IX. Neurology

THE **NERVOUS SYSTEM** is the most complicated and highly organized of the various systems which make up the human body. It is the 1
mechanism concerned with the correlation and integration of various bodily processes and the reactions and adjustments of the organism to its environment. In addition the cerebral cortex is concerned with conscious life. It may be divided into two parts, **central** and **peripheral.**

The **central nervous system** consists of the **encephalon** or **brain,** contained within the cranium, and the **medulla spinalis** or **spinal** 2
cord, lodged in the vertebral canal; the two portions are continuous with one another at the level of the upper border of the atlas vertebra.

The **peripheral nervous system** consists of a series of nerves by which the central nervous system is connected with the various tissues of the body. For descriptive purposes these nerves may be arranged in two groups, **cerebrospinal** and **sympathetic,** the arrangement, however, being an arbitrary one, since the two groups are intimately connected and closely intermingled. Both the cerebrospinal and sympathetic nerves have nuclei of origin (the somatic efferent and sympathetic efferent) as well as nuclei of termination (somatic afferent and sympathetic afferent) in the central nervous system. The cerebrospinal nerves are forty-three in number on either side—twelve **cranial,** attached to the brain, and thirty-one **spinal,** to the medulla spinalis. They are associated with the functions of the special and general senses and with the voluntary movements of the body. The sympathetic nerves transmit the impulses which regulate the movements of the viscera, determine the caliber of the bloodvessels, and control the phenomena of secretion. In relation with them are two rows of **central ganglia,** situated one on either side of the middle line in front of the vertebral column; these ganglia are intimately connected with the medulla spinalis and the spinal nerves, and are also joined to each other by vertical strands of nerve fibers so as to constitute a pair of knotted cords, the **sympathetic trunks,** which reach from the base of the skull to the coccyx. The sympathetic nerves issuing from the ganglia form three great prevertebral plexuses which supply the thoracic, abdominal, and pelvic viscera; in relation to the walls of these viscera intricate nerve plexuses and numerous **peripheral ganglia** are found.

2. Development of the Nervous System

The entire nervous system is of ectodermal origin, and its first rudiment is seen in the neural groove which extends along the dorsal aspect of the 1
embryo (Fig. 17). By the elevation and ultimate fusion of the neural folds, the groove is converted into the neural tube (Fig. 19).The anterior end of the neural tube becomes expanded to form the three primary brain-vesicles; the cavity of the tube is subsequently modified to form the ventricular cavities of the brain, and the central canal of the medulla spinalis; from the wall the nervous elements and the neuroglia of the brain and medulla spinalis are developed.

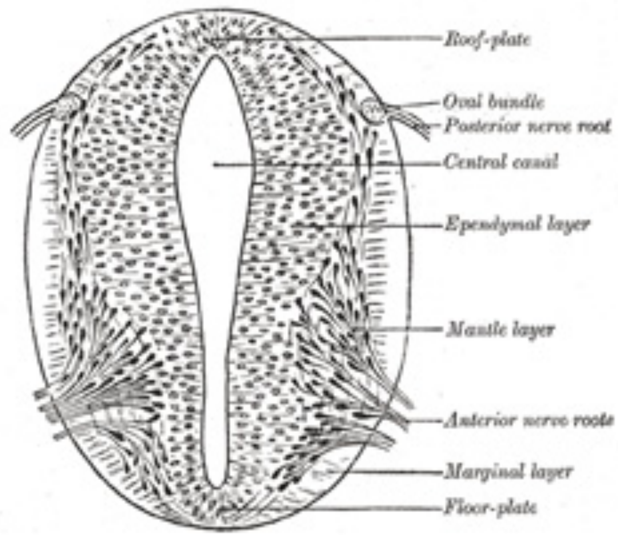


FIG. 640– Section of medulla spinalis of a four weeks' embryo. (His.) (See enlarged image)

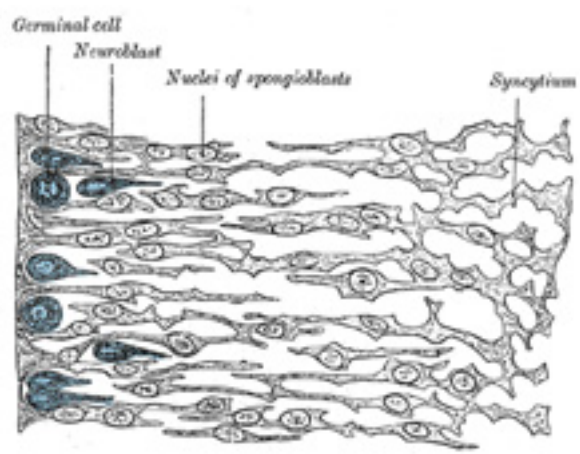


FIG. 641– Transverse section of the medulla spinalis of a human embryo at the beginning of the fourth week. The left edge of the figure corresponds to the lining of the central canal. (His.) (See enlarged image)

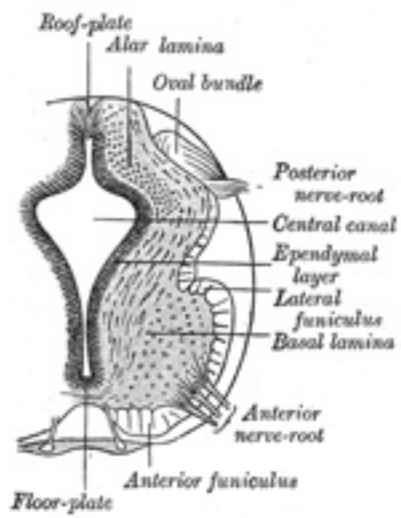


FIG. 642– aged about four and a half weeks. (See enlarged image)

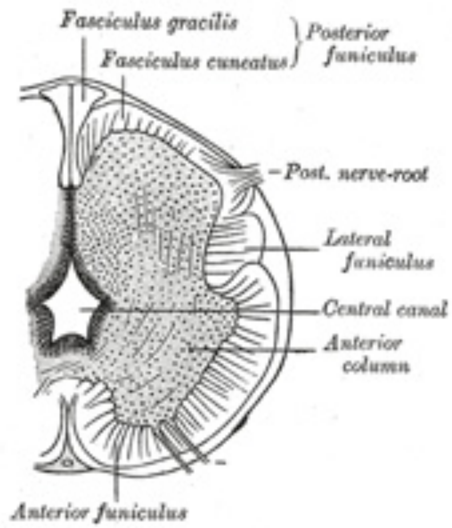


FIG. 643– aged about three months. (See enlarged image)

The Medulla Spinalis.—At first the wall of the neural tube is composed of a single layer of columnar ectodermal cells. Soon the side-walls become thickened, while the dorsal and ventral parts remain thin, and are named the **roof-** and **floor-plates** (Figs. 640, 642, 643). A transverse section of the tube at this stage presents an oval outline, while its lumen has the appearance of a slit. The cells which constitute the wall of the tube proliferate rapidly, lose their cell-boundaries and form a syncytium. This syncytium consists at first of dense protoplasm with closely packed nuclei, but later it opens out and forms a looser meshwork with the cellular strands arranged in a radiating manner from the central canal. Three layers may now be defined—an internal or ependymal, an intermediate or mantle, and an external or marginal. The **ependymal layer** is ultimately converted into the ependyma of the central canal; the processes of its cells pass outward toward the periphery of the medulla spinalis. The **marginal layer** is devoid of nuclei, and later forms the supporting framework for the white funiculi of the medulla spinalis. The **mantle layer** represents the whole of the future gray columns of the medulla spinalis; in it the cells are differentiated into two sets, viz., (*a*)**spongioblasts** or **young neuroglia cells,** and (*b*) **germinal cells,** which are the parents of the **neuroblasts** or **young nerve cells** (Fig. 641). The spongioblasts are at first connected to one another by filaments of the syncytium; in these, fibrils are developed, so that as the neuroglial cells become defined they exhibit their characteristic mature appearance with multiple processes proceeding from each cell. The germinal cells are large, round or oval, and first make their appearance between the ependymal cells on the sides of the central canal. They increase rapidly in number, so that by the fourth week they form an almost continuous layer on each side of the tube. No germinal cells are found in the roof- or floor-plates; the roof-plate retains, in certain regions of the brain, its epithelial character; elsewhere, its cells become 2 spongioblasts. By subdivision the germinal cells give rise to the neuroblasts or young nerve cells, which migrate outward from the sides of the central canal into the mantle layer and neural crest, and at the same time become pear-shaped; thetapering part of the cell undergoes still further elongation, and forms the axiscylinder of the cell.

The lateral walls of the medulla spinalis continue to increase in thickness, and the canal widens out near its dorsal extremity, and assumes a 3
somewhat lozengeshaped appearance. The widest part of the canal serves to subdivide the lateral wall of the neural tube into a**dorsal** or **alar,** and a **ventral** or **basal lamina** (Figs. 642, 643), a subdivision which extends forward into the brain. At a later stage the ventral part of the canal widens out, while the dorsal part is first reduced to a mere slit and then becomes obliterated by the approximation and fusion of its walls; the ventral part of the canal persists and forms the central canal of the adult medulla spinalis. The caudal end of the canal exhibits a conical expansion which is known as the **terminal ventricle.**

The ventral part of the mantle layer becomes thickened, and on cross-section appears as a triangular patch between the marginal and ependymal 4
layers. This thickening is the rudiment of the anterior column of gray substance, and contains many neuroblasts, the axis-cylinders of which pass out through the marginal layer and form the anterior roots of the spinal nerves (Figs. 640, 642, 643). The thickening of the mantle layer gradually extends in a dorsal direction, and forms the posterior column of gray substance. The axons of many of the neuroblasts in the alar lamina run forward, and cross in the floor-plate to the opposite side of the medulla spinalis; these form the rudiment of the anterior white commissure.

About the end of the fourth week nerve fibers begin to appear in the marginal layer. The first to develop are the short intersegmental fibers from 5
the neuroblasts in the mantle zone, and the fibers of the dorsal nerve roots which grow into the medulla spinalis from the cells of the spinal ganglia. By the sixth week these dorsal root fibers form a well-defined **oval bundle** in the peripheral part of the alar lamina; this \?\?\ gradually increases in size, and spreading toward the middle line forms the rudiment of the posterior funiculus. The long intersegmental fibers begin to appear about the third month and the cerebrospinal fibers about the fifth month. All nerve fibers are at first destitute of medullary sheaths. Different groups of fibers receive their sheaths at different times—the dorsal and ventral nerve roots about the fifth month, the cerebrospinal fibers after the ninth month.

By the growth of the anterior columns of gray substance, and by the increase in size of the anterior funiculi, a furrow is formed between the 6
lateral halves of the cord anteriorly; this gradually deepens to form the anterior median fissure. The mode of formation of the posterior septum is somewhat uncertain. Many believe that it is produced by the growing together of the walls of the posterior part of the central canal and by the development from its ependymal cells of a septum of fibrillated tissue which separates the future funiculi graciles.

Up to the third month of fetal life the medulla spinalis occupies the entire length of the vertebral canal, and the spinal nerves pass outward at 7
right angles to the medulla spinalis. From this time onward, the vertebral column grows more rapidly than the medulla spinalis, and the latter, being fixed above through its continuity with the brain, gradually assumes a higher position within the canal. By the sixth month its lower end reaches only as far as the upper end of the sacrum; at birth it is on a level with the third lumbar vertebra, and in the adult with the lower border of the first or upper border of the second lumbar vertebra. A delicate filament, the **filum terminale,** extends from its lower end as far as the coccyx.

The Spinal Nerves.—Each spinal nerve is attached to the medulla spinalis by an anterior or ventral and a posterior or dorsal root. 8

The fibers of the anterior roots are formed by the axons of the neuroblasts which lie in the ventral part of the mantle layer; these axons grow out 9
through the overlying marginal layer and become grouped to form the anterior nerve root (Fig. 641).

The fibers of the posterior roots are developed from the cells of the spinal ganglia. Before the neural groove is closed to form the neural tube a 10 ridge of ectodermal cells, the **ganglion ridge** or **neural crest** (Fig. 644), appears along the prominent margin of each neural fold. When the folds meet in the middle line the two ganglion ridges fuse and form a wedge-shaped area along the line of closure of the tube. The cells of this area proliferate rapidly opposite the primitive segments and then migrate in a lateral and ventral direction to the sides of the neural tube, where they ultimately form a series of oval-shaped masses, the future spinal ganglia. These ganglia are arranged symmetrically on the two sides of the neural tube and, except in the region of the tail, are equal in number to the primitive segments. The cells of the ganglia, like the cells of the mantle layer, are of two kinds, viz.,**spongioblasts** and **neuroblasts.** The spongioblasts develop into the neuroglial cells of the ganglia. The neuroblasts are at first round or oval in shape, but soon assume the form of spindles the extremities of which gradually elongate into central and peripheral processes. The central processes grow medialward and, becoming connected with the neural tube, constitute the fibers of the posterior nerve roots, while the peripheral processes grow lateralward to mingle with the fibers of the anterior root in the spinal nerve. As development proceeds the original bipolar form of the cells changes; the two processes become approximated until they ultimately arise from a single stem in a T-shaped manner. Only in the ganglia of the acoustic nerve is the bipolar form retained. More recent observers hold, however, that the T-form is derived from the branching of a single process which grows out from the cell.

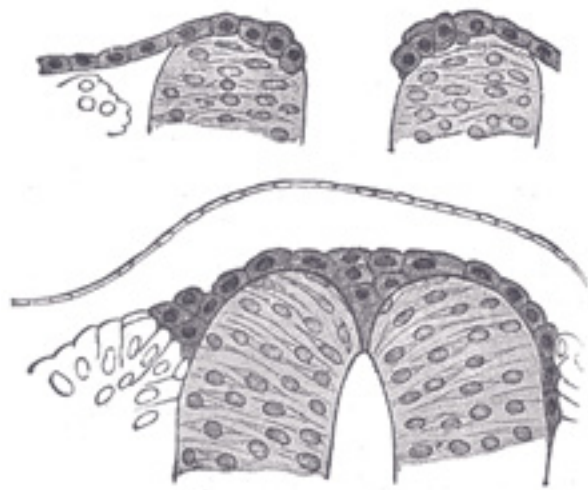


FIG. 644– Two stages in the development of the neural crest in the human embryo. (Lenhossèk.) (See enlarged image)

The anterior or ventral and the posterior or dorsal nerve roots join immediately beyond the spinal ganglion to form the **spinal nerve,** which then *11*
divides into anterior, posterior, and visceral divisions. The anterior and posterior divisions proceed directly to their areas of distribution without further association with ganglion cells (Fig. 645). The visceral divisions are distributed to the thoracic, abdominal, and pelvic viscera, to reach which they pass through the sympathetic trunk, and many of the fibers form arborizations around the ganglion cells of this trunk. Visceral

branches are not given off from all the spinal nerves; they form two groups, viz., (*a*) **thoracico-lumbar,** from the first or second thoracic, to the second or third lumbar nerves; and (*b*) **pelvic,** from the second and third, or third and fourth sacral nerves.

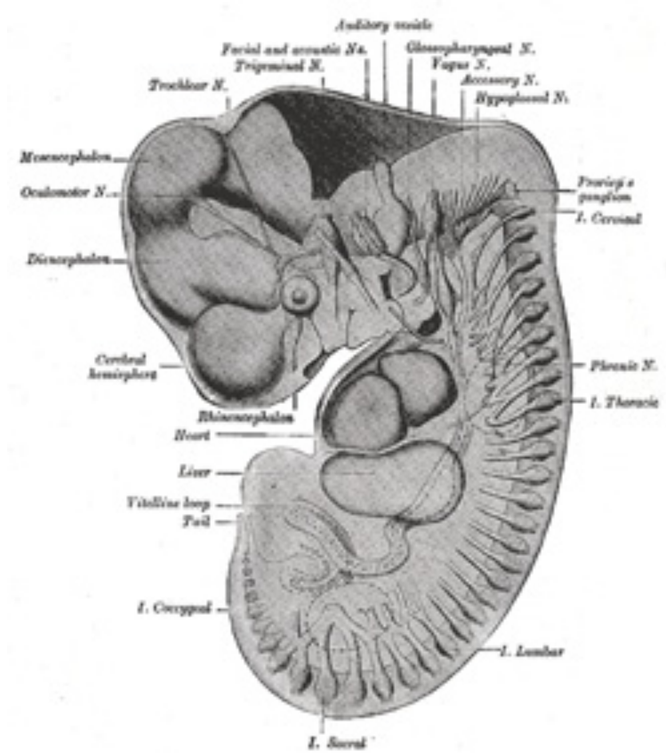


FIG. 645– Reconstruction of periphera nerves of a human embryo of 10.2 mm. (After His.) The abducent nerve is not labelled, but is seen passing forward to the eye under the mandibular and maxillary nerves. (See enlarged image)

The Brain.—The brain is developed from the anterior end of the neural tube, which at an early period becomes expanded into three vesicles, the primary cerebral vesicles (Fig. 18).These are marked off from each other by intervening constrictions, and are named the **fore-brain** or **prosencephalon,** the **mid-brain** or **mesencephalon,** and the **hind-brain** or**rhombencephalon**—the last being continuous with the 12 medulla spinalis. As the result of unequal growth of these different parts three flexures are formed and the embryonic brain becomes bent on itself in a somewhat zigzag fashion; the two earliest flexures are concave ventrally and are associated with corresponding flexures of the whole head. The first flexure appears in the region of the mid-brain, and is named the **ventral cephalic flexure**(Fig. 650). By means of it the fore-brain is bent in a ventral direction around the anterior end of the notochord and fore-gut, with the result that the floor of the fore-brain comes to lie almost parallel with that of the hind-brain. This flexure causes the mid-brain to become, for a time, the most prominent part of the brain, since its dorsal surface corresponds with the convexity of the curve. The second bend appears at the junction of the hind-brain and medulla spinalis. This is termed the **cervical flexure** (Fig. 652), and increases from the third to the end of the fifth week, when the hind-brain forms nearly a right angle with the medulla spinalis; after the fifth week erection of the head takes place and the cervical flexure diminishes and disappears. The third bend is named the **pontine flexure** (Fig. 652),because it is found in the region of the future pons Varoli. It differs from the other two in that (*a*) its convexity is forward, and (*b*) it does not affect the head. The lateral walls of the brain-tube, like those of the medulla spinalis, are divided by internal furrows into alar or dorsal and basal or ventral laminæ (Fig. 646).

