVES OF THE EXTERNAL GENITAL ORGANS.

The vaso-constrictor nerves for the external genital organs leave the cord in the first two lumbar nerves and pass to sacral ganglia, being thence distributed, as postganglionic fibers, in branches of the pudic nerve. The vaso-dilator nerves arise in *the nervus erigens* and pass to pelvic ganglia, from which, as postganglionic fibers, they follow the course of the blood-vessels.

VASO-MOTOR NERVES OF THE INTERNAL GENITAL ORGANS AND THE BLADDER.

The vaso-constrictor nerves of the internal genital organs leave the cord in the first two lumbar nerves and pass to the inferior mesenteric ganglion, from which, as postganglionic fibers, they are distributed in the hypogastric nerve. The vaso-dilator nerves arise in the nervus erigens and are distributed as postganglionic fibers from pelvic ganglia.

The vaso-motor nerves of the bladder, both constrictor and dilator, have practically the same origin and course as the corresponding nerves of the internal genital organs, the main difference being only in their destination.

CHAPTER III.

FUNCTIONS AND PROPERTIES OF THE VASO-MOTOR NERVES.

The Vaso-constrictor Nerves.

The effect of vaso-constrictor activity is to maintain the muscular tone and the normal caliber of the blood-vessels, thus regulating, to a large extent, the arterial pressure and the flow of the blood.

The controlling factor in vaso-constriction is the vaso-constrictor center in the medulla, from which the fibers pass down the lateral columns of the cord and end about the vaso-constrictor neurons in the anterior horns of the spinal gray matter. The center is motor in function and is constantly active, its activity being maintained, and, for the most part, regulated, reflexly—that is, by impulses received through afferent nerves. The nerves which convey the regulating impulses are of two classes, *pressor nerves* and *depressor nerves.* Pressor nerves are those whose impulses increase the activity of the center and thereby cause an increased constriction of the arterioles and a rise of arterial pressure. Depressor nerves are those whose impulses inhibit the activity of the center and thereby cause a relaxation of the arterioles and a fall of arterial pressure. Most of the larger nerve-trunks contain both pressor and depressor fibers, though the pressor fibers predominate, and whether the stimulation of a nerve-trunk gives a pressor or a depressor effect, depends upon which set of fibers respond to the stimulus.

Common and well-known effects of both pressor and depressor activity are those produced by the influences of thermal stimuli. A brief application of cold to the skin, for example, whether by exposure or otherwise, results in blanching, due to the fact that the nerves which first respond to the cold stimulus have a pressor effect on the vaso-constrictor center, or some part of it, and reflexly increase the constriction of the cutaneous vessels, thereby diminishing the flow of blood in the skin. The subsequent reddening of the skin from the flushing of the cutaneous vessels, when the cold stimulus is applied for a considerable time, may be either the reflex effect of a secondary stimulation of the depressor fibers, or, what is more probable, the result of a reflex vaso-dilation. Heat, though at first reflexly stimulating the vaso-dilator nerves, if applied for a sufficient period of time and over a sufficient area of the body, eventually has a depressor effect on the vaso-constrictor center, the result of which is a vascular relaxation with a lowering of arterial tone and arterial pressure. Atmospheric temperature, acting as it does on the whole surface of the body, has most important effects, both pressor and depressor in character, on the vaso-constrictor center and corresponding influences on the circulation.

A marked example of depressor activity is that manifested by *the depressor nerve of the heart*, formed by afferent fibers of the pneumogastric nerve. If the arterioles become constricted to the extent of creating a peripheral resistance that the heart is unable to overcome, the depressor nerve is mechanically stimulated, the effect of the stimulation is transmitted to the vaso-constrictor center, the activity of the center is diminished and the constriction of the arterioles reduced, enabling the heart to resume its normal contractions.

Though the action of the vaso-constrictor center is regularly maintained by the stimulus of afferent impulses, it is modified, to a considerable extent, by conditions in the cerebral cortex. Mental work, as previously explained, has a stimulating effect on certain parts of the center, with the final and important result that the blood is increased in the brain. Emotional conditions have various effects. Sudden fear, for example, accelerates the center and increases vascular constriction, which, in case of the cutaneous vessels, is manifested by pallor of the skin. Some other emotions—embarrassment, for instance—inhibit the center, causing vascular relaxation and the increased blood-flow that is seen in the face as a blush. Mental depression tends to render the center increasingly susceptible to all the influences that play upon it, and if such conditions are long continued, the center finally becomes fatigued, control of the circulation is diminished, blood-pressure is abnormally reduced and pathological consequences ultimately ensue. On the other hand, normal mental states are potent factors in preserving the tonic activity of the center and, consequently, in maintaining the normal flow of the blood.