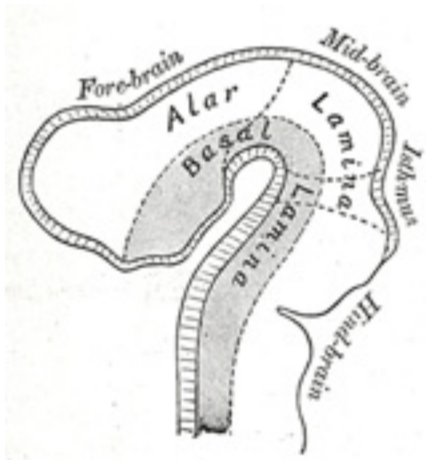


FIG. 646– Diagram to illustrate the alar and basal laminæ of brain vesicles. (His.) (See enlarged image)

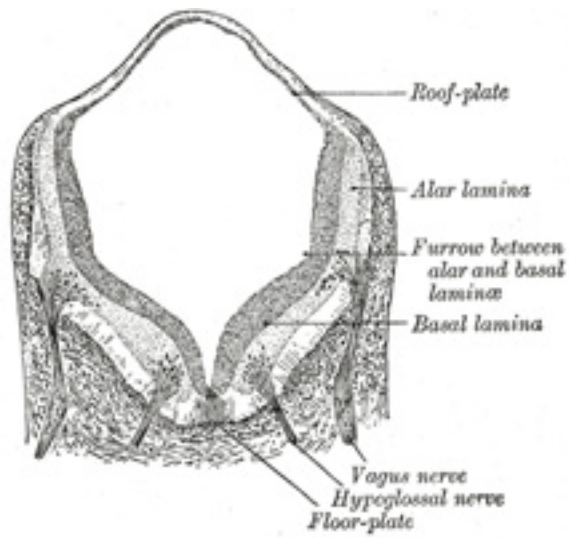


FIG. 647– Transverse section of medulla oblongata of human embryo. X 32. (Kollmann.) (See enlarged image)

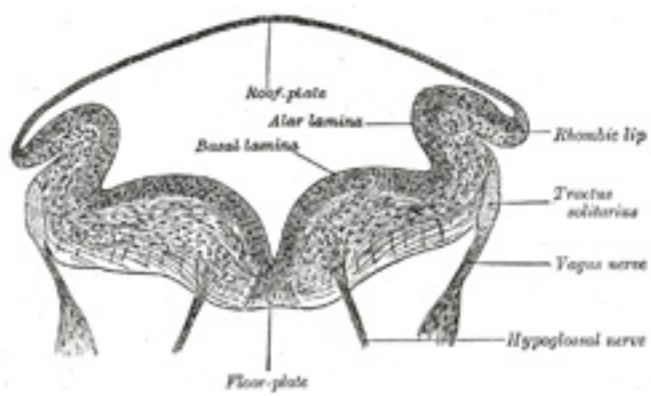


FIG. 648– Transverse section of medulla oblongata of human embryo. (After His.) (See enlarged image)

The Hind-brain or Rhombencephalon.—The cavity of the hind-brain becomes the fourth ventricle. At the time when the ventral cephalic flexure makes its appearance, the length of the hind-brain exceeds the combined lengths of the other two vesicles. Immediately behind the mid-brain it exhibits a marked constriction, the **isthmus rhombencephali** (Fig. 650, *Isthmus*), which is best seen when the brain is viewed from the dorsal aspect. From the isthmus the anterior medullary velum and the superior peduncle of the cerebellum are formed. It is customary to divide the rest of the hind-brain into two parts, viz., an upper, called the **metencephalon,** and a lower, the **myelencephalon.** The cerebellum is developed by a thickening of the roof, and the pons by a thickening in the floor and lateral walls of the metencephalon. The floor and lateral walls of the myelencephalon are thickened to form the medulla oblongata; its roof remains thin, and, retaining to a great extent its epithelial nature, is expanded in a lateral direction. Later, by the growth and backward extension of the cerebellum, the roof is folded inward toward the cavity of the fourth ventricle; it assists in completing the dorsal wall of this cavity, and is also invaginated to form the ependymal covering of its choroid plexuses. Above it is continuous with the posterior medullary velum; below, with the obex and ligulæ. *13*

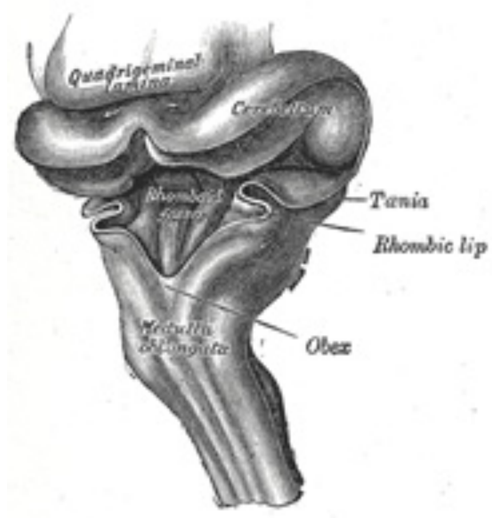


FIG. 649– Hind-brain of a human embryo of three months—viewed from behind and partly from left side. (From model by His.) (See enlarged image)

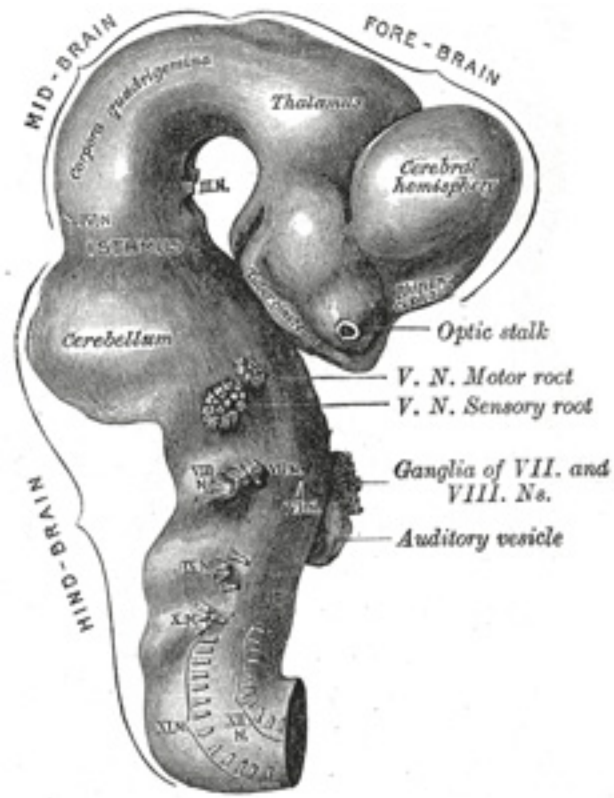


FIG. 650– Exterior of brain of human embryo of four and a half weeks. (From model by His.) (See enlarged image)

The development of the **medulla oblongata** resembles that of the medulla spinalis, but at the same time exhibits one or two interesting modifications. On transverse section the myelencephalon at an early stage is seen to consist of two lateral walls, connected across the middle line by floor- and roof-plates (Figs. 647 and 648). Each lateral wall consists of an alar and a basal lamina, separated by an internal furrow, the remains of which are represented in the adult brain by the sulcus limitans on the rhomboid fossa. The contained cavity is more or less triangular in outline, the base being formed by the roof-plate, which is thin and greatly expanded transversely. Pear-shaped neuroblasts are developed in the alar and basal laminæ. and their narrow stalks are elongated to form the axis-cylinders of the nerve fibers. Opposite the furrow or boundary between the alar and basal laminæ a bundle of nerve fibers attaches itself to the outer surface of the alar lamina. This is named the**tractus** *14*

solitarius (Fig. 648), and is formed by the sensory fibers of the glossopharyngeal and vagus nerves. It is the homologue of the **oval bundle** seen in the medulla spinalis, and, like it, is developed by an ingrowth of fibers from the ganglia of the neural crest. At first it is applied to the outer surface of the alar lamina, but it soon becomes buried, owing to the growth over it of the neighboring parts. By the fifth week the dorsal part of the alar lamina bends in a lateral direction along its entire length, to form what is termed the **rhombic lip**(Figs. 648, 649). Within a few days this lip becomes applied to, and unites with, the outer surface of the main part of the alar lamina, and so covers in the tractus solitarius and also the spinal root of the trigeminal nerve; the nodulus and flocculus of the cerebellum are developed from the rhombic lip.

Neuroblasts accumulate in the mantle layer; those in the basal lamina correspond with the cells in the anterior gray column of the medulla *15*
spinalis, and, like them, give origin to motor nerve fibers; in the medulla oblongata they are, however, arranged in groups or nuclei, instead of forming a continuous column. From the alar lamina and its rhombic lip, neuroblasts migrate into the basal lamina, and become aggregated to form the olivary nuclei, while many send their axis-cylinders through the floor-plate to the opposite side, and thus constitute the rudiment of the raphé of the medulla oblongata. By means of this thickening of the ventral portion, the motor nuclei are buried deeply in the interior, and, in the adult, are found close to the rhomboid fossa. This is still further accentuated: (*a*) by the development of the pyramids, which are formed about the fourth month by the downward growth of the motor fibers from the cerebral cortex; and (*b*) by the fibers which pass to and from the cerebellum. On the rhomboid fossa a series of six temporary furrows appears; these are termed the **rhombic grooves.** They bear a definite relationship to certain of the cranial nerves; thus, from before backward the first and second grooves overlie the nucleus of the trigeminal; the third, the nucleus of the facial; the fourth, that of the abducent; the fifth, that of the glossopharyngeal; and the sixth, that of the vagus.

The **pons** is developed from the ventro-lateral wall of the metencephalon by a process similar to that which has been described for the medulla *16*
oblongata.

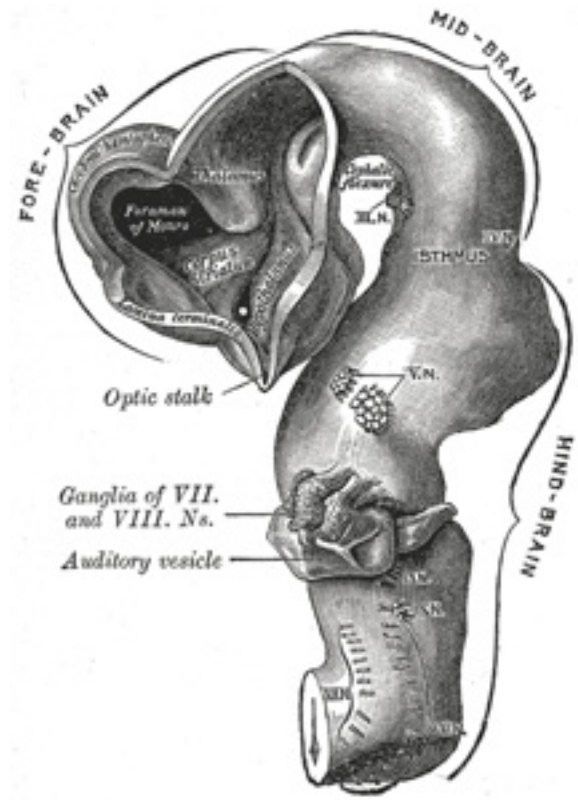


FIG. 651– Brain of human embryo of four and a half weeks, showing interior of fore-brain. (From model by His.) (See enlarged image)

The **cerebellum** is developed in the roof of the anterior part of the hind-brain (Figs. 649 to 654). The alar laminæ of this region become 17
thickened to form two lateral plates which soon fuse in the middle line and produce a thick lamina which roofs in the upper part of the cavity of the hind-brain vesicle; this constitutes the rudiment of the cerebellum, the outer surface of which is originally smooth and convex. The fissures of the cerebellum appear first in the vermis and floccular region, and traces of them are found during the third month; the fissures on the cerebellar hemispheres do not appear until the fifth month. The primitive fissures are not developed in the order of their relative size in the adult—thus the horizontal sulcus in the fifth month is merely a shallow groove. The best marked of the early fissures are: (*a*) the **fissura prima** between the developing culmen and declive, and (*b*) the **fissura secunda** between the future pyramid and uvula. The flocculus and nodule

are developed from the rhombic lip, and are therefore recognizable as separate portions before any of the other cerebellar lobules. The groove produced by the bending over of the rhombic lip is here known as the **floccular fissure;** when the two lateral walls fuse, the right and left floccular fissures join in the middle line and their central part becomes the **post-nodular fissure.**

On the ventricular surface of the cerebellar lamina a transverse furrow, the **incisura fastigii,** appears, and deepens to form the tent-like recess of the roof of the fourth ventricle. The rudiment of the cerebellum at first projects in a dorsal direction; but, by the backward growth of the cerebrum, it is folded downward and somewhat flattened, and the thin roof-plate of the fourth ventricle, originally continuous with the posterior border of the cerebellum, is projected inward toward the cavity of the ventricle. *18*

The Mid-brain or Mesencephalon.—The mid-brain (Figs. 650 to 654) exists for a time as a thin-walled cavity of some size, and is separated from the isthmus rhombencephali behind, and from the fore-brain in front, by slight constrictions. Its cavity becomes relatively reduced in diameter, and forms the cerebral aqueduct of the adult brain. Its basal laminæ increase in thickness to form the cerebral peduncles, which are at first of small size, but rapidly enlarge after the fourth month. The neuroblasts of these laminæ are grouped in relation to the sides and floor of the cerebral aqueduct, and constitute the nuclei of the oculomotor and trochlear nerves, and of the mesencephalic root of the trigeminal nerve. By a similar thickening process its alar laminæ are developed into the quadrigeminal lamina. The dorsal part of the wall for a time undergoes expansion, and presents an internal median furrow and a corresponding external ridge; these, however, disappear, and the latter is replaced by a groove. Subsequently two oblique furrows extend medialward and backward, and the thickened lamina is thus subdivided into the superior and inferior colliculi. *19*

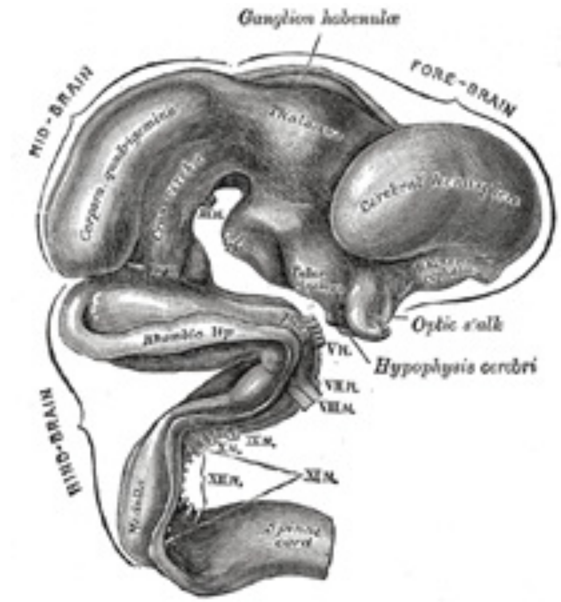


FIG. 652– Exterior of brain of human embryo of five weeks. (From model by His.) (See enlarged image)

The Fore-brain or Prosencephalon.—A transverse section of the early fore-brain shows the same parts as are displayed in similar sections of the medulla spinalis and medulla oblongata, viz., a pair of thick lateral walls connected by thin floor-and roof-plates. Moreover, each lateral wall exhibits a division into a dorsal or alar and a ventral or basal lamina separated internally by a furrow termed the **sulcus of Monro.** This sulcus ends anteriorly at the medial end of the optic stalk, and in the adult brain is retained as a slight groove extending backward from the interventricular foramen to the cerebral aqueduct. 20

At a very early period—in some animals before the closure of the cranial part of the neural tube—two lateral diverticula, the **optic vesicles,** appear, one on either side of the fore-brain; for a time they communicate with the cavity of the fore-brain by relatively wide openings. The peripheral parts of the vesicles expand, while the proximal parts are reduced to tubular stalks, the **optic stalks.** The optic vesicle gives rise to the retina and the epithelium on the back of the ciliary body and iris; the optic stalk is invaded by nerve fibers to form the optic nerve. The fore-brain then grows forward, and from the alar laminæ of this front portion the cerebral hemispheres originate as diverticula which rapidly expand to form two large pouches, one on either side. The cavities of these diverticula are the rudiments of the lateral ventricles; they communicate with the median part of the fore-brain cavity by relatively wide openings, which ultimately form the interventricular foramen. The median portion of 21 the wall of the fore-brain vesicle consists of a thin lamina, the **lamina terminalis** (Figs. 654, 657), which stretches from the interventricular foramen to the recess at the base of the optic stalk. The anterior part of the fore-brain, including the rudiments of the cerebral hemispheres, is named the **telencephalon,** and its posterior portion is termed the**diencephalon;** both of these contribute to the formation of the third ventricle.

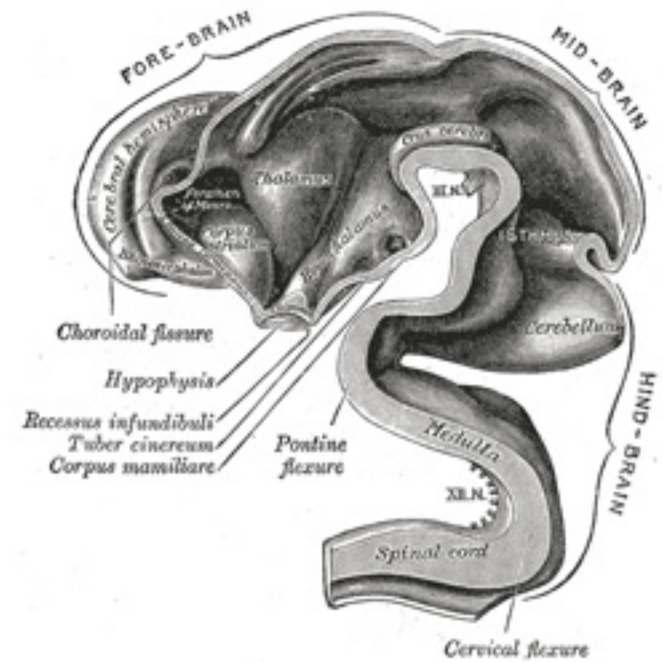


FIG. 653– Interior of brain of human embryo of five weeks. (From model by His.) (See enlarged image)

The Diencephalon.—From the alar lamina of the diencephalon, the thalamus, metathalamus, and epithalamus are developed. 22
The **thalamus** (Figs. 650 to 654) arises as a thickening which involves the anterior two-thirds of the alar lamina. The two thalami are visible, for a time, on the surface of the brain, but are subsequently hidden by the cerebral hemispheres which grow backward over them. The thalami extend medialward and gradually narrow the cavity between them into a slit-like aperture which forms the greater part of the third ventricle; their medial surfaces ultimately adhere, in part, to each other, and the **intermediate mass** of the ventricle is developed across the area of contact. The**metathalamus** comprises the geniculate bodies which originate as slight outward bulgings of the alar lamina. In the adult the lateral

geniculate body appears as an eminence on the lateral part of the posterior end of the thalamus, while the medial is situated on the lateral aspect of the mid-brain. The **epithalamus** includes the pineal body, the posterior commissure, and the trigonum habenulæ. The pineal body arises as an upward the evagination of roof-plate immediately in front of the midbrian; this evagination becomes solid with the exception of its proximal part, which persists as the recessus pinealis. In lizards the pineal evagination is elongated into a stalk, and its peripheral extremity is expanded into a vesicle, in which a rudimentary lens and retina are formed; the stalk becomes solid and nerve fibers make their appearance in it, so that in these animals the pineal body forms a rudimentary eye. The posterior commissure is formed by the ingrowth of fibers into the depression behind and below the pineal evagination, and the trigonum habenulæ is developed in front of the pineal recess.

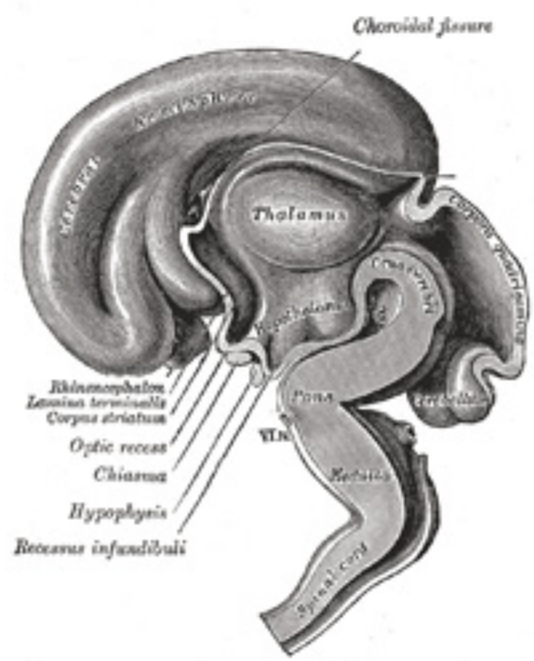


FIG. 654– Median sagittal section of brain of human embryo of three months. (From model by His.) (See enlarged image)

From the basal laminæ of the diencephalon the **pars mamillaris hypothalami** is developed; this comprises the corpora mamillaria and the posterior part of the tuber cinereum. The corpora mamillaria arise as a single thickening, which becomes divided into two by a median furrow during the third month. *23*

The roof-plate of the diencephalon, in front of the pineal body, remains thin and epithelial in character, and is subsequently invaginated by the choroid plexuses of the third ventricle. 24

The Telencephalon.—This consists of a median portion and two lateral diverticula. The median portion forms the anterior part of the cavity of the third ventricle, and is closed below and in front by the lamina terminalis. The lateral diverticula consist of outward pouchings of the alar laminæ; the cavities represent the lateral ventricles, and their walls become thickened to form the nervous matter of the cerebral hemispheres. The roof-plate of the telencephalon remains thin, and is continuous in front with the lamina terminalis and behind with the roof-plate of the diencephalon. In the basal laminæ and floor-plate the **pars optica hypothalami** is developed; this comprises the anterior part of the tuber cinereum, the infundibulum and posterior lobe of the hypophysis, and the optic chiasma. The anterior part of the tuber cinereum is derived from the posterior part of the floor of the telencephalon; the infundibulum and posterior lobe of the hypophysis arise as a downward diverticulum from the floor. The most dependent part of the diverticulum becomes solid and forms the posterior lobe of the hypophysis; the anterior lobe of the hypophysis is developed from a diverticulum of the ectodermal lining of the stomodeum. The optic chiasma is formed by the meeting and partial decussation of the optic nerves, which subsequently grow backward as the optic tracts and end in the diencephalon. 25

The **cerebral hemispheres** arise as diverticula of the alar laminæ of the telencephalon (Figs. 650 to 654); they increase rapidly in size and ultimately overlap the structures developed from the mid- and hind-brains. This great expansion of the hemispheres is a characteristic feature of the brains of mammals, and attains its maximum development in the brain of man. Elliott-Smith divides each cerebral hemisphere into three fundamental parts, viz., the **rhinencephalon,** the **corpus striatum,** and the **neopallium.** 26

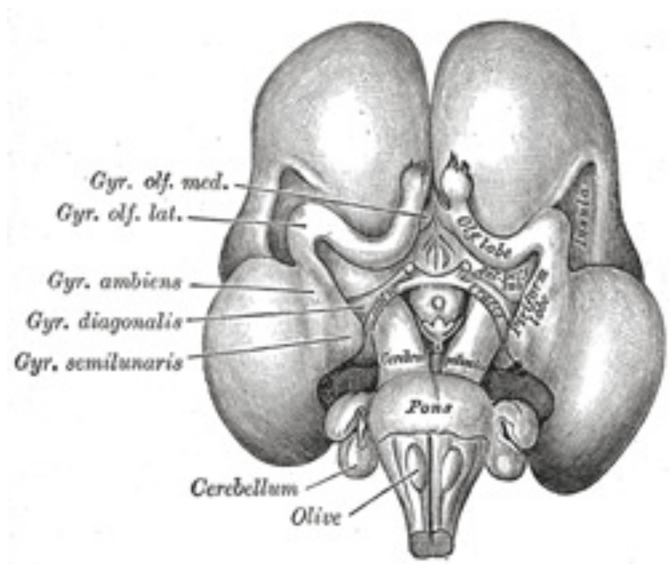


FIG. 655– Inferior surface of brain of embryo at beginning of fourth month. (From Kollmann.) (See enlarged image)

The **rhinencephalon** (Fig. 655) represents the oldest part of the telencephalon, and forms almost the whole of the hemisphere in fishes, amphibians, and reptiles. In man it is feebly developed in comparison with the rest of the hemisphere, and comprises the following parts, viz., the olfactory lobe (consisting of the olfactory tract and bulb and the trigonum olfactorium), the anterior perforated substance, the septum pellucidum, the subcallosal, supracallosal, and dentate gyri, the fornix, the hippocampus, and the uncus. The rhinencephalon appears as a longitudinal elevation, with a corresponding internal furrow, on the under surface of the hemisphere close to the lamina terminalis; it is separated from the lateral surface of the hemisphere by a furrow, the **external rhinal fissure,** and is continuous behind with that part of the hemisphere, which will ultimately form the anterior end of the temporal lobe. The elevation becomes divided by a groove into an anterior and a posterior part. The anterior grows forward as a hollow stalk the lumen of which is continuous with the anterior part of the ventricular cavity. During the third month the stalk becomes solid and forms the rudiment of the olfactory bulb and tract; a strand of gelatinous tissue in the interior of the bulb indicates the position of the original cavity. From the posterior part the anterior perforated substance and the pyriform lobe are developed; at the beginning of the fourth month the latter forms a curved elevation continuous behind with the medial surface of the temporal lobe, and consisting, from before backward, of the gyrus olfactorius lateralis, gyrus ambiens, and gyrus semilunaris, parts which in the adult brain are represented by the lateral root of the olfactory tract and the uncus. The position and connections of the remaining portions of the rhinencephalon are described with the anatomy of the brain. *27*

The **corpus striatum** (Figs. 651 and 653) appears in the fourth week as a triangular thickening of the floor of the telencephalon between the optic recess and the interventricular foramen, and continuous behind with the thalamic part of the diencephalon. It increases in size, and by the second month is seen as a swelling in the floor of the future lateral ventricle; this swelling reaches as far as the posterior end of the primitive hemisphere, and when this part of the hemisphere grows backward and downward to form the temporal lobe, the posterior part of the corpus striatum is carried into the roof of the inferior horn of the ventricle, where it is seen as the tail of the caudate nucleus in the adult brain. During the fourth and fifth months the corpus striatum becomes incompletely subdivided by the fibers of the internal capsule into two masses, an inner, the **caudate nucleus,** and an outer, the **lentiform nucleus.** In front, the corpus striatum is continuous with the anterior perforated substance; laterally it is confluent for a time with that portion of the wall of the vesicle which is developed into the insula, but this continuity is subsequently interrupted by the fibers of the external capsule. *28*

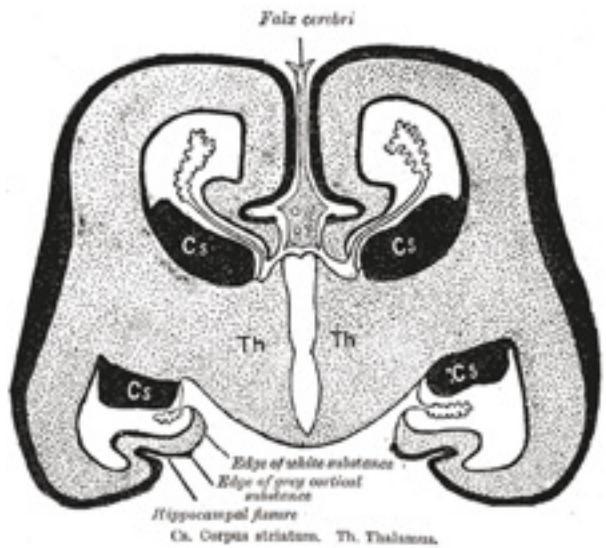


FIG. 656– Diagrammatic coronal section of brain to show relations of neopallium. (After His.) *Cs*. Corpus striatum. *Th*. Thalamus. (See enlarged image)

The **neopallium** (Fig. 656) forms the remaining, and by far the greater, part of the cerebral hemisphere. It consists, at an early stage, of a 29
relatively large, more or less hemispherical cavity—the primitive **lateral ventricle**—enclosed by a thin wall from which the cortex of the hemisphere is developed. The vesicle expands in all directions, but more especially upward and backward, so that by the third month the hemispheres cover the diencephalon, by the sixth they overlap the mid-brain, and by the eighth the hind-brain.

The median lamina uniting the two hemispheres does not share in their expansion, and thus the hemispheres are separated by a deep cleft, the 30
forerunner of the longitudinal fissure, and this cleft is occupied by a septum of mesodermal tissue which constitutes the primitive **falx cerebri.** Coincidently with the expansion of the vesicle, its cavity is drawn out into three prolongations which represent the horns of the future lateral ventricle; the hinder end of the vesicle is carried downward and forward and forms the inferior horn; the posterior horn is produced somewhat later, in association with the backward growth of the occipital lobe of the hemisphere. The roof-plate of the primitive fore-brain remains thin and of an epithelial character; it is invaginated into the lateral ventricle along the medial wall of the hemisphere. This invagination constitutes the choroidal fissure, and extends from the interventricular foramen to the posterior end of the vesicle. Mesodermal tissue, continuous with that of the primitive falx cerebri, and carrying bloodvessels with it, spreads between the two layers of the invaginated fold and forms the rudiment of the tela choroidea; the margins of the tela become highly vascular and form the choroid plexuses which for some months almost completely fill the ventricular cavities; the tela at the same time invaginates the epithelial roof of the diencephalon to form the choroid plexuses

of the third ventricle. By the downward and forward growth of the posterior end of the vesicle to form the temporal lobe the choroidal fissure finally reaches from the interventricular foramen to the extremity of the inferior horn of the ventricle.

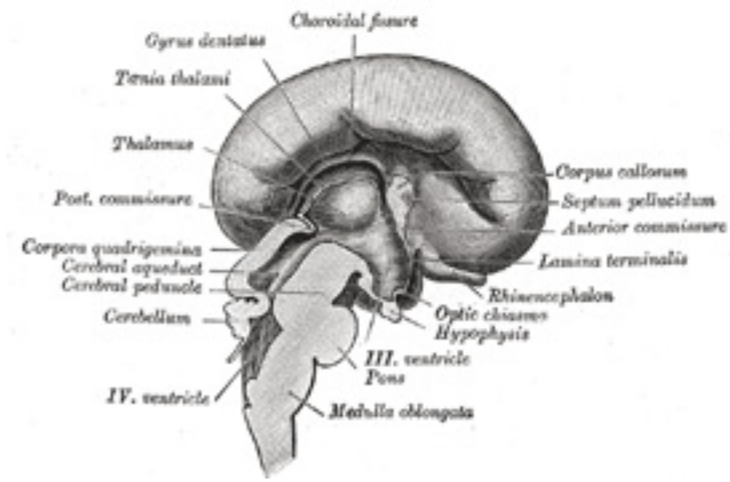


FIG. 657– Median sagittal section of brain of human embryo of four months. (Marchand.) (See enlarged image)

Parallel with but above and in front of the choroidal fissure the medial wall of the cerebral vesicle becomes folded outward and gives rise to 31
the **hippocampal fissure** on the medial surface and to a corresponding elevation, the **hippocampus,** within the ventricular cavity. The gray or ganglionic covering of the wall of the vesicle ends at the inferior margin of the fissure is a thickened edge; beneath this the marginal or reticular layer (future white substance) is exposed and its lower thinned edge is continuous with the epithelial invagination covering the choroid plexus (Fig. 656). As a result of the later downward and forward growth of the temporal lobe the hippocampal fissure and the parts associated with it extend from the interventricular foramen to the end of the inferior horn of the ventricle. The thickened edge of gray substance becomes the gyrus dentatus, the fasciola cinerea and the supra- and subcallosal gyri, while the free edge of the white substance forms the fimbria hippocampi and the body and crus of the fornix. The corpus callosum is developed within the arch of the hippocampal fissure, and the upper part of the fissure forms, in the adult brain, the callosal fissure on the medial surface of the hemisphere.

The Commissures (Fig. 657).—The development of the posterior commissure has already been referred to (page 743). The great commissures 32
of the hemispheres, viz., the **corpus callosum,** the **fornix,** and **anterior commissures,** arise from the lamina terminalis. About the fourth month a small thickening appears in this lamina, immediately in front of the interventricular foramen. The lower part of this thickening is soon constricted off, and fibers appear in it to form the anterior commissure. The upper part continues to grow with the hemispheres, and is invaded

by two sets of fibers. Transverse fibers, extending between the hemispheres, pass into its dorsal part, which is now differentiated as the corpus callosum (in rare cases the corpus callosum is not developed). Into the ventral part longitudinal fibers from the hippocampus pass to the lamina terminalis, and through that structure to the corpora mamillaria; these fibers constitute the fornix. A small portion, lying antero-inferiorly between the corpus callosum and fornix, is not invaded by the commissural fibers; it remains thin, and later a cavity, the cavity of the **septum pellucidum,** forms in its interior.

Fissures and Sulci.—The outer surface of the cerebral hemisphere is at first smooth, but later it exhibits a number of elevations or convolutions, *33*
separated from each other by fissures and sulci, most of which make their appearance during the sixth or seventh months of fetal life. The term *fissure* is applied to such grooves as involve the entire thickness of the cerebral wall, and thus produce corresponding eminences in the ventricular cavity, while the *sulci* affect only the superficial part of the wall, and therefore leave no impressions in the ventricle. The fissures comprise the **choroidal** and **hippocampal** already described, and two others, viz., the **calcarine** and **collateral,** which produce the swellings known respectively as the **calcar avis** and the **collateral eminence** in the ventricular cavity. Of the sulci the following may be referred to, viz., the **central sulcus** (*fissure of Rolando*), which is developed in two parts; the **intraparietal sulcus** in four parts; and the **cingulate sulcus** in two or three parts. The **lateral cerebral** or **Sylvian fissure** differs from all the other fissures in its mode of development. It appears about the third month as a depression, the **Sylvian fossa,** on the lateral surface of the hemisphere (Fig. 658); this fossa corresponds with the position of the corpus striatum, and its floor is moulded to form the insula. The intimate connection which exists between the cortex of the insula and the subjacent corpus striatum prevents this part of the hemisphere wall from expanding at the same rate as the portions which surround it. The neighboring parts of the hemisphere therefore gradually grow over and cover in the insula, and constitute the temporal, parietal, frontal, and orbital opercula of the adult brain. The frontal and orbital opercula are the last to form, but by the end of the first year after birth the insula is completely submerged by the approximation of the opercula. The fissures separating the opposed margins of the opercula constitute the composite lateral cerebral fissure.

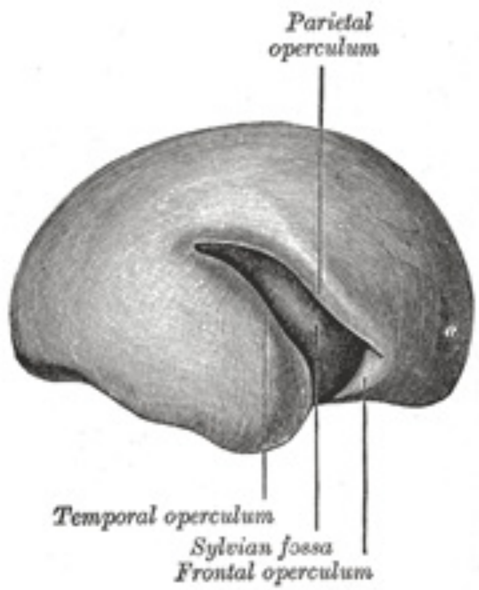


FIG. 658– Outer surface of cerebral hemisphere of human embryo of about five months. (See enlarged image)

If a section across the wall of the hemisphere about the sixth week be examined microscopically it will be found to consist of a thin marginal or 34
reticular layer, a thick ependymal layer, and a thin intervening mantle layer. Neuroblasts from the ependymal and mantle layers migrate into the deep part of the marginal layer and form the cells of the cerebral cortex. The nerve fibers which form the underlying white substance of the hemispheres consist at first of outgrowths from the cells of the corpora striata and thalami; later the fibers from the cells of the cortex are added. Medullation of these fibers begins about the time of birth and continues until puberty. A summary of the parts derived from the brain vesicles is given in the following table:

	1. Myelencephalon	Medulla oblongata
		Lower part of fourth ventricle.
Hind-brain or Rhombencephalon		Pons
	2. Metencephalon	Cerebellum
		Intermediate part of fourth ventricle.

	3. Isthmus rhombencephali	Anterior medullary velum Brachia conjunctiva cerebelli. Upper part of fourth ventricle.
Mid-brain or Mesencephalon.............................		Cerebral peduncles Lamina quadrigemina Cerebral aqueduct.
Fore-brain or Prosencephalon	1. Diencephalon	Thalamus Metathalamus Epithalamus Pars mamillaris hypothalami Posterior part of third ventricle.
	2. Telencephalon	Anterior part of third ventricle Pars optica hypothalami Cerebral hemispheres Lateral ventricles Interventricular foramen.

The Cranial Nerves.—With the exception of the olfactory, optic, and acoustic nerves, which will be especially considered, the cranial nerves 35 are developed in a similar manner to the spinal nerves (see page 735). The sensory or afferent nerves are derived from the cells of the ganglion rudiments of the neural crest. The central processes of these cells grow into the brain and form the roots of the nerves, while the peripheral processes extend outward and constitute their fibers of distribution (Fig. 645). It has been seen, in considering the development of the medulla oblongata (page 739), that the **tractus solitarius** (Fig. 660),derived from the fibers which grow inward from the ganglion rudiments of the glossopharyngeal and vagus nerves, is the homologue of the **oval bundle** in the cord which had its origin in the posterior nerve roots. The motor or efferent nerves arise as outgrowths of the neuroblasts situated in the basal laminæ of the mid- and hindbrain. While, however, the spinal motor nerve roots arise in one series from the basal lamina, the cranial motor nerves are grouped into two sets, according as they spring from the medial or lateral parts of the basal lamina. To the former set belong the oculomotor, trochlear, abducent, and hypoglossal nerves; to the latter, the accessory and the motor fibers of the trigeminal, facial, glossopharyngeal, vagus nerves (Figs. 659, 660).

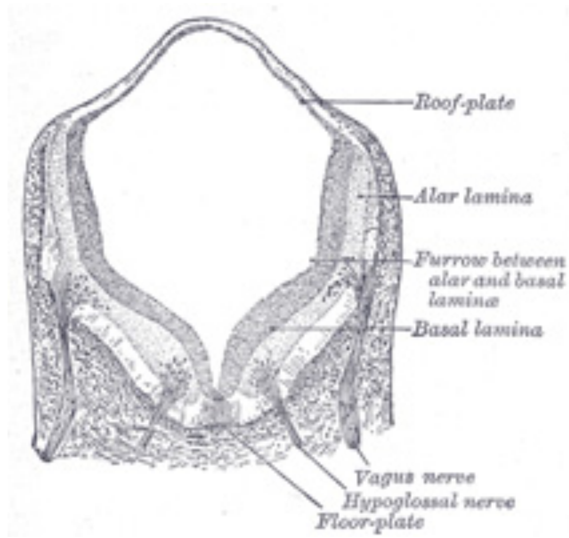


FIG. 659– Transverse section of medulla oblongata of human embryo. X 32. (Kollmann) (See enlarged image)

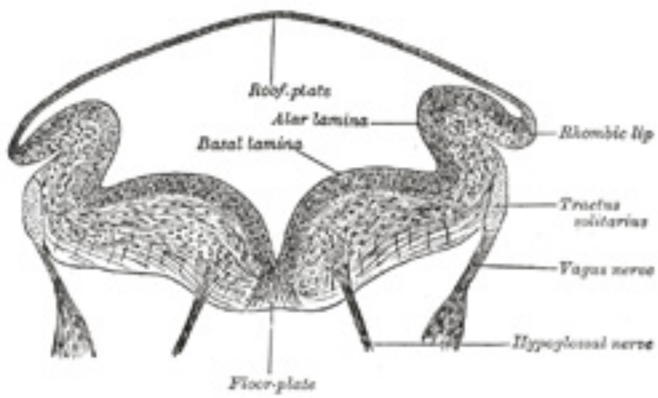


FIG. 660– Transverse section of medulla oblongata of human embryo. (After His.) (See enlarged image)

3. The Spinal Cord or Medulla Spinalis

The **medulla spinalis** or **spinal cord** forms the elongated, nearly cylindrical, part of the central nervous system which occupies the upper two-thirds of the vertebral canal. Its average length in the male is about 45 cm., in the female from 42 to 43 cm., while its weight amounts to about 30 gms. It extends from the level of the upper border of the atlas to that of the lower border of the first, or upper border of the second, lumbar vertebra. Above, it is continuous with the brain; below, it ends in a conical extremity, the **conus medullaris,** from the apex of which a delicate filament, the **filum terminale,** descends as far as the first segment of the coccyx (Fig. 661). 1

The position of the medulla spinalis varies with the movements of the vertebral column, its lower extremity being drawn slightly upward when the column is flexed. It also varies at different periods of life; up to the third month of fetal life the medulla spinalis is as long as the vertebral canal, but from this stage onward the vertebral column elongates more rapidly than the medulla spinalis, so that by the end of the fifth month the medulla spinalis terminates at the base of the sacrum, and at birth about the third lumbar vertebra. 2