As is now evident, the action of the vaso-constrictor nerves, under normal conditions, is determined by the impulses discharged by the vaso-constrictor center, but there is evidence that they are also capable of independent action, under the stimulus of afferent impulses transmitted directly to the nerves themselves. In spinal traumata, in which the connection is broken between any of the peripheral nerves and the controlling vaso-constrictor center, the blood-vessels that receive their innervation from the part of the cord below the injury immediately lose their tone. But after a time, even with a continuance of the lesion, the lost tone is more or less restored, and the restoration must be attributed, for the most part, to the property of independent action inherent either in the spinal or the sympathetic neurons whose fibers form the vaso-constrictor nerves. There is some evidence that both sets of neurons possess this property in some degree. Its importance in certain pathological conditions of the spinal cord, especially in a limited lateral sclerosis, cannot be overestimated.

The Vaso-dilator Nerves.

Vaso-dilator activity lessens the contraction of the circular muscles of the arterioles, as a result of which the vessels are expanded and the quantity of blood which they contain is increased. The vaso-dilator nerves, unlike the vaso-constrictor nerves, are not constantly active, nor, so far as known, are they controlled from a general center. Under normal conditions, their activity is displayed only at the same time and in the same degree as that of their respective organs, the effect of which, under such conditions, is an increase in the blood-supply of the organs, in proportion to their functional needs. Their activity is modified in some instances by mental states and mental processes, the chorda tympani nerve and the nervus erigens, for example, being especially sensitive to cerebral influences. It is also possible that blushing, under the influence of embarrassing emotions, is another event assignable to the same cause, though, in this case, since the vaso-dilation extends to other parts than the face, it seems more probable, as previously observed, that the effect is produced by inhibition of the vaso-constrictor center. An important property of these nerves is a high degree of irritability with a corresponding responsiveness to abnormal stimuli, and in acute disorders, particularly when of an irritative character, vaso-dilation is one of the earliest and most constant manifestions.

All vaso-dilation assumes a previous vaso-constriction to a greater or less extent. Consequently the effects of vaso-dilator activity will depend not only upon the strength of the reflex stimulus but also upon the muscular tone of the vessels, the greatest effects, under a given stimulus and on a given set of vessels, being produced when the vessels are in the highest state of tone. Vaso-dilation in one part is normally accompanied by a compensatory vaso-constriction in other parts. Otherwise, the vaso-dilation would be ineffective in the way of increasing the blood-supply, and the general arterial pressure would be abnormally reduced.

CHAPTER IV.

INNERVATION OF THE VISCERAL ORGANS AND THE PHYSIOLOGICAL ACTION OF THE VISCERAL NERVES.

The Iris and the Ciliary Muscle.

THE efferent (pupillo-dilator) fibers, which supply the dilator pupillae muscle of the iris, arise from a group of cells situated in the lower cervical region of the cord and known as the *cilio-spinal center.* The fibers leave the cord in the first and second thoracic nerves and ascend in the sympathetic trunk to the superior cervical ganglion, from which postganglionic fibers, passing first with the ophthalmic division of the fifth nerve and then with the nasal nerve and the long ciliary nerves, continue the path to the muscle. The afferent path from the eye to the cilio-spinal center is along the optic nerve to the midbrain, and thence by new fibers which arise in the midbrain and descend to the center in the cord.

The efferent (pupillo-constrictor) fibers, which supply the ciliary muscle and the sphincter muscle of the iris, arise in the nucleus of the third cranial nerve and pass to the ciliary ganglion, from which their course to the muscles is continued by postganglionic fibers running in the short ciliary nerves. The afferent path from the eye to the motor center is along the optic nerve to the anterior quadrigemina, and thence by other fibers which pass to the anterior part of the oculomotor nucleus, where the motor cells lie.

When the dilator fibers are stimulated, the radiating fibers of the dilator-pupillæ muscle are contracted, the iris is drawn back and the pupil is enlarged.

When the fibers to the sphincter of the iris are stimulated, the sphincter is contracted, the iris is drawn forward and the size of the pupil is diminished.