The medulla spinalis does not fill the part of the vertebral canal in which it lies; it is ensheathed by three protective membranes, separated from each other by two concentric spaces. The three membranes are named from without inward, the **dura mater,** the**arachnoid,** and the **pia mater.** The **dura mater** is a strong, fibrous membrane which forms a wide, tubular sheath; this sheath extends below the termination of the medulla spinalis and ends in a pointed cul-de-sac at the level of the lower border of the second sacral vertebra. The dura mater is separated from the wall of the vertebral canal by the**epidural cavity,** which contains a quantity of loose areolar tissue and a plexus of veins; between the dura mater and the subjacent arachnoid is a capillary interval, the **subdural cavity,** which contains a small quantity of fluid, probably of the nature of lymph. The**arachnoid** is a thin, transparent sheath, separated from the pia mater by a comparatively wide interval, the **subarachnoid cavity,** which is filled with cerebrospinal fluid. The **pia mater** closely invests the medulla spinalis and sends delicate septa into its substance; a narrow band, the **ligamentum denticulatum,** extends along each of its lateral surfaces and is attached by a series of pointed processes to the inner surface of the dura mater. 3

Thirty-one pairs of spinal nerves spring from the medulla spinalis, each nerve having an anterior or ventral, and a posterior or dorsal root, the latter being distinguished by the presence of an oval swelling, the **spinal ganglion,** which contains numerous nerve cells. Each root consists of several bundles of nerve fibers, and at its attachment extends for some distance along the side of the medulla spinalis. The pairs of spinal nerves are grouped as follows: cervical 8, thoracic 12, lumbar 5, sacral 5, coccygeal 1, and, for convenience of description, the medulla spinalis is divided into cervical, thoracic, lumbar and sacral regions, corresponding with the attachments of the different groups of nerves. 4

Although no trace of transverse segmentation is visible on the surface of the medulla spinalis, it is convenient to regard it as being built up of a series of superimposed **spinal segments** or **neuromeres,** each of which has a length equivalent to the extent of attachment of a pair of spinal nerves. Since the extent of attachment of the successive pairs of nerves varies in different parts, it follows that the spinal segments are of varying lengths; thus, in the cervical region they average about 13 mm., in the mid-thoracic region about 26 mm., while in the lumbar and sacral regions they diminish rapidly from about 15 mm. at the level of the first pair of lumbar nerves to about 4 mm. opposite the attachments of the lower sacral nerves. 5

FIG. 661– Sagittal section of vertebral canal to show the lower end of the medulla spinalis and the filum terminale. *Li, Lv*. First and fifth lumbar vertebræ. *Sii*. Second sacral vertebra. 1. Dura mater. 2. Lower part of tube of dura mater. 3. Lower extremity of medulla spinalis. 4. Intradural, and 5, Extradural portions of filum terminale. 6. Attachment of filum terminale to first segment of coccyx. (Testut.) (See enlarged image)

As a consequence of the relative inequality in the rates of growth of the medulla spinalis and vertebral column, the nerve roots, which in the early embryo passed transversely outward to reach their respective intervertebral foramina, become more and more oblique in direction from above downward, so that the lumbar and sacral nerves descend almost vertically to reach their points of exit. From the appearance these nerves present at their attachment to the medulla spinalis and from their great length they are collectively termed the **cauda equina** (Fig. 662). *6*

The **filum terminale** is a delicate filament, about 20 cm. in length, prolonged downward from the apex of the conus medullaris. It consists of two parts, an upper and a lower. The upper part, or **filum terminale internum,** measures about 15 cm. in length and reaches as far as the lower border of the second sacral vertebra. It is contained within the tubular sheath of dura mater, and is surrounded by the nerves forming the cauda *7* equina, from which it can be readily recognized by its bluish-white color. The lower part, or **filum terminale externum,** is closely invested by, and is adherent to, the dura mater; it extends downward from the apex of the tubular sheath and is attached to the back of the first segment of the coccyx. The filum terminale consists mainly of fibrous tissue, continuous above with that of the pia mater. Adhering to its outer surface, however, are a few strands of nerve fibers which probably represent rudimentary second and third coccygeal nerves; further, the central canal of the medulla spinalis extends downward into it for 5 or 6 cm.

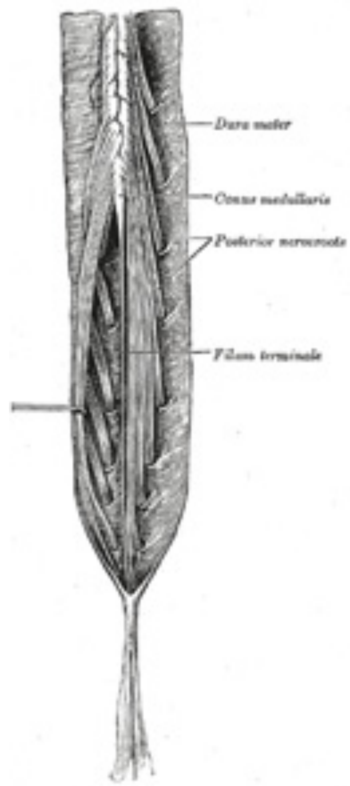


FIG. 662– Cauda equina and filum terminale seen from behind. The dura mater has been opened and spread out, and the arachnoid has been removed. (See enlarged image)

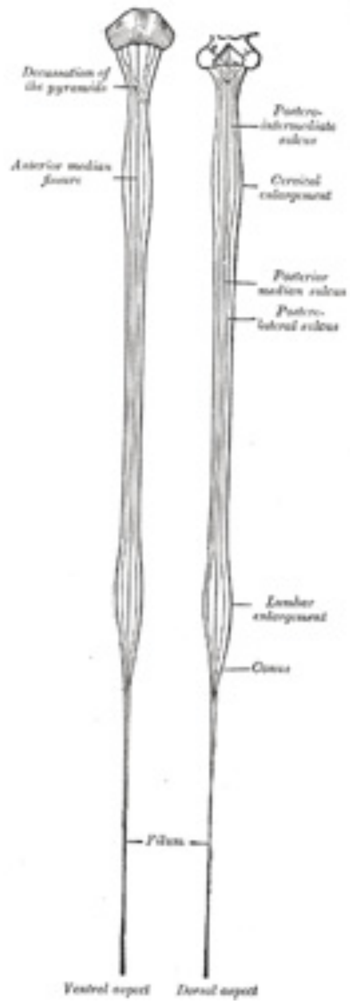


FIG. 663– Diagrams of the medulla spinalis. (See enlarged image)

Enlargements.—The medulla spinalis is not quite cylindrical, being slightly flattened from before backward; it also presents two swellings or enlargements, an upper or cervical, and a lower or lumbar (Fig. 663). 8

The **cervical enlargement** is the more pronounced, and corresponds with the attachments of the large nerves which supply the upper limbs. It extends from about the third cervical to the second thoracic vertebra, its maximum circumference (about 38 mm.) being on a level with the attachment of the sixth pair of cervical nerves. 9

The **lumbar enlargement** gives attachment to the nerves which supply the lower limbs. It commences about the level of the ninth thoracic vertebra, and reaches its maximum circumference, of about 33 mm., opposite the last thoracic vertebra, below which it tapers rapidly into the conus medullaris. 10

Fissures and Sulci (Fig. 664).—An anterior median fissure and a posterior median sulcus incompletely divide the medulla spinalis into two symmetrical parts, which are joined across the middle line by a commissural band of nervous matter. 11

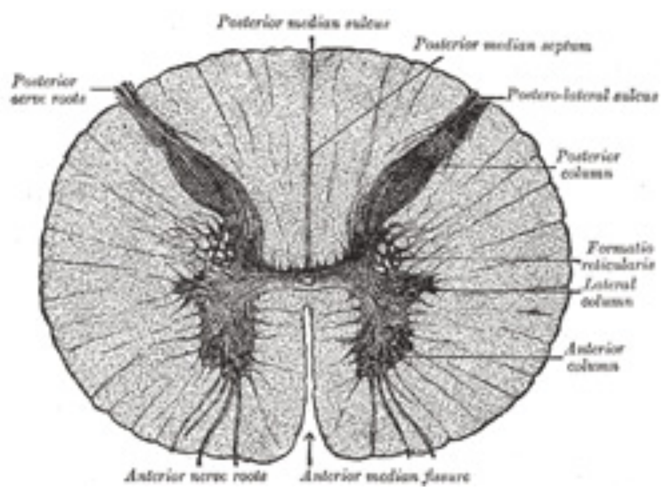


FIG. 664– Transverse section of the medulla spinalis in the mid-thoracic region. (See enlarged image)

The **Anterior Median Fissure** (*fissura mediana anterior*) has an average depth of about 3 mm., but this is increased in the lower part of the medulla spinalis. It contains a double fold of pia mater, and its floor is formed by a transverse band of white substance, the**anterior white commissure,** which is perforated by bloodvessels on their way to or from the central part of the medulla spinalis. 12

13 The **Posterior Median Sulcus** (*sulcus medianus posterior*) is very shallow; from it a septum of neuroglia reaches rather more than half-way into the substance of the medulla spinalis; this septum varies in depth from 4 to 6 mm., but diminishes considerably in the lower part of the medulla spinalis.

14 On either side of the posterior median sulcus, and at a short distance from it, the posterior nerve roots are attached along a vertical furrow named the **posterolateral sulcus.** The portion of the medulla spinalis which lies between this and the posterior median sulcus is named the **posterior funiculus.** In the cervical and upper thoracic regions this funiculus presents a longitudinal furrow, the **postero-intermediate sulcus;** this marks the position of a septum which extends into the posterior funiculus and subdivides it into two fasciculi—a medial, named the **fasciculus gracilis** (*tract of Goll*); and a lateral, the **fasciculus cuneatus**(*tract of Burdach*) (Fig. 672). The portion of the medulla spinalis which lies in front of the posterolateral sulcus is termed the **antero-lateral region.** The anterior nerve roots, unlike the posterior, are not attached in linear series, and their position of exit is not marked by a sulcus. They arise by separate bundles which spring from the anterior column of gray substance and, passing forward through the white substance, emerge over an area of some slight width. The most lateral of these bundles is generally taken as a dividing line which separates the antero-lateral region into two parts, viz., an **anterior funiculus,** between the anterior median fissure and the most lateral of the anterior nerve roots; and a **lateral funiculus,** between the exit of these roots and the postero-lateral sulcus. In the upper part of the cervical region a series of nerve roots passes outward through the lateral funiculus of the medulla spinalis; these unite to form the spinal portion of the accessory nerve, which runs upward and enters the cranial cavity through the foramen magnum.

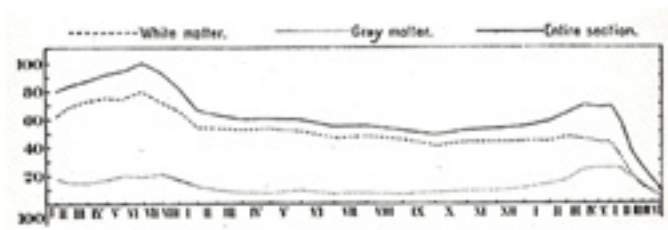


FIG. 665– Curves showing the sectional area at different levels of the cord. The ordinates show the area in sq. mm. (Donaldson and Davis.) (See enlarged image)

15 **The Internal Structure of the Medulla Spinalis.**—On examining a transverse section of the medulla spinalis (Fig. 664) it is seen to consist of gray and white nervous substance, the former being enclosed within the latter.

16 **Gray Substance** (***substantia grisea centralis***)**.**—The gray substance consists of two symmetrical portions, one in each half of the medulla spinalis: these are joined across the middle line by a transverse commissure of gray substance, through which runs a minute canal, the **central canal,** just visible to the naked eye. In a transverse section each half of the gray substance is shaped like a comma or crescent, the concavity of which is directed laterally; and these, together with the intervening gray commissure, present the appearance of the letter H. An imaginary

coronal plane through the central canal serves to divide each crescent into an **anterior** or **ventral,** and a **posterior** or **dorsal column.**

The **Anterior Column** (*columna anterior; anterior cornu*), directed forward, is broad and of a rounded or quadrangular shape. Its posterior part is termed the base, and its anterior part the **head,** but these are not differentiated from each other by any well-defined constriction. It is separated from the surface of the medulla spinalis by a layer of white substance which is traversed by the bundles of the anterior nerve roots. In the thoracic region, the postero-lateral part of the anterior column projects lateralward as a triangular field, which is named the **lateral column** (*columna lateralis; lateral cornu*). *17*

The **Posterior Column** (*columna posterior; posterior cornu*) is long and slender, and is directed backward and lateralward: it reaches almost as far as the posterolateral sulcus, from which it is separated by a thin layer of white substance, the **tract of Lissauer.** It consists of a **base,** directly continuous with the base of the anterior horn, and a **neck** or slightly constricted portion, which is succeeded by an oval or fusiform area, termed the **head,** of which the **apex** approaches the posterolateral sulcus. The apex is capped by a V-shaped or crescentic mass of translucent, gelatinous neuroglia, termed the **substantia gelatinosa of Rolando,** which contains both neuroglia cells, and small nerve cells. Between the anterior and posterior columns the gray substance extends as a series of processes into the lateral funiculus, to form a net-work called the **formatio reticularis.** *18*

The quantity of gray substance, as well as the form which it presents on transverse section, varies markedly at different levels. In the thoracic region it is small, not only in amount but relatively to the surrounding white substance. In the cervical and lumbar enlargements it is greatly increased: in the latter, and especially in the conus medullaris, its proportion to the white substance is greatest (Fig. 665). In the cervical region its posterior column is comparatively narrow, while its anterior is broad and expanded; in the thoracic region, both columns are attenuated, and the lateral column is evident; in the lumbar enlargement, both are expanded; while in the conus medullaris the gray substance assumes the form of two oval masses, one in each half of the cord, connected together by a broad gray commissure. *19*

The **Central Canal** (*canalis centralis*) runs throughout the entire length of the medulla spinalis. The portion of gray substance in front of the canal is named the **anterior gray commissure;** that behind it, the **posterior gray commissure.** The former is thin, and is in contact anteriorly with the anterior white commissure: it contains a couple of longitudinal veins, one on either side of the middle line. The posterior gray commissure reaches from the central canal to the posterior median septum, and is thinnest in the thoracic region, and thickest in the conus medullaris. The central canal is continued upward through the lower part of the medulla oblongata, and opens into the fourth ventricle of the brain; below, it reaches for a short distance into the filum terminale. In the lower part of the conus medullaris it exhibits a fusiform dilatation, the **terminal ventricle;** this has a vertical measurement of from 8 to 10 mm., is triangular on cross-section with its base directed forward, and tends to undergo obliteration after the age of forty years. *20*

FIG. 666– Transverse sections of the medulla spinalis at different levels. (See enlarged image)

Throughout the cervical and thoracic regions the central canal is situated in the anterior third of the medulla spinalis; in the lumbar enlargement 21
it is near the middle, and in the conus medullaris it approaches the posterior surface. It is filled with cerebrospinal fluid, and lined by ciliated, columnar epithelium, outside of which is an encircling band of gelatinous substance, the **substantia gelatinosa centralis.** This gelatinous substance consists mainly of neuroglia, but contains a few nerve cells and fibers; it is traversed by processes from the deep ends of the columnar ciliated cells which line the central canal (Fig. 667).

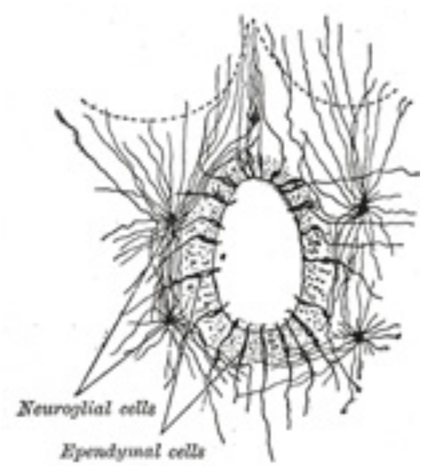


FIG. 667– Section of central canal of medulla spinalis, showing ependymal and neuroglial cells. (v. Lenhossek.) (See enlarged image)

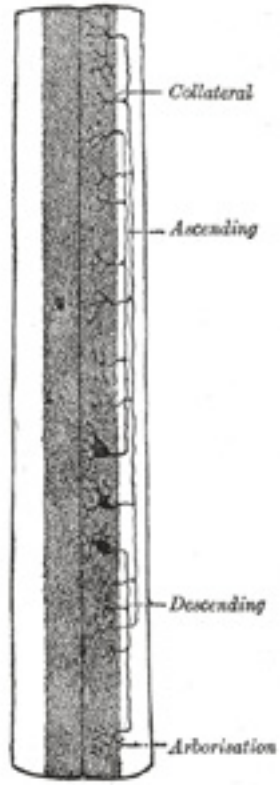


FIG. 668– Cells of medulla spinalis. Diagram showing in longitudinal section the intersegmental neurons of the medulla spinalis. The gray and white parts correspond respectively to the gray and white substance of the medulla spinalis. (Poirier.) (See enlarged image)

Structure of the Gray Substance.—The gray substance consists of numerous nerve cells and nerve fibers held together by neuroglia. *22*
Throughout the greater part of the gray substance the neuroglia presents the appearance of a sponge-like network, but around the central canal and on the apices of the posterior columns it consists of the gelatinous substance already referred to. The nerve cells are multipolar, and vary greatly in size and shape. They consist of (1) motor cells of large size, which are situated in the anterior horn, and are especially numerous in the cervical and lumbar enlargements; the axons of most of these cells pass out to form the anterior nerve roots, but before leaving the white

substance they frequently give off collaterals, which reënter and ramify in the gray substance. 113 (2) Cells of small or medium size, whose axons pass into the white matter, where some pursue an ascending, and others a descending course, but most of them divide in a T-shape manner into descending and ascending processes. They give off collaterals which enter and ramify in the gray substance, and the terminations of the axons behave in a similar manner. The lengths of these axons vary greatly: some are short and pass only between adjoining spinal segments, while others are longer and connect more distant segments. These cells and their processes constitute a series of **association** or **intersegmental neurons** (Fig. 668), which link together the different parts of the medulla spinalis. The axons of most of these cells are confined to that side of the medulla spinalis in which the nerve cells are situated, but some cross to the opposite side through the anterior commissure, and are termed **crossed commissural fibers.** Some of these latter end directly in the gray substance, while others enter the white substance, and ascend or descend in it for varying distances, before finally terminating in the gray substance. (3) Cells of the type II of Golgi, limited for the most part to the posterior column, are found also in the substantia gelatinosa of Rolando; their axons are short and entirely confined to the gray substance, in which they break up into numerous fine filaments. Most of the nerve cells are arranged in longitudinal columns, and appear as groups on transverse section (Figs. 669, 670, 671).

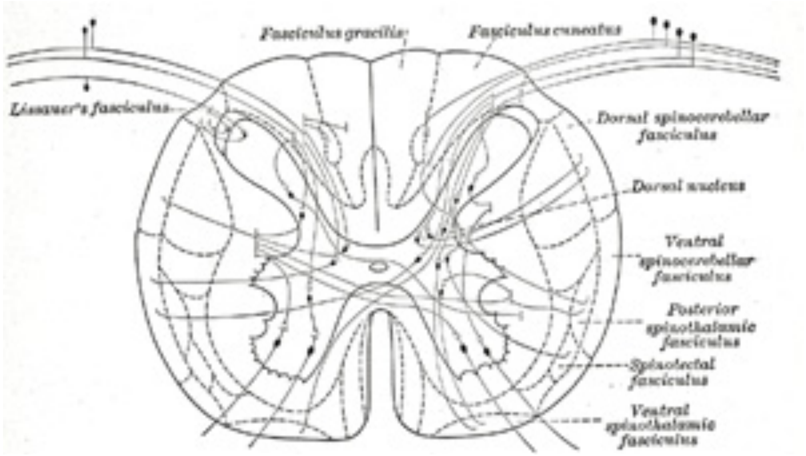


FIG. 669– Diagram showing a few of the connections of afferent (sensory) fibers of the posterior root with the efferent fibers from the ventral column and with the various long ascending fasciculi. (See enlarged image)

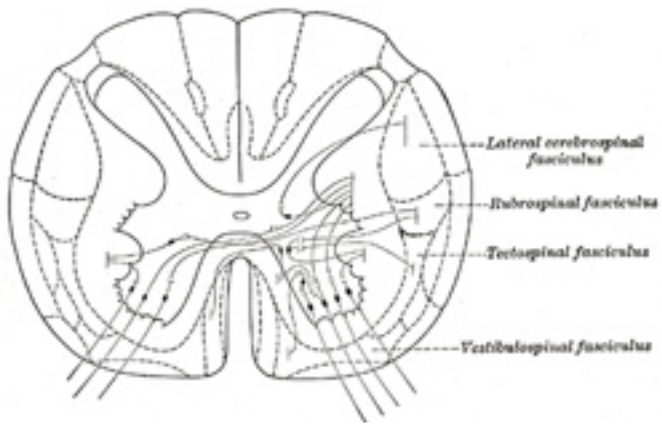


FIG. 670– Diagram showing possible connection of long descending fibers from higher centers with the motor cells of the ventral column through association fibers. (See enlarged image)

Nerve Cells in the Anterior Column.—The nerve cells in the anterior column are arranged in columns of varying length. The longest occupies 23
the medial part of the anterior column, and is named the **antero-medial column:** it is well marked in C4, C5, again from C8 to L4, it disappears in L5 and S1 but is well marked in S2, S3 and S4 (Bruce). [114] Behind it is a **dorso-medial column** of small cells, which is not represented in L5, S1, S2 nor below S4. Its axons probably pass into the dorsal rami of the spinal nerves to supply the dorsal musculature of the spinal column. In the cervical and lumbar enlargements, where the anterior column is expanded in a lateral direction, the following additional columns are present, viz.: (*a*) **antero-lateral,** which consists of two groups, one in C4, C5, C6 the other in C6, C7, C8 in the cervical enlargement and of a group from L2 to S2 in the lumbo-sacral enlargement; (*b*) **postero-lateral,** in the lower five cervical, lower four lumbar, and upper three sacral segments; (*c*) **post-postero-lateral,** in the last cervical, first thoracic, and upper three sacral segments; and (*d*) a **central,** in the lower four lumbar and upper two sacral segments. These cell groups are evidently related to the nerve roots of the brachial and sacral plexuses and supply fibers to the muscles of the arm and leg. Throughout the base of the anterior column are scattered solitary cells, the axons of some of which form crossed commissural fibers, while others constitute the motor fibers of the posterior nerve roots. (See footnote, page 755.)

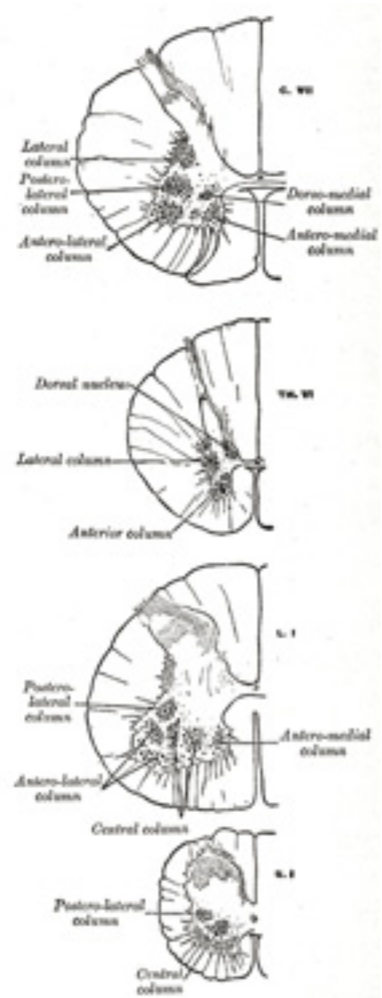


FIG. 671– Transverse sections of the medulla spinalis at different levels to show the arrangement of the principal cell columns. (See enlarged image)

Nerve Cells in the Lateral Column.—These form a column which is best marked where the lateral gray column is differentiated, viz., in the thoracic region; 115 but it can be traced throughout the entire length of the medulla spinalis in the form of groups of small cells which are situated in the anterior part of the formatio reticularis. In the upper part of the cervical region and lower part of the medulla oblongata as well as in the third and fourth sacral segments this column is again differentiated. In the medulla it is known as the **lateral nucleus.** The cells of this column are fusiform or star-shaped, and of a medium size: the axons of some of them pass into the anterior nerve roots, by which they are carried to the sympathetic nerves: they constitute the white rami and are sympathetic or visceral efferent fibers; they are also known as **preganglionic fibers of the sympathetic system;** the axons of others pass into the anterior and lateral funiculi, where they become longitudinal. 24

Nerve Cells in the Posterior Column.—1. The **dorsal nucleus** (*nucleus dorsalis; column of Clarke*) occupies the medial part of the base of the posterior column, and appears on the transverse section as a well-defined oval area. It begins below at the level of the second or third lumbar nerve, and reaches its maximum size opposite the twelfth thoracic nerve. Above the level of the ninth thoracic nerve its size diminishes, and the column ends opposite the last cervical or first thoracic nerve. It is represented, however, in the other regions by scattered cells, which become aggregated to form a **cervical nucleus** opposite the third cervical nerve, and a **sacral nucleus** in the middle and lower part of the sacral region. Its cells are of medium size, and of an oval or pyriform shape; their axons pass into the peripheral part of the lateral funiculus of the same side, and there ascend, probably in**dorsal spinocerebellar** (*direct cerebellar*) **fasciculus.** 2. The **nerve cells in the substantia gelatinosa of Rolando** are arranged in three zones: a posterior or marginal, of large angular or fusiform cells; an intermediate, of small fusiform cells; and an anterior, of star-shaped cells. The axons of these cells pass into the lateral and posterior funiculi, and there assume a vertical course. In the anterior zone some Golgi cells are found whose short axons ramify in the gray substance. 3. **Solitary cells** of varying form and size are scattered throughout the posterior column. Some of these are grouped to form the **posterior basal column** in the base of the posterior column, lateral to the dorsal nucleus; the posterior basal column is well-marked in the gorilla (Waldeyer), but is ill-defined in man. The axons of its cells pass partly to the posterior and lateral funiculi of the same side, and partly through the anterior white commissure to the lateral funiculus of the opposite side. Golgi cells, type II, located in this region send axons to the lateral and ventral columns. 25

A few star-shaped or fusiform nerve cells of varying size are found in the substantia gelatinosa centralis. Their axons pass into the lateral funiculus of the same, or of the opposite side. 26

The nerve fibers in the gray substance form a dense interlacement of minute fibrils among the nerve cells. This interlacement is formed partly of axons which pass from the cells in the gray substance to enter the white funiculi or nerve roots; partly of the axons of Golgi's cells which ramify only in the gray substance; and partly of collaterals from the nerve fibers in the white funiculi which, as already stated, enter the gray substance and ramify within it. 27

White Substance (*substantia alba*).—The white substance of the medulla spinalis consists of medullated nerve fibers imbedded in a spongelike net-work of neuroglia, and is arranged in three funiculi: anterior, lateral, and posterior. The anterior funiculus lies between the anterior median fissure and the most lateral of the anterior nerve roots: the lateral funiculus between these nerve roots and the postero-lateral sulcus; and the posterior funiculus between the postero-lateral and the posterior median sulci (Fig. 672). The fibers vary greatly in thickness, the smallest being found in the fasciculus gracilis, the **tract of Lissauer,** and inner part of the lateral funiculus; while the largest are situated in the anterior 28 funiculus, and in the peripheral part of the lateral funiculus. Some of the nerve fibers assume a more or less transverse direction, as for example those which cross from side to side in the anterior white commissure, but the majority pursue a longitudinal course and are divisible into (1) those connecting the medulla spinalis with the brain and conveying impulses to or from the latter, and (2) those which are confined to the medulla spinalis and link together its different segments, *i. e.,* intersegmental or association fibers.

Nerve Fasciculi.—The longitudinal fibers are grouped into more or less definite bundles or fasciculi. These are not recognizable from each other 29
in the normal state, and their existence has been determined by the following methods: (1) A. Waller discovered that if a bundle of nerve fibers be cut, the portions of the fibers which are separated from their cells rapidly degenerate and become atrophied, while the cells and the parts of the fibers connected with them undergo little alteration. 116 This is known as **Wallerian degeneration.** Similarly, if a group of nerve cells be destroyed, the fibers arising from them undergo degeneration. Thus, if the motor cells of the cerebral cortex be destroyed, or if the fibers arising from these cells be severed, a **descending degeneration** from the seat of injury takes place in the fibers. In the same manner, if a spinal ganglion be destroyed, or the fibers which pass from it into the medulla spinalis be cut, an **ascending degeneration** will extend along these fibers. (2) Pathological changes, especially in man, have given important information by causing ascending and descending degenerations. (3) By tracing the development of the nervous system, it has been observed that at first the nerve fibers are merely naked axis-cylinders, and that they do not all acquire their medullary sheaths at the same time; hence the fibers can be grouped into different bundles according to the dates at which they receive their medullary sheaths. (4) Various methods of staining nervous tissue are of great value in tracing the course and mode of termination of the axis-cylinder processes.

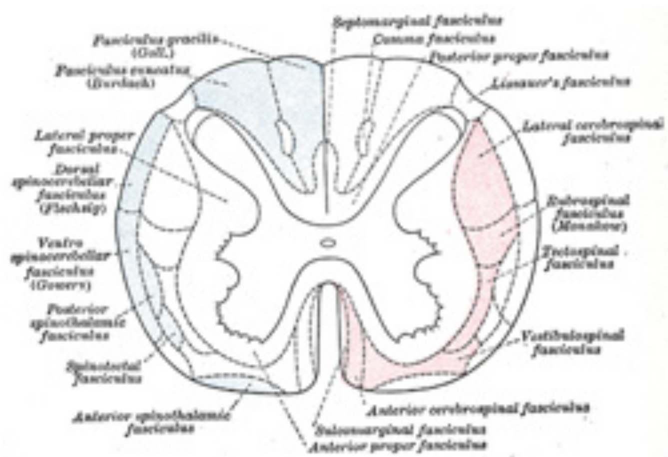


FIG. 672– Diagram of the principal fasciculi of the spinal cord. (See enlarged image)

Fasciculi in the Anterior Funiculus.—*Descending Fasciculi.*—The **anterior cerebrospinal** (*fasciculus cerebrospinalis anterior; direct* 30
pyramidal tract), which is usually small, but varies inversely in size with the lateral cerebrospinal fasciculus. It lies close to the anterior median fissure, and is present only in the upper part of the medulla spinalis; gradually diminishing in size as it descends, it ends about the middle of the thoracic region. It consists of descending fibers which arise from cells in the motor area of the cerebral hemisphere of the same side, and which, as they run downward in the medulla spinalis, cross in succession through the anterior white commissure to the opposite side, where they end, either directly or indirectly, by arborizing around the motor cells in the anterior column. A few of its fibers are said to pass to the lateral column of the same side and to the gray matter at the base of the posterior column. They conduct voluntary motor impulses from the precentral gyrus to the motor centers of the cord.

The **vestibulospinal fasciculus,** situated chiefly in the marginal part of the funiculus and mainly derived from the cells of Deiters' nucleus, of 31
the same and the opposite side, *i. e.,*the chief terminal nucleus of the vestibular nerve. Fibers are also contributed to this fasciculus from scattered cells of the articular formation of the medulla oblongata, the pons and the mid-brain (tegmentum). The other terminal nuclei of the vestibular nerve also contribute fibers. In the brain stem these fibers form part of the median longitudinal bundle. The fasciculus can be traced to the sacral region. Its terminals and collaterals end either directly or indirectly among the motor cells of the anterior column. This fasciculus is probably concerned with equilibratory reflexes.

The **tectospinal fasciculus,** situated partly in the anterior and partly in the lateral funiculus, is mainly derived from the opposite superior 32
colliculus of the mid-brain. The fibers from the superior colliculus cross the median raphé in the fountain decussation of Meynert and descend as the ventral longitudinal bundle in the reticular formation of the brain-stem. Its collaterals and terminals end either directly or indirectly among the motor cells of the anterior column of the same side. Since the superior colliculus is an important visual reflex center, the tectospinal fasciculus is probably concerned with visual reflexes.

Ascending Fasciculi.—The **ventral spinothalamic fasciculus,** situated in the marginal part of the funiculus and intermingled more or less with 33
the vestibulo-spinal fasciculus, is derived from cells in the posterior column or intermediate gray matter of the opposite side. Their axons cross in the anterior commissure. This is a somewhat doubtful fasciculus and its fibers are supposed to end in the thalamus and to conduct certain of the touch impulses.

The remaining fibers of the anterior funiculus constitute what is termed the **anterior proper fasciculus** (*fasciculus anterior proprius; anterior* 34
basis bundle). It consists of (*a*) longitudinal intersegmental fibers which arise from cells in the gray substance, more especially from those of the medial group of the anterior column, and, after a longer or shorter course, reënter the gray substance; (*b*) fibers which cross in the anterior white commissure from the gray substance of the opposite side.

Fasciculi in the Lateral Funiculus.—1. *Descending Fasciculi*.—(*a*) The **lateral cerebrospinal fasciculus** (*fasciculus cerebrospinalis lateralis;* 35
crossed pyramidal tract) extends throughout the entire length of the medulla spinalis, and on transverse section appears as an oval area in front of the posterior column and medial to the cerebellospinal. Its fibers arise from cells in the motor area of the cerebral hemisphere of the opposite side. They pass downward in company with those of the anterior cerebrospinal fasciculus through the same side of the brain as that from which they originate, but they cross to the opposite side in the medulla oblongata and descend in the lateral funiculus of the medulla spinalis.

It is probable [117] that the fibers of the anterior and lateral cerebrospinal fasciculi are not related in this direct manner with the cells of the 36 anterior column, but terminate by arborizing around the cells at the base of the posterior column and the cells of Clarke's column, which in turn link them to the motor cells in the anterior column, usually of several segments of the cord. In consequence of these interposed neurons the fibers of the cerebrospinal fasciculi correspond not to individual muscles, but to associated groups of muscles.

The anterior and lateral cerebrospinal fasciculi constitute the motor fasciculi of the medulla spinalis and have their origins in the motor cells of the cerebral cortex. They descend through the internal capsule of the cerebrum, traverse the cerebral peduncles and pons and enter the pyramid of the medulla oblongata. In the lower part of the latter about two-thirds of them cross the middle line and run downward in the lateral funiculus as the lateral cerebrospinal fasciculus, while the remaining fibers do not cross the middle line, but are continued into the same side of the medulla spinalis, where they form the anterior cerebrospinal fasciculus. The fibers of the latter, however, cross the middle line in the anterior white commissure, and thus all the motor fibers from one side of the brain ultimately reach the opposite side of the medulla spinalis. The proportion of fibers which cross in the medulla oblongata is not a constant one, and thus the anterior and lateral cerebrospinal fasciculi vary inversely in size. Sometimes the former is absent, and in such cases it may be presumed that the decussation of the motor fibers in the medulla oblongata has been complete. The fibers of these two fasciculi do not acquire their medullary sheaths until after birth. In some animals the motor fibers are situated in the posterior funiculus. *37*

(*b*) The **rubrospinal fasciculus** (Monakow) (*prepyramidal tract*), lies on the ventral aspect of the lateral cerebrospinal fasciculus and on transverse section appears as a somewhat triangular area. Its fibers descend from the mid-brain, where they have their origin in the red nucleus of the tegmentum of the opposite side. Its terminals and collaterals end either directly or indirectly in relation with the motor cells of the anterior column. The rubrospinal fasciculus is supposed to be concerned with cerebellar reflexes since fibers which pass from the cerebellum through the superior peduncle send many collaterals and terminals to the red nucleus. *38*

(*c*) The **olivospinal fasciculus** (Helweg) arises in the vicinity of the inferior olivary nucleus in the medulla oblongata, and is seen only in the cervical region of the medulla spinalis, where it forms a small triangular area at the periphery, close to the most lateral of the anterior nerve roots. Its exact origin and its mode of ending have not yet been definitely made out. *39*

2. Ascending Fasciculi.—(*a*) The **dorsal spinocerebellar fasciculus** (*fasciculus cerebellospinalis; direct cerebellar tract of Flechsig*) is situated at the periphery of the posterior part of the lateral funiculus, and on transverse section appears as a flattened band reaching as far forward as a line drawn transversely through the central canal. Medially, it is in contact with the lateral cerebrospinal fasciculus, behind, with the fasciculus of Lissauer. It begins about the level of the second or third lumbar nerve, and increasing in size as it ascends, passes to the vermis of the cerebellum through the inferior peduncle. Its fibers are generally regarded as being formed by the axons of the cells of the dorsal nucleus (*Clarke's column*); they receive their medullary sheaths about the sixth or seventh month of fetal life. Its fibers are supposed to conduct impulses of unconscious muscle sense. *40*

The **superficial antero-lateral fasciculus** (*tract of Gowers*) consists of four fasciculi, the ventral spinocerebellar, the lateral spinothalamic, the spinotectal and the ventral spinothalamic. *41*

(*b*) The **ventral spinocerebellar fasciculus** (*Gowers*) skirts the periphery of the lateral funiculus in front of the dorsal spinocerebellar fasciculus. In transverse section it is shaped somewhat like a comma, the expanded end of which lies in front of the dorsal spinocerebellar fasciculus while the tail reaches forward into the anterior funiculus. Its fibers come from the same but mostly from the opposite side of the medulla spinalis and cross both in the anterior white commissure and in the gray commissure; they are probably derived from the cells of the dorsal nucleus and from other cells of the posterior column and the intermediate portion of the gray matter. The ventral spinocerebellar fasciculus begins about the level of the third pair of lumbar nerves, and can be followed into the medulla oblongata and pons almost to the level *42* of the inferior colliculus where it crosses over the superior peduncle and then passes backward along its medial border to reach the vermis of the cerebellum. In the pons it lies along the lateral edge of the lateral lemniscus. Some of its fibers join the dorsal spinocerebellar fasciculus at the level of the inferior peduncle and pass with them into the cerebellum. Other fibers are said to continue upward in the dorso-lateral part of the tegmentum of the mid-brain probably as far as the thalamus.

(*c*) The **lateral spinothalamic fasciculus** is supposed to come from cells in the dorsal column and the intermediate gray matter whose axons 43
cross in the anterior commissure to the opposite lateral funiculus where they pass upward on the medial side of the ventral spinocerebellar fasciculus; on reaching the medulla oblongata they continue in the formatio reticularis near the median fillet and probably terminate in the ventro-lateral region of the thalamus. It is supposed to conduct impulses of pain and temperature. The lateral and ventral spinothalamic fasciculi are sometimes termed the **secondary sensory fasciculus** or**spinal lemniscus.**

(*d*) The **spinotectal fasciculus** is supposed to arise in the dorsal column and terminate in the (inferior ?) and superior colliculi. It is situated 44
ventral to the lateral spinothalamic fasciculus, but its fibers are more or less intermingled with it. It is also known as the **spino-quadrigeminal system of Mott.** In the brain-stem the fibers run lateral from the inferior olive, ventro-lateral from the superior olive, then ventro-medial from the spinal tract of the trigeminal; the fibers come to lie in the medial portion of the lateral lemniscus.

(*e*) The **fasciculus of Lissauer** is a small strand situated in relation to the tip of the posterior column close to the entrance of the posterior nerve 45
roots. It consists of fine fibers which do not receive their medullary sheaths until toward the close of fetal life. It is usually regarded as being formed by some of the fibers of the posterior nerve roots, which ascend for a short distance in the tract and then enter the posterior column, but since its fibers are myelinated later than those of the posterior nerve roots, and do not undergo degeneration in locomotor ataxia, they are probably intersegmental in character.

In addition the fasciculus or **tract of Lissauer** contains great numbers of fine non-medullated fibers derived mostly from the dorsal roots but 46
partly endogenous in origin. These fibers are intimately related to the substantia gelatinosa which is probably the terminal nucleus. The non-medullated fibers ascend or descend for short distances not exceeding one or two segments, but most of them enter the substantia gelatinosa at or near the level of their origin. Ransom 118 suggests that these non-medullated fibers and the substantia gelatinosa are concerned with the reflexes associated with pain impulses.