When the fibers to the ciliary muscle are stimulated, the muscle is contracted and the shortening of the muscle pulls forward the choroid coat of the eyeball, thereby lessening the tension of the suspensory ligament of the lens and enabling the lens to increase its convexity. This is a reflex act and is known as the *accommodation reflex*, but it occurs only in connection with the voluntary act of adjusting the eyes to near objects—an act which, in addition to the contraction of the ciliary muscle, involves also contraction of the internal recti muscles, causing the eyes to converge, and contraction of the sphincter of the iris, by which, in consequence of the diminution in the size of the pupil, the light rays are better focused on the retina.

The activity of the motor cells whose fibers supply the constrictor and dilator muscles of the iris is normally determined in the act of accommodation and by the reflex stimulation of light acting on the retina. Modifications of their normal activity occur under the influences of impulses from the cerebral cortex and of sensory impulses from peripheral parts of the body. The emotional state of fear or the sensation of pain, for instance, will have an inhibitory effect on the cells of the constrictor fibers and cause dilation of the pupils, while other emotional states and other kinds of sensations may cause constriction. There are also drugs by the action of which the size of the pupil may be modified, those that cause constriction being known as miotics, and those that cause dilation, as mydriatics. But in these cases the action of the drug is sometimes exerted on the nerves and sometimes directly on the muscles.

The Heart.

The heart receives inhibitory fibers through the pneumogastric nerves and cardiac ganglia, and motor (accelerator) fibers through the second, third and fourth thoracic nerves and the front thoracic and inferior cervical ganglia.

The inhibitory fibers, under moderate stimulation, slow the action of the heart, and, under stronger stimulation, also diminish the force of the beat. It is not believed, however, that the different effects are produced by different fibers.

When the accelerator fibers are stimulated, the action of the heart is quickened, and, in some cases, the strength of the beat is increased. In this case it is probable that the different effects are produced by the action of different fibers, those that increase the force of the beat being known as augmentor fibers. Some of the fibers which pass by way of the stellate ganglion are believed to have an augmenting function.

The cardio-inhibitory center—the group of cells that give rise to the inhibitory fibers in the medulla—is kept in more or less constant or tonic activity by the influences of impulses constantly received through afferent nerves. By the same influences its activity may also be modified. The afferent fibers, the stimulation of which is most effective in this respect are those distributed in the respiratory tract and the abdominal viscera. A blow on the abdomen (the so-called solar plexus blow) will so inhibit the action of the heart as to cause fainting, and a blow of sufficient force on the larynx will cause death. These effects are produced reflexly through afferent fibers of the pneumogastric nerves. Less effects, both accelerating and inhibitory in their nature, may be produced by stimulation of afferent nerves in other parts of the body. The activity of the center is also affected by emotional states, through the intercentral fibers connecting the cortex and medulla.

The cells that form the accelerator center are in the cervical part of the cord, but their exact location has not been determined. The fact that the accelerator fibers may be influenced to a considerable extent by stimulation of the lower cervical nerves, would seem to indicate that, at least, a part of the center is in the lower cervical region. And it is not improbable that it extends upward as high as the medulla. This center, like the inhibitory center, is normally in tonic activity and is subject in the same way to stimulation and inhibition by cerebral and sensory impulses.

Besides its efferent fibers, the heart is also supplied with *the depressor nerve*, consisting of afferent fibers, the stimulation of which has an inhibitory effect on the vaso-constrictor center and thereby removes any excess of peripheral resistance that the heart may at any time be laboring to overcome. This mechanism, by diminishing the force of the heart beat, conserves the energy of the heart.

The Oesophagus.

The oesophagus receives motor fibers, and its cardiac sphincter receives inhibitory fibers, through the pneumogastric nerves and ganglia in the oesophageal walls. These fibers are reflexly stimulated when food enters the oesophagus, and their activity causes peristalsis of the oesophagus and relaxation of the sphincter, the effect of which is the passage of food into the stomach. The afferent fibers, the stimulation of which incites the reflex, are of pneumogastric origin.

The Bronchi.

Physiological investigations have demonstrated that the bronchi are supplied with motor (broncho-constrictor) and with inhibitory (broncho-dilator) fibers through the pneumogastric nerves and ganglia of the pulmonary plexuses and bronchial walls. There is clinical evidence that constrictor fibers are also received from the thoracic part of the spinal cord, their origin being within the area extending approximately from the third to the seventh segment. Stimulation of the constrictor fibers narrows the bronchi, and stimulation of the dilator fibers widens them, the resistance to the ingoing and outgoing currents of air being increased in the one case and diminished in the other. The conditions under which the two sets of fibers are normally stimulated have not been determined, nor has it been shown that the constrictor fibers, like motor fibers in general, are in tonic activity. They are excessively active, however, in asthma, and are reflexly stimulated when injurious gases come in contact with the nasal mucous membrane, their action in the latter case being protective.

The Stomach, Small Intestine, Ascending and Transverse Colon.

The motor fibers of these parts are derived through the pneumogastric nerves and ganglia of the solar plexus and its derivatives. The inhibitory fibers are derived through the splanchnic nerves, those for the stomach leaving the cord in the thoracic nerves from the fifth to the eighth or ninth, and those for the intestines in the nerves from the sixth thoracic to the first or second lumbar. Both sets of fibers are normally stimulated reflexly, and their activity regulates the gastric and intestinal movements. Their action, however, may be affected by psychical states, some emotions stopping all peristalsis. Besides their extrinsic innervation, the stomach and intestines also contain in their walls the plexuses of Meissner and Auerbach, by the action of which the peristaltic movements are believed to be co-ordinated.

The Descending Colon and Rectum and the Internal Sphincter Ani.

Both the motor and the inhibitory fibers of these parts arise in the spinal cord. The inhibitory fibers of the descending colon and rectum leave the cord in the last two thoracic and the first two lumbar nerves and pass to the inferior mesenteric ganglion, from which as postganglionic fibers they are distributed by way of the hypogastric nerve. The motor fibers of these parts leave the cord in the nervus erigens and reach their destination through pelvic ganglia and their postganglonic branches.

The internal sphincter receives its motor fibers by way of the lumbar and hypogastric nerves, and its inhibitory fibers through the nervus erigens.

The fibers from the thoracic and lumbar segments are most of the time in tonic activity, restraining the peristalsis of the rectum and keeping its orifice closed. The sacral fibers are active only occasionally and under special conditions.

The Gall Bladder and Duct.

The gall bladder and gall duct receive efferent innervation through the pneumogastric and splanchnic nerves, by way of the solar and other ganglia. The pneumogastric fibers are motor to the gall bladder and inhibitory to the duct, and when stimulated they cause the expulsion of bile from the gall bladder into the duodenum. The splanchnic fibers are inhibitory to the gall bladder and motor to the duct, and the combined effect of their action is to keep the gall bladder dilated and the duct contracted, thus preventing the discharge of bile. The pneumogastric fibers are active during digestion ; the splanchnic fibers are called into play when digestion has ceased.

The Spleen.

The spleen is supplied through the splanchnic nerves with motor fibers, the stimulation of which causes a diminution in its volume, and with inhibitory fibers, the stimulation of which causes dilation. These fibers are distributed to the muscle-cells in the trabeculae. The conditions of their activity and their normal stimuli have not been conclusively determined.

The Bladder.

The bladder receives two sets of efferent fibers from the spinal cord. One set leave the cord in the eleventh and twelfth thoracic and the first two lumbar nerves and pass to the inferior mesenteric ganglion, from which, as postganglionic fibers, they reach the bladder by way of the hypogastric nerve. Of these fibers those distributed to the bladder walls are inhibitory and those distributed to the sphincter of the bladder are motor. When stimulated the combined effect of their action is to retain the bladder contents.

The other set of fibers leave the cord in the nervus erigens and reach the bladder as postganglionic fibers from pelvic ganglia. These fibers when stimulated have a motor effect on the bladder walls and an inhibitory effect on the sphincter. The combined effect of their action tends to expel the contents of the bladder.

Both sets of fibers are normally stimulated reflexly, but their activity is subject to modification under the influence of impulses received from the cerebrum, through efferent tracts in the spinal cord.

The Uterus.

The uterus, like the other pelvic viscera, receives two sets of efferent fibers, both of which are of spinal origin. One set leave the cord in the first two lumbar nerves, and possibly also in the last thoracic nerves, and reach the uterus as postganglionic fibers from the inferior mesenteric ganglion. When stimulated these fibers keep the walls of the uterus relaxed and the neck contracted—a condition that exists in pregnancy.

The other set of fibers are derived through the nervus erigens and pelvic ganglia. These fibers when stimulated cause contraction of the walls of the uterus and relaxation of the neck. The most frequent manifestation of their activity is at parturition.

The Seminal Vesicles.

Through the first two lumbar nerves and pelvic ganglia the seminal vesicles receive efferent fibers, the stimulation of which causes the emission of semen. These fibers are known as ejaculatory nerves, and the cells from which they arise in the lumbar part of the cord, as the ejaculatory center. They are stimulated both reflexly and by impulses from the cerebrum.

INDEX.