(*f*) The **lateral proper fasciculus** (*fasciculus lateralis proprius; lateral basis bundle*) constitutes the remainder of the lateral column, and is 47
continuous in front with the anterior proper fasciculus. It consists chiefly of intersegmental fibers which arise from cells in the gray substance, and, after a longer or shorter course, reënter the gray substance and ramify in it. Some of its fibers are, however, continued upward into the brain under the name of the **medial longitudinal fasciculus.**

Fasciculi in the Posterior Funiculus.—This funiculus comprises two main fasciculi, viz., the **fasciculus gracilis,** and the **fasciculus** 48
cuneatus. These are separated from each other in the cervical and upper thoracic regions by the postero-intermediate septum, and consist mainly of ascending fibers derived from the posterior nerve roots.

The **fasciculus gracilis** (*tract of Goll*) is wedge-shaped on transverse section, and lies next the posterior median septum, its base being at the 49
surface of the medulla spinalis, and its apex directed toward the posterior gray commissure. It increases in size from below upward, and consists of long thin fibers which are derived from the posterior nerve roots, and ascend as far as the medulla oblongata, where they end in the nucleus gracilis.

The **fasciculus cuneatus** (*tract of Burdach*) is triangular on transverse section, and lies between the fasciculus gracilis and the posterior column, its base corresponding with the surface of the medulla spinalis. Its fibers, larger than those of the fasciculus gracilis, are mostly derived from the same source, viz., the posterior nerve roots. Some ascend for only a short distance in the tract, and, entering the gray matter, come into close relationship with the cells of the dorsal nucleus; while others can be traced as far as the medulla oblongata, where they end in the gracile and cuneate nuclei. 50

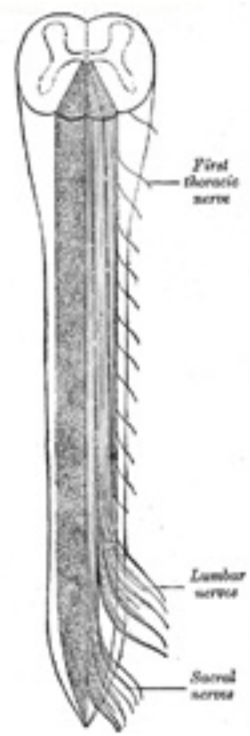


FIG. 673– Formation of the fasciculus gracilis. Medulla spinalis viewed from behind. To the left, the fasciculus gracilis is shaded. To the right, the drawing shows that the fasciculus gracilis is formed by the long fibers of the posterior roots, and that in this tract the sacral nerves lie next the median plane, the lumbar to their lateral side, and the thoracic still more laterally. (Poirier.) (See enlarged image)

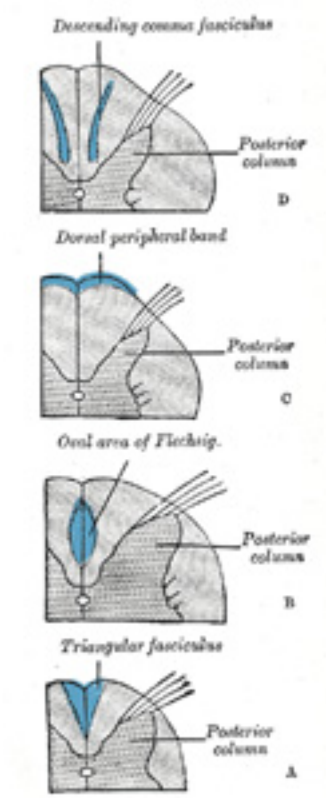


FIG. 674– Descending fibers in the posterior funiculi, shown at different levels. *A*. In the conus medullaris. *B*. In the lumbar region. *C*. In the lower thoracic region. *D*. In the upper thoracic region. (After Testut.) (See enlarged image)

The fasciculus gracilis and fasciculus cuneatus conduct (1) impulses of conscious muscle sense, neurons of the second order from the nucleus 51
gracilis and nucleus cuneatus, pass in the median lemniscus to the thalamus and neurons of the third order from the thalamus to the cerebral cortex; (2) impulses of unconscious muscle sense, *via* neurons of the second order from the nucleus gracilis and nucleus cuneatus pass in the internal and external arcuate fibers of the medulla oblongata to the inferior peduncle and through it to the cerebellum; (3) impulses of tactile discrimination, *via* neurons of the second order from the nucleus cuneatus and nucleus gracilis pass in the median lemniscus to the thalamus, neurons of the third order pass from the thalamus to the cortex.

The **Posterior Proper Fasciculus** (*posterior ground bundle; posterior basis bundle*) arises from cells in the posterior column; their axons 52
bifurcate into ascending and descending branches which occupy the ventral part of the funiculus close to the gray column. They are intersegmental and run for varying distances sending off collaterals and terminals to the gray matter.

Some descending fibers occupy different parts at different levels. In the cervical and upper thoracic regions they appear as a **comma-shaped** 53
fasciculus in the lateral part of the fasciculus cuneatus, the blunt end of the comma being directed toward the posterior gray commissure; in the lower thoracic region they form a **dorsal peripheral band** on the posterior surface of the funiculus; in the lumbar region, they are situated by the side of the posterior median septum, and appear on section as a semi-elliptical bundle, which, together with the corresponding bundle of the opposite side, forms the **oval area of Flechsig;** while in the conus medullaris they assume the form of a **triangular strand** in the postero-medial part of the fasciculus gracilis. These descending fibers are mainly intersegmental in character and derived from cells in the posterior column, but some consist of the descending branches of the posterior nerve roots. The comma-shaped fasciculus was supposed to belong to the second category, but against this view is the fact that it does not undergo descending degeneration when the posterior nerve roots are destroyed.

Roots of the Spinal Nerves.—As already stated, each spinal nerve possesses two roots, an**anterior** and a **posterior,** which are attached to the 54
surface of the medulla spinalis opposite the corresponding column of gray substance (Fig. 675); their fibers become medullated about the fifth month of fetal life.

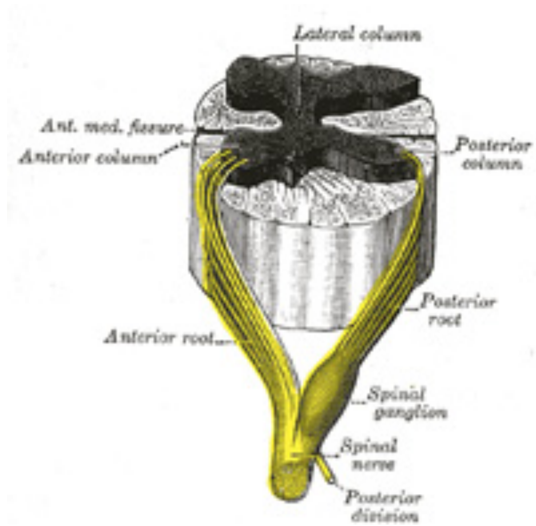


FIG. 675– A spinal nerve with its anterior and posterior roots. (See enlarged image)

The **Anterior Nerve Root** (*radix anterior*) consists of efferent fibers, which are the axons of the nerve cells in the ventral part of the anterior and lateral columns. A short distance from their origins, these axons are invested by medullary sheaths and, passing forward, emerge in two or three irregular rows over an area which measures about 3 mm. in width. *55*

The **Posterior Root** (*radix posterior*) comprises some six or eight fasciculi, attached in linear series along the postero-lateral sulcus. It consists of afferent fibers which arise from the nerve cells in a spinal ganglion. Each ganglion cell gives off a single fiber which divides in a T-shaped manner into two processes, medial and lateral. The lateral processes extend to the sensory end-organs of the skin, muscles, tendons, joints, etc. (*somatic receptors*), and to the sensory end-organs of the viscera (*visceral receptors*). The medial processes of the ganglion cells grow into the medulla spinalis as the posterior roots of the spinal nerves. *56*

The posterior nerve root enters the medulla spinalis in three chief bundles, medial, intermediate, and lateral. The **medial** strand passes directly into the fasciculus cuneatus: it consists of coarse fibers, which acquire their medullary sheaths about the fifth month of intrauterine life; the **intermediate** strand consists of coarse fibers, which enter the gelatinous substance of Rolando; the **lateral** is composed of fine fibers, which assume a longitudinal direction in the tract of Lissauer, and do not acquire their medullary sheaths until after birth. In addition to these medullated fibers there are great numbers of non-medullated fibers which enter with the lateral bundle. They are more numerous than the myelinated fibers. They arise from the small cells of the spinal ganglia by T-shaped axons similar to the myelinated. They are distributed with the peripheral nerves chiefly to the skin, only a few are found in the nerves to the muscles. 119 *57*

Having entered the medulla spinalis, all the fibers of the posterior nerve roots divide into ascending and descending branches, and these in their turn give off collaterals which enter the gray substance (Fig. 676). The descending fibers are short, and soon enter the gray substance. The ascending fibers are grouped into long, short, and intermediate: the long fibers ascend in the fasciculus cuneatus and fasciculus gracilis as far as the medulla oblongata, where they end by arborizing around the cells of the cuneate and gracile nuclei; the short fibers run upward for a distance of only 5 or 6 mm. and enter the gray substance; while the intermediate fibers, after a somewhat longer course, have a similar destination. All fibers entering the gray substance end by arborizing around its nerve cells or the dendrites of cells, those of intermediate length being especially associated with the cells of the dorsal nucleus. *58*

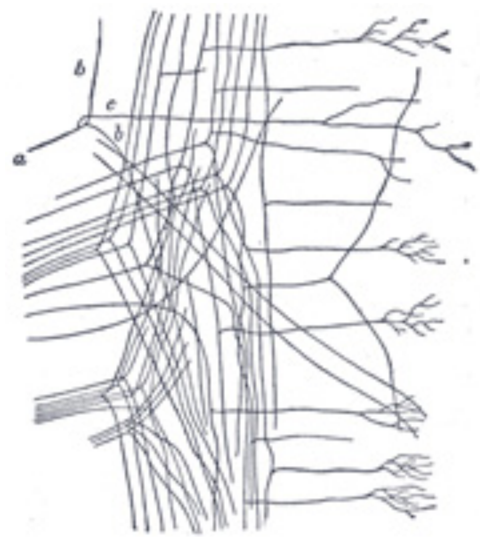


FIG. 676– Posterior roots entering medulla spinalis and dividing into ascending and descending branches. (Van Gehuchten.) *a*. Stem fiber. *b, b*. Ascending and descending limbs of bifurcation. *c*. Collateral arising from stem fiber. (See enlarged image)

The long fibers of the posterior nerve roots pursue an oblique course upward, being situated at first in the lateral part of the fasciculus cuneatus: *59*
higher up, they occupy the middle of this fasciculus, having been displaced by the accession of other entering fibers; while still higher, they ascend in the fasciculus gracilis. The upper cervical fibers do not reach this fasciculus, but are entirely confined to the fasciculus cuneatus. The localization of these fibers is very precise: the sacral nerves lie in the medial part of the fasciculus gracilis and near its periphery, the lumbar nerves lateral to them, the thoracic nerves still more laterally; while the cervical nerves are confined to the fasciculus cuneatus (Fig. 673).

Note 113. Lenhossek and Cajal found that in the chick embryo the axons of a few of these nerve cells passed backward through the posterior column, and emerged as the *motor fibers* of the *posterior nerve roots*. These fibers are said to control the peristaltic movements of the intestine. Their presence, in man, has not yet been determined. [back]

Note 114. Topographical Atlas of the Spinal Cord, 1901. [back]

Note 115. According to Bruce and Pirie (B. M> J., November 17, 1906) this column extends from the middle of the eighth cervical segment to the lower part of the second lumbar or the upper part of the third lumbar segment. [back]

Note 116. Somewhat later a change, termed *chromatolysis,* takes place in the nerve cells, and consists of a breaking down and an ultimate disappearance of the Nissl bodies. Further, the body of the cell is swollen, the nucleus displaced toward the periphery, and the part of the axon still attached to the altered cell is diminished in size and somewhat atrophied. Under favorable conditions the cell is capable of reassuming its normal appearance, and its axon may grow again. [back]

Note 117. Schäfer, Proc. Physiolog. Soc., 1899. [back]

Note 118. Ransom, Am. Jour. Anat., 1914; Brain, 1915. [back]

Note 119. Ransom, Brain, 1915, 38. [back]

4. The Brain or Encephalon

General Considerations and Divisions.—The brain, is contained within the cranium, and constitutes the upper, greatly expanded part of the central nervous system. In its early embryonic condition it consists of three hollow vesicles, termed the **hind-brain** or**rhombencephalon,** the **mid-brain** or **mesencephalon,** and the **fore-brain** or**prosencephalon;** and the parts derived from each of these can be recognized in the adult(Fig. 677). Thus in the process of development the wall of the hind-brain undergoes modification to form the medulla oblongata, the pons, and cerebellum, while its cavity is expanded to form the fourth ventricle. The mid-brain forms only a small part of the adult brain; its cavity becomes the **cerebral aqueduct** (*aqueduct of Sylvius*), which serves as a tubular communication between the third and fourth ventricles; while its walls are thickened to form the corpora quadrigemina and cerebral peduncles. The fore-brain undergoes great modification: its anterior part or **telencephalon** expands laterally in the form of two hollow vesicles, the cavities of which become the lateral ventricles, while the surrounding walls form the cerebral hemispheres and their commissures; the cavity of the posterior part or**diencephalon** forms the greater part of the third ventricle, and from its walls are developed most of the structures which bound that cavity. *1*

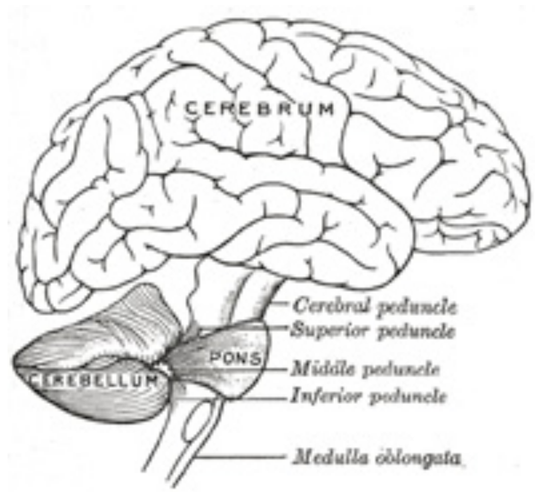


FIG. 677– Scheme showing the connections of the several parts of the brain. (After Schwalbe.) (See enlarged image)

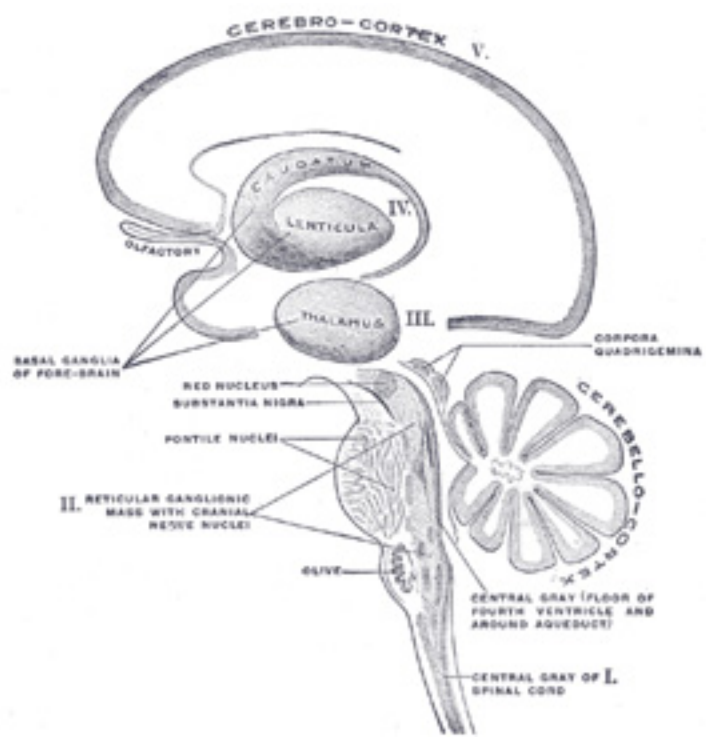


FIG. 678– Schematic representation of the chief ganglionic categories (I to V). (Spitzka.) (See enlarged image)

4a. The Hind-brain or Rhombencephalon

The **hind-brain** or **rhombencephalon** occupies the posterior fossa of the cranial cavity and lies below a fold of dura mater, the **tentorium cerebelli.** It consists of (*a*) the**myelencephalon,** comprising the medulla oblongata and the lower part of the fourth ventricle; (*b*) the **metencephalon,** consisting of the pons, cerebellum, and the intermediate part of the fourth ventricle; and (*c*) the **isthmus rhombencephali,** a constricted portion immediately adjoining the mid-brain and including the superior peduncles of the cerebellum, the anterior medullary velum, and the upper part of the fourth ventricle. *1*

The Medulla Oblongata (***spinal bulb***)**.**—The medulla oblongata extends from the lower margin of the pons to a plane passing transversely below the pyramidal decussation and above the first pair of cervical nerves; this plane corresponds with the upper border of the atlas behind, and the middle of the odontoid process of the axis in front; at this level the medulla oblongata is continuous with the medulla spinalis. Its anterior surface is separated from the basilar part of the occipital bone and the upper part of the odontoid process by the membranes of the brain and the occipitoaxial ligaments. Its posterior surface is received into the fossa between the hemispheres of the cerebellum, and the upper portion of it forms the lower part of the floor of the fourth ventricle. *2*

The medulla oblongata is pyramidal in shape, its broad extremity being directed upward toward the pons, while its narrow, lower end is continuous with the medulla spinalis. It measures about 3 cm. in length, about 2 cm. in breadth at its widest part, and about 1.25 cm. in thickness. The central canal of the medulla spinalis is prolonged into its lower half, and then opens into the cavity of the fourth ventricle; the medulla oblongata may therefore be divided into a lower *closed part* containing the central canal, and an upper *open part*corresponding with the lower portion of the fourth ventricle. *3*

The **Anterior Median Fissure** (*fissura mediana anterior; ventral or ventromedian fissure*) contains a fold of pia mater, and extends along the entire length of the medulla oblongata: it ends at the lower border of the pons in a small triangular expansion, termed the **foramen cecum.** Its lower part is interrupted by bundles of fibers which cross obliquely from one side to the other, and constitute the **pyramidal decussation.** Some fibers, termed the **anterior external arcuate fibers,** emerge from the fissure above this decussation and curve lateralward and upward over the surface of the medulla oblongata to join the inferior peduncle. *4*

The **Posterior Median Fissure** (*fissura mediana posterior; dorsal or dorsomedian fissure*) is a narrow groove; and exists only in the closed part of the medulla oblongata; it becomes gradually shallower from below upward, and finally ends about the middle of the medulla oblongata, where the central canal expands into the cavity of the fourth ventricle. *5*

These two fissures divide the closed part of the medulla oblongata into symmetrical halves, each presenting elongated eminences which, on surface view, are continuous with the funiculi of the medulla spinalis. In the open part the halves are separated by the anterior median fissure, and by a median raphé which extends from the bottom of the fissure to the floor of the fourth ventricle. Further, certain of the cranial nerves pass through the substance of the medulla oblongata, and are attached to its surface in series with the roots of the spinal nerves; thus, the fibers of the hypoglossal nerve represent the upward continuation of the anterior nerve roots, and emerge in linear series from a furrow termed the **antero-lateral sulcus.** Similarly, the accessory, vagus, and glossopharyngeal nerves correspond with the posterior nerve roots, and are attached to the bottom of a sulcus named the **postero-lateral sulcus.** Advantage is taken of this arrangement to subdivide each half of the medulla oblongata into three districts, **anterior, middle,** and **posterior.**Although these three districts appear to be directly continuous with the corresponding funiculi of the medulla spinalis, they do not necessarily contain the same fibers, since some of the fasciculi of the medulla spinalis end in the medulla oblongata, while others alter their course in passing through it. *6*

The **anterior district** (Fig. 679) is named the **pyramid** (*pyramis medullæ oblongatæ*) and lies between the anterior median fissure and the antero-lateral sulcus. **Its** upper end is slightly constricted, and between it and the pons the fibers of the abducent nerve emerge; a little below the pons it becomes enlarged and prominent, and finally tapers into the anterior funiculus of the medulla spinalis, with which, at first sight, it appears to be directly continuous. *7*

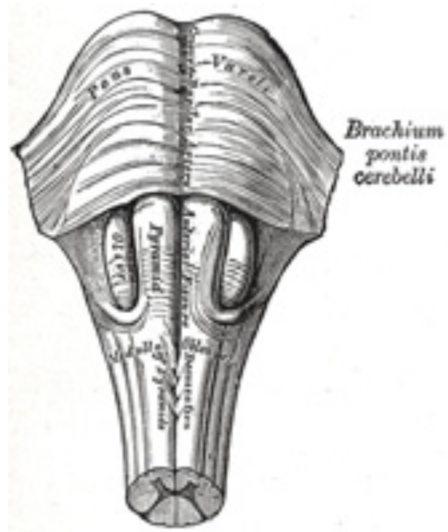


FIG. 679– Medulla oblongata and pons. Anterior surface. (See enlarged image)

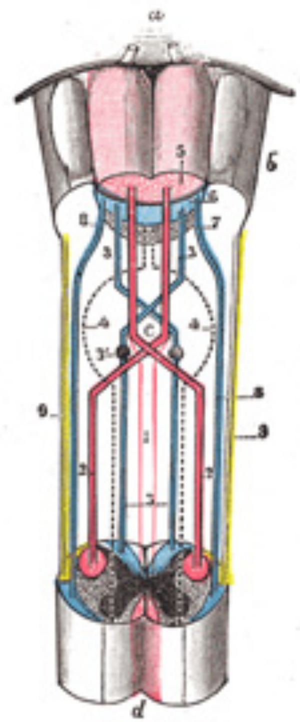


FIG. 680– Decussation of pyramids. Scheme showing passage of various fasciculi from medulla spinalis to medulla oblongata. *a*. Pons. *b*. Medulla oblongata. *c*. Decussation of the pyramids. *d*. Section of cervical part of medulla spinalis. 1. Anterior cerebrospinal fasciculus (in red). 2. Lateral cerebrospinal fasciculus (in red). 3. Sensory tract (fasciculi gracilis et cuneatus) (in blue). 3'. Gracile and cuneate nuclei. 4. Antero-lateral proper fasciculus (in dotted line). 5. Pyramid. 6. Lemniscus. 7. Medial longitudinal fasciculus. 8. Ventral spinocerebellar fasciculus (in blue). 9. Dorsal spinocerebellar fasciculus (in yellow). (Testut.) (See enlarged image)

The two pyramids contain the motor fibers which pass from the brain to the medulla oblongata and medulla spinalis, corticobulbar and corticospinal fibers. When these pyramidal fibers are traced downward it is found that some two-thirds or more of them leave the pyramids in successive bundles, and decussate in the anterior median fissure, forming what is termed the **pyramidal decussation.** Having crossed the middle line, they pass down in the posterior part of the lateral funiculus as the lateral cerebrospinal fasciculus. The remaining fibers—*i. e.,* those which occupy the lateral part of the pyramid—do not cross the middle line, but are carried downward as the anterior cerebrospinal 8 fasciculus (Fig. 680) into the anterior funiculus of the same side.

The greater part of the anterior proper fasciculus of the medulla spinalis is continued upward through the medulla oblongata under the name of the **medial longitudinal fasciculus.** 9

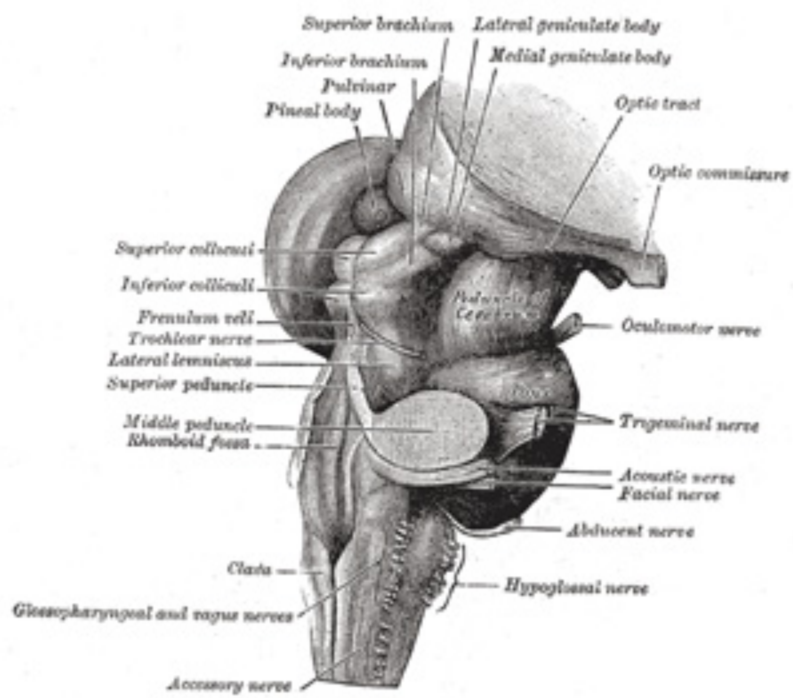


FIG. 681– Hind- and mid-brains; postero-lateral view. (See enlarged image)

The **lateral district** (Fig. 681) is limited in front by the antero-lateral sulcus and the roots of the hypoglossal nerve, and behind by the postero-lateral sulcus and the roots of the accessory, vagus, and glossopharyngeal nerves. Its upper part consists of a prominent oval mass which is named the **olive,** while its lower part is of the same width as the lateral funiculus of the medulla spinalis, and appears on the surface to be a direct continuation of it. As a matter of fact, only a portion of the lateral funiculus is continued upward into this district, for the lateral cerebrospinal fasciculus passes into the pyramid of the opposite side, and the dorsal spinocerebellar fasciculus is carried into the inferior peduncle in the posterior district. The ventral spinocerebellar fasciculus is continued upward on the lateral surface of the medulla oblongata in 10 the same relative position it occupies in the spinal cord until it passes under cover of the external arcuate fibers. It passes beneath these fibers just dorsal to the olive and ventral to the roots of the vagus and glossopharyngeal nerves; it continues upward through the pons along the dorsolateral edge of the lateral lemniscus. The remainder of the lateral funiculus consists chiefly of the lateral proper fasciculus. Most of these fibers dip beneath the olive and disappear from the surface; but a small strand remains superficial to the olive. In a depression at the upper end of this strand is the acoustic nerve.

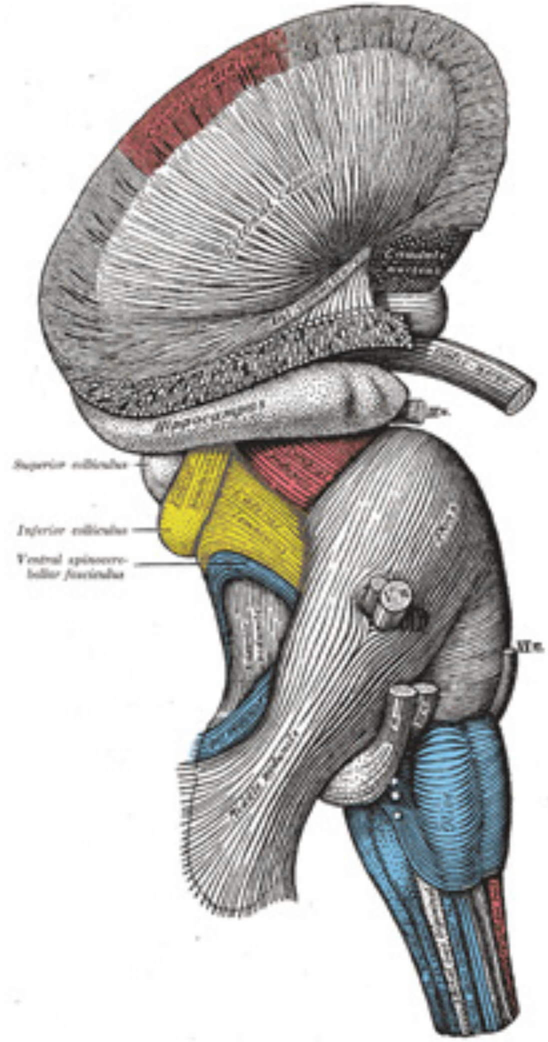
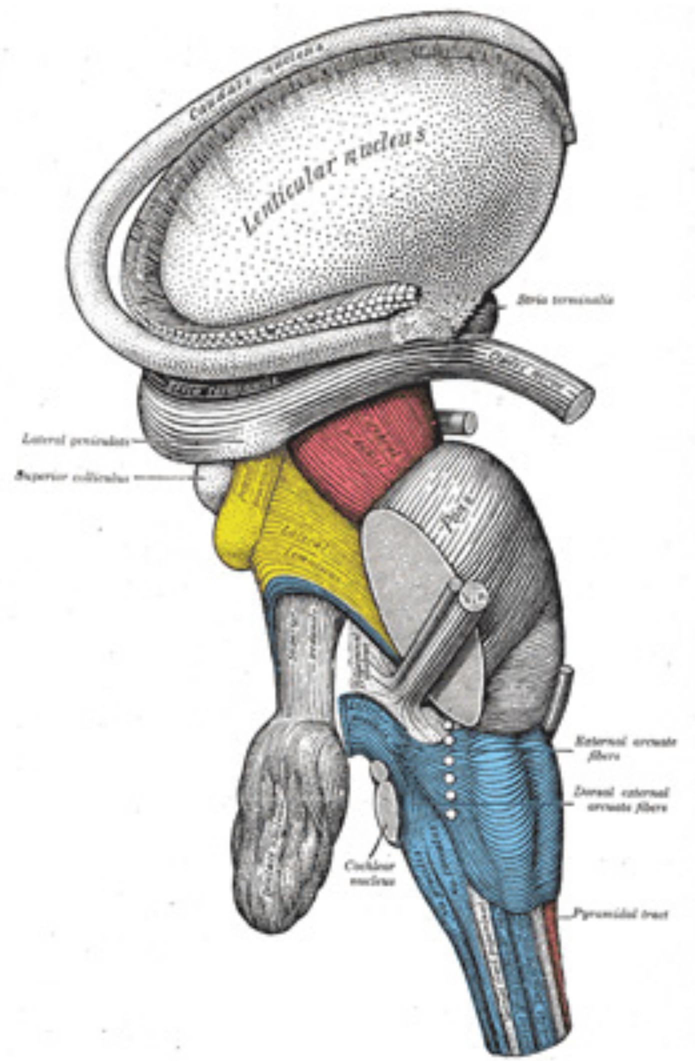


FIG. 682– Superficial dissection of brain-stem. Lateral view. (See enlarged image)



Caudate nucleus
Lenticular nucleus
Stria terminalis
Lateral geniculate
Superior colliculus
Pons
External arcuate fibers
Dorsal external arcuate fibers
Cochlear nucleus
Pyramidal tract

FIG. 683– Dissection of brain-stem. Lateral view. (See enlarged image)

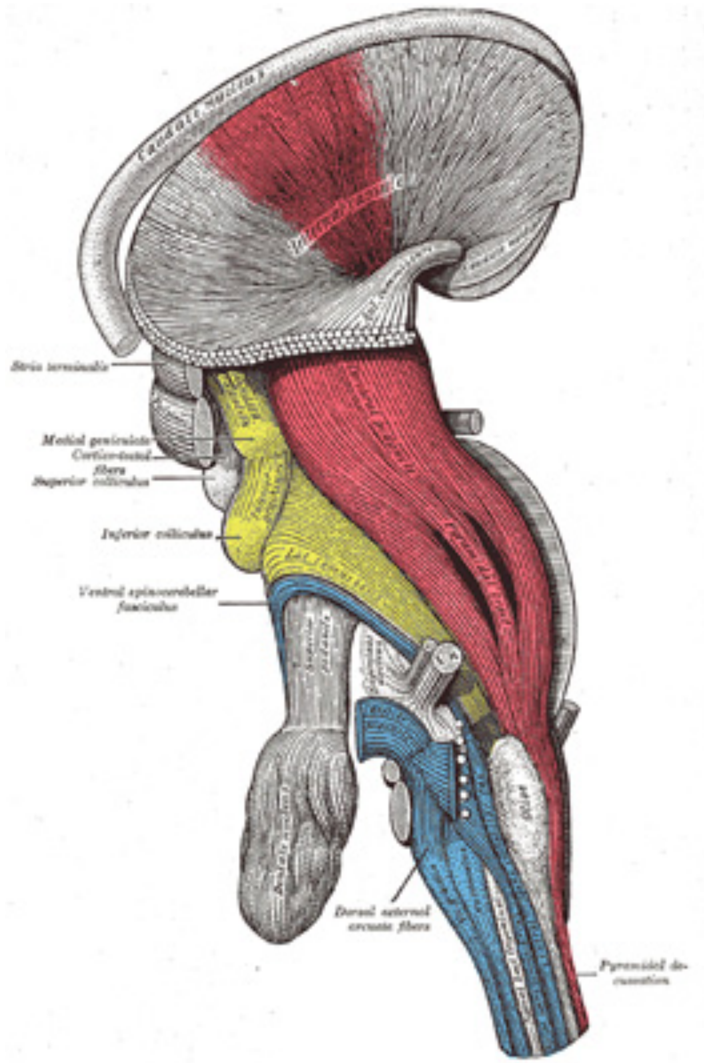


FIG. 684– Deep dissection of brain-stem. Lateral view. (See enlarged image)

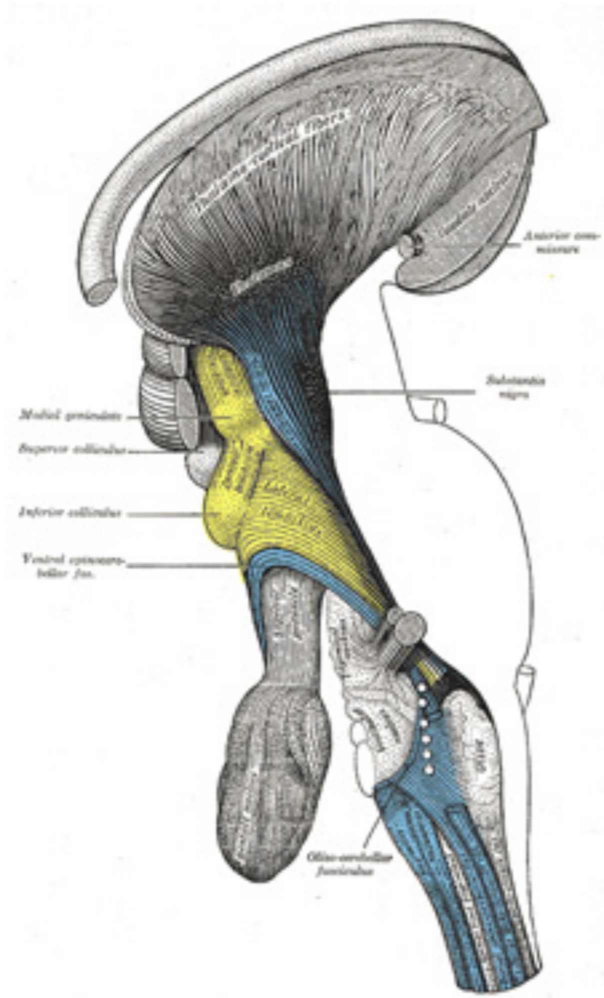


FIG. 685– Deep dissection of brain-stem. Lateral view. (See enlarged image)

The **olive** (*oliva; olivary body*) is situated lateral to the pyramid, from which it is separated by the antero-lateral sulcus, and the fibers of the hypoglossal nerve. Behind, it is separated from the postero-lateral sulcus by the ventral spinocerebellar fasciculus. In the depression between the upper end of the olive and the pons lies the acoustic nerve. It measures about 1.25 cm. in length, and between its upper end and the pons there is a slight depression to which the roots of the facial nerve are attached. The external arcuate fibers wind across the lower part of the pyramid and olive and enter the inferior peduncle. *11*

The **posterior district** (Fig. 686) lies behind the postero-lateral sulcus and the roots of the accessory, vagus, and the glossopharyngeal nerves, and, like the lateral district, is divisible into a lower and an upper portion. *12*

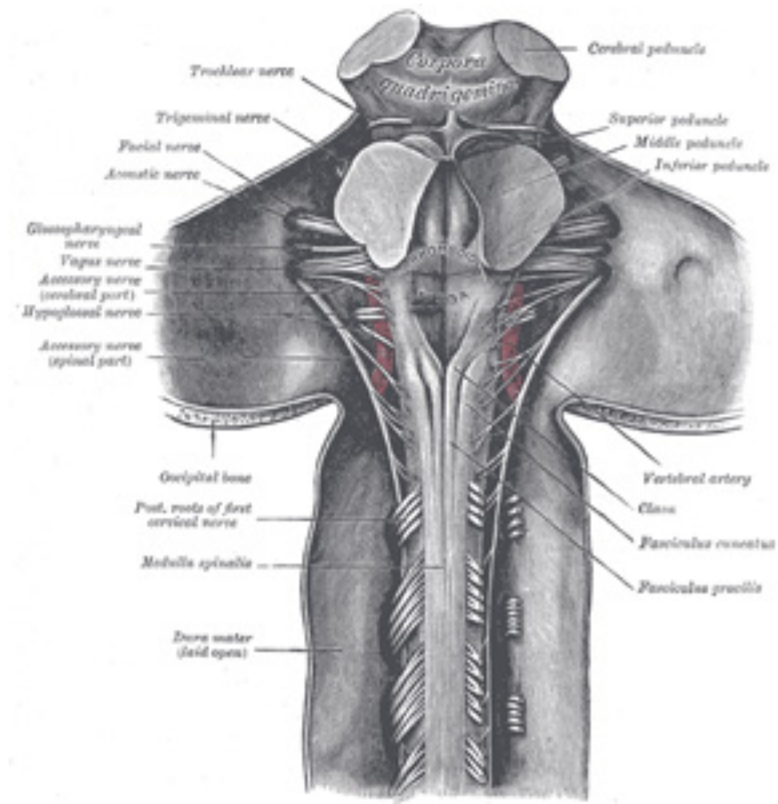


FIG. 686– Upper part of medulla spinalis and hind- and mid-brains; posterior aspect, exposed *in situ*. (See enlarged image)

13 The **lower part** is limited behind by the posterior median fissure, and consists of the**fasciculus gracilis** and the **fasciculus cuneatus.** The fasciculus gracilis is placed parallel to and along the side of the posterior median fissure, and separated from the fasciculus cuneatus by the postero-intermediate sulcus and septum. The gracile and cuneate fasciculi are at first vertical in direction; but at the lower part of the rhomboid fossa they diverge from the middle line in a V-shaped manner, and each presents an elongated swelling. That on the fasciculus gracilis is named the **clava,** and is produced by a subjacent nucleus of gray matter, the **nucleus gracilis;** that on the fasciculus cuneatus is termed the **cuneate tubercle,** and is likewise caused by a gray nucleus, named the **nucleus cuneatus.** The fibers of these fasciculi terminate by arborizing around the cells in their respective nuclei. A third elevation, produced by the substantia gelatinosa of Rolando, is present in the lower part of the posterior district of the medulla oblongata. It lies on the lateral aspect of the fasciculus cuneatus, and is separated from the surface of the medulla oblongata by a band of nerve fibers which form the spinal tract (spinal root) of the trigeminal nerve. Narrow below, this elevation gradually expands above, and ends, about 1.25 cm. below the pons, in a tubercle, the **tubercle of Rolando** (*tuber cinereum*).

14 The **upper part** of the posterior district of the medulla oblongata is occupied by the**inferior peduncle,** a thick rope-like strand situated between the lower part of the fourth ventricle and the roots of the glossopharyngeal and vagus nerves. The inferior peduncles connect the medulla spinalis and medulla oblongata with the cerebellum, and are sometimes named the **restiform bodies.** As they pass upward, they diverge from each other, and assist in forming the lower part of the lateral boundaries of the fourth ventricle; higher up, they are directed backward, each passing to the corresponding cerebellar hemisphere. Near their entrance, into the cerebellum they are crossed by several strands of fibers, which run to the median sulcus of the rhomboid fossa, and are named the **striæ medullares.** The inferior peduncle appears to be the upward continuation of the fasciculus gracilis and fasciculus cuneatus; this, however, is not so, as the fibers of these fasciculi end in the gracile and cuneate nuclei. The constitution of the inferior peduncle will be subsequently discussed.

15 Caudal to the striæ medullares the inferior peduncle is partly covered by the corpus pontobulbare (Essick 120), a thin mass of cells and fibers extending from the pons between the origin of the VII and VIII cranial nerves.

16 **Internal Structure of the Medulla Oblongata.**—Although the external form of the medulla oblongata bears a certain resemblance to that of the upper part of the medulla spinalis, its internal structure differs widely from that of the latter, and this for the following principal reasons: (1) certain fasciculi which extend from the medulla spinalis to the brain, and *vice versa,* undergo a rearrangement in their passage through the medulla oblongata; (2) others which exist in the medulla spinalis end in the medulla oblongata; (3) new fasciculi originate in the gray substance of the medulla oblongata and pass to different parts of the brain; (4) the gray substance, which in the medulla spinalis forms a continuous H-shaped column, becomes greatly modified and subdivided in the medulla oblongata, where also new masses of gray substance are added; (5) on account of the opening out of the central canal of the medulla spinalis, certain parts of the gray substance, which in the medulla spinalis were more or less centrally situated, are displayed in the rhomboid fossa; (6) the medulla oblongata is intimately associated with many of the cranial nerves, some arising form, and others ending in, nuclei within its substance.

17 **The Cerebrospinal Fasciculi.**—The downward course of these fasciculi from the pyramids of the medulla oblongata and their partial decussation have already been described (page 761). In crossing to reach the lateral funiculus of the opposite side, the fibers of the lateral

cerebrospinal fasciculi extend backward through the anterior columns, and separate the head of each of these columns from its base (Figs. 687, 688). The base retains its position in relation to the ventral aspect of the central canal, and, when the latter opens into the fourth ventricle, appears in the rhomboid fossa close to the middle line, where it forms the nuclei of the hypoglossal and abducent nerves; while above the level of the ventricle it exists as the nuclei of the trochlear and oculomotor nerves in relation to the floor of the cerebral aqueduct. The head of the column is pushed lateralward and forms the**nucleus ambiguus,** which gives origin from below upward to the cranial part of the accessory and the motor fibers of the vagus and glossopharyngeal, and still higher to the motor fibers of the facial and trigeminal nerves.

The **fasciculus gracilis** and **fasciculus cuneatus** constitute the posterior sensory fasciculi of the medulla spinalis; they are prolonged upward *18*
into the lower part of the medulla oblongata, where they end respectively in the nucleus gracilis and nucleus cuneatus. These two nuclei are continuous with the central gray substance of the medulla spinalis, and may be regarded as dorsal projections of this, each being covered superficially by the fibers of the corresponding fasciculus. On transverse section (Fig. 694) the nucleus gracilis appears as a single, more or less quadrangular mass, while the nucleus cuneatus consists of two parts: a larger, somewhat triangular, **medial nucleus,** composed of small or medium-sized cells, and a smaller **lateral nucleus** containing large cells.

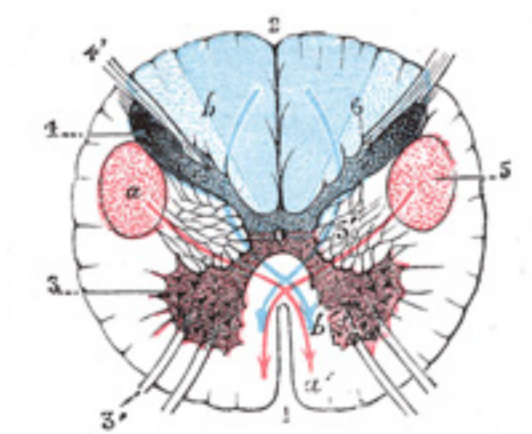


FIG. 687– Section of the medulla oblongata through the lower part of the decussation of the pyramids. (Testut.) 1. Anterior median fissure. 2. Posterior median sulcus. 3. Anterior column (in red), with 3', anterior root. 4. Posterior column (in blue), with 4', posterior roots. 5. Lateral cerebrospinal fasciculus. 6. Posterior funiculus. The red arrow, *a, a'*,indicates the course the lateral cerebrospinal fasciculus takes at the level of the decussation of the pyramids; the blue arrow, *b, b',* indicates the course which the sensory fibers take. (See enlarged image)

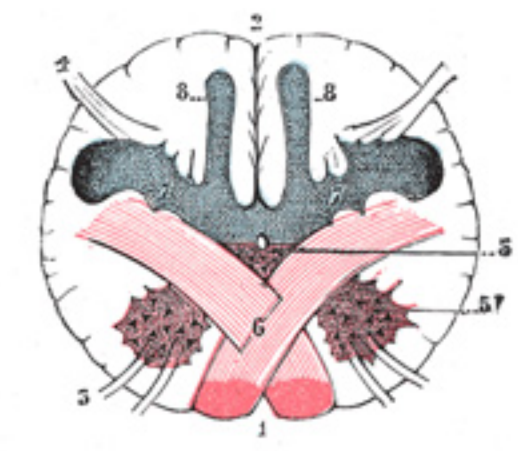


FIG. 688– Section of the medulla oblongata at the level of the decussation of the pyramids. (Testut.) 1. Anterior median fissure. 2. Posterior median sulcus. 3. Motor roots. 4. Sensory roots. 5. Base of the anterior column, from which the head (5') has been detached by the lateral cerebrospinal fasciculus. 6. Decussation of the lateral cerebrospinal fasciculus. 7. Posterior columns (in blue). 8. Gracile nucleus. (See enlarged image)

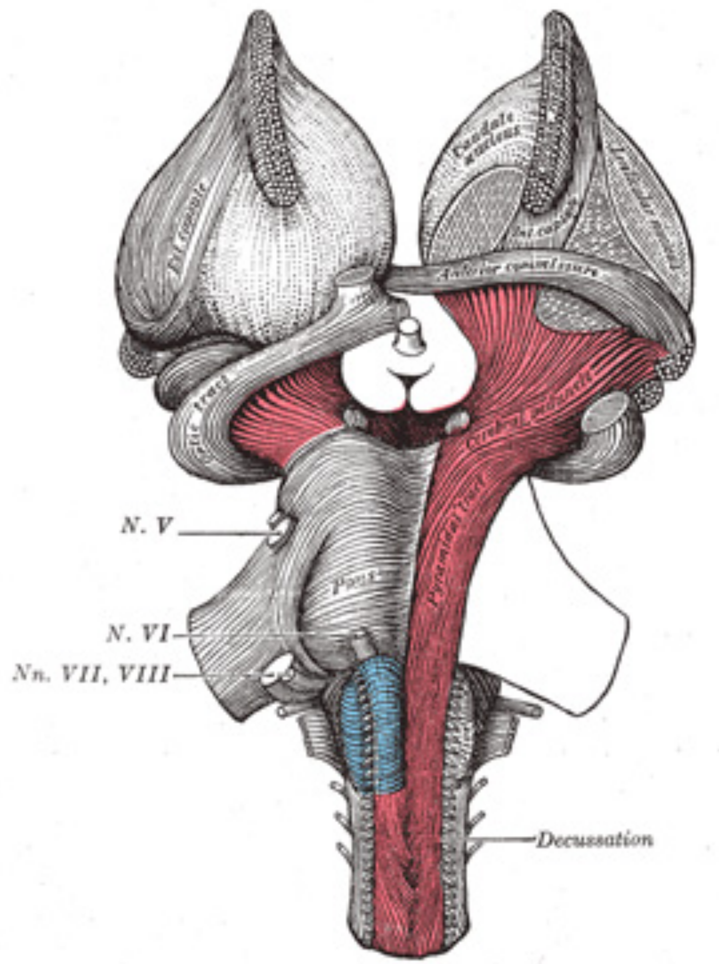


FIG. 689– Superficial dissection of brain-stem. Ventral view. (See enlarged image)

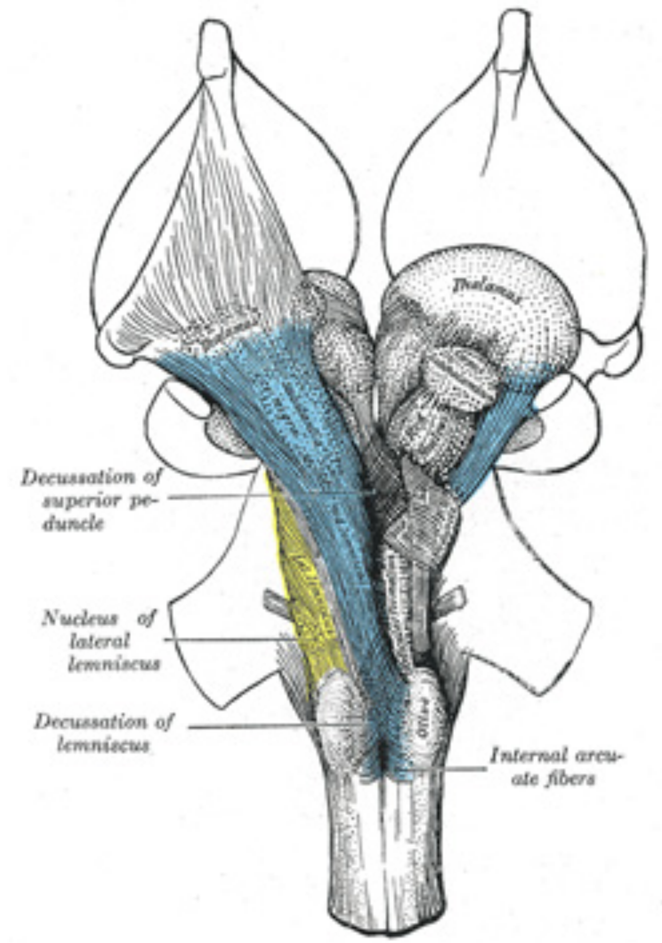


FIG. 690– Deep dissection of brain-stem. Ventral view. (See enlarged image)

The fibers of the fasciculus gracilis and fasciculus cuneatus end by arborizing around the cells of these nuclei (Fig. 692). From the cells of the nuclei new fibers arise; some of these are continued as the posterior external arcuate fibers into the inferior peduncle, and through it to the cerebellum, but most of them pass forward through the neck of the posterior column, thus cutting off its head from its base (Fig. 693). Curving 19 forward, they decussate in the middle line with the corresponding fibers of the opposite side, and run upward immediately behind the cerebrospinal fibers, as a flattened band, named the**lemniscus** or **fillet.** The decussation of these sensory fibers is situated above that of the motor fibers, and is named the **decussation of the lemniscus** or **sensory decussation.** The**lemniscus** is joined by the spinothalamic fasciculus (page 792), the fibers of which are derived from the cells of the gray substance of the opposite side of the medulla spinalis.

The base of the posterior column at first lies on the dorsal aspect of the central canal, but when the latter opens into the fourth ventricle, it *20*
appears in the lateral part of the rhomboid fossa. It forms the terminal nuclei of the sensory fibers of the vagus and glossopharyngeal nerves, and is associated with the vestibular part of the acoustic nerve and the sensory root of the facial nerve. Still higher, it forms a mass of pigmented cells—the **locus cæruleus**—in which some of the sensory fibers of the trigeminal nerve appear to end. The head of the posterior column forms a long nucleus, in which the fibers of the spinal tract of the trigeminal nerve largely end.

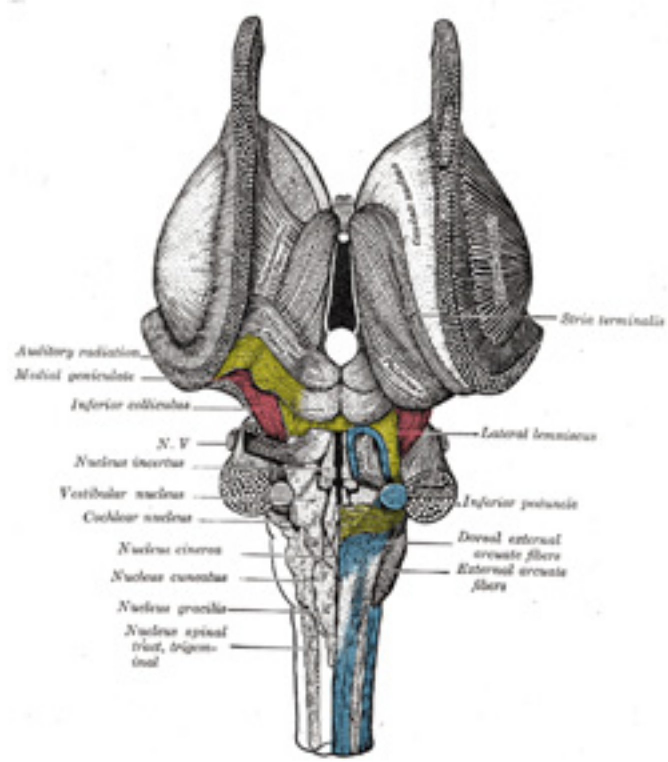


FIG. 691– Dissection of brain-stem. Dorsal view. The nuclear masses of the medulla are taken from model by Weed, Carnegie Publication, No. 19. (See enlarged image)

The **dorsal spinocerebellar fasciculus** (*fasciculus cerebellospinalis; direct cerebellar tract*) leaves the lateral district of the medulla 21
oblongata; most of its fibers are carried backward into the inferior peduncle of the same side, and through it are conveyed to the cerebellum; but some run upward with the fibers of the lemniscus, and, reaching the inferior colliculus, undergo decussation, and are carried to the cerebellum through the superior peduncle.

The **proper fasciculi** (*basis bundles*) of the anterior and lateral funiculi largely consist of intersegmental fibers, which link together the 22
different segments of the medulla spinalis; they assist in the production of the formatio reticularis of the medulla oblongata, and many of them are accumulated into a fasciculus which runs up close to the median raphé between the lemniscus and the rhomboid fossa; this strand is named the **medial longitudinal fasciculus,** and will be again referred to.

Gray Substance of the Medulla Oblongata (Figs. 694, 695).—In addition to the gracile and cuneate nuclei, there are several other nuclei to be 23
considered. Some of these are traceable from the gray substance of the medulla spinalis, while others are unrepresented in it.

1. The **hypoglossal nucleus** is derived from the base of the anterior column; in the lower closed part of the medulla oblongata it is situated on 24
the ventrolateral aspect of the central canal; but in the upper part it approaches the rhomboid fossa, where it lies close to the middle line, under an eminence named the **trigonum hypoglossi** (Fig. 709). Numerous fibers connect the two nuclei, both nuclei send long dendrons across the midline to the opposite nucleus; commissure fibers also connect them. The nucleus measures about 2 cm. in length, and consists of large multipolar nerve cells, similar to those in the anterior column of the spinal cord, whose axons constitute the roots of the hypoglossal nerve. These nerve roots leave the ventral side of the nucleus, pass forward between the white reticular formation and the gray reticular formation, some between the inferior olivary nucleus and the medial accessory olivary nucleus, and emerge from the antero-lateral sulcus.

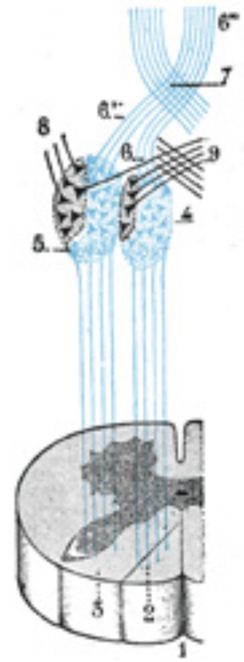


FIG. 692– Superior terminations of the posterior fasciculi of the medulla spinalis. 1. Posterior median sulcus. 2. Fasciculus gracilis. 3. Fasciculus cuneatus. 4. Gracile nucleus. 5. Cuneate nucleus. 6, 6', 6''. Sensory fibers forming the lemniscus. 7. Sensory decussation. 8. Cerebellar fibers uncrossed (in black). 9. Cerebellar fibers crossed (in black). (Testut.) (See enlarged image)

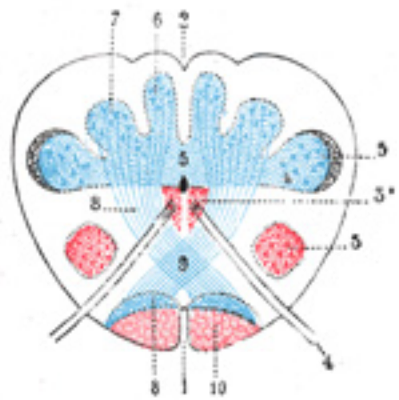


FIG. 693– Transverse section passing through the sensory decussation. (Schematic.) 1. Anterior median fissure. 2. Posterior median sulcus. 3, 3. Head and base of anterior column (in red). 4. Hypoglossal nerve. 5. Bases of posterior columns. 6. Gracile nucleus. 7. Cuneate nucleus. 8, 8. Lemniscus. 9. Sensory decussation. 10. Cerebrospinal fasciculus. (Testut.) (See enlarged image)

2. The **nucleus ambiguus** (Figs. 696, 697), the somatic motor nucleus of the glossopharyngeal, vagus and cranial portion of the accessory 25
nerves, is the continuation into the medulla oblongata of the dorso-lateral cell group of the anterior column of the spinal cord. Its large multipolar cells are like those in the anterior column of the cord; they form a slender column in the deep part of the formatio reticularis grisea about midway between the dorsal accessory olive and the nucleus of the spinal tract of the trigeminal. It extends from the level of the decussation of the median fillet to the upper end of the medulla oblongata. Its fibers first pass backward toward the floor of the fourth ventricle and then curve rather abruptly lateralward and ventrally to join the fibers from the dorsal nucleus.

3. The **dorsal nucleus** (Figs. 696, 698), nucleus ala cinerea, often called the **sensory nucleus** or the terminal nucleus of the sensory fibers of 26
the glossopharyngeal and vagus nerves, is probably a mixed nucleus and contains not only the terminations of the sympathetic afferent or sensory fibers and the cells connected with them but contains also cells which give rise to sympathetic efferent or preganglionic fibers. These preganglionic fibers terminate in sympathetic ganglia from which the impulses are carried by other neurons. The cells of the dorsal nucleus are spindle-shaped, like those of the posterior column of the spinal cord, and the nucleus is usually considered as representing the base of the posterior column. It measures about 2 cm. in length, and in the lower, closed part of the medulla oblongata is situated behind the hypoglossal nucleus; whereas in the upper, open part it lies lateral to that nucleus, and corresponds to an eminence, named the **ala cinerea**(*trigonum vagi*), in the rhomboid fossa.

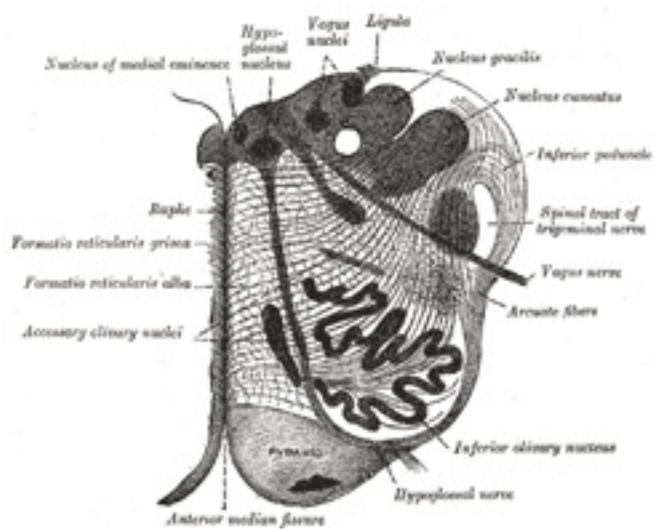


FIG. 694– Section of the medulla oblongata at about the middle of the olive. (Schwalbe.) (See enlarged image)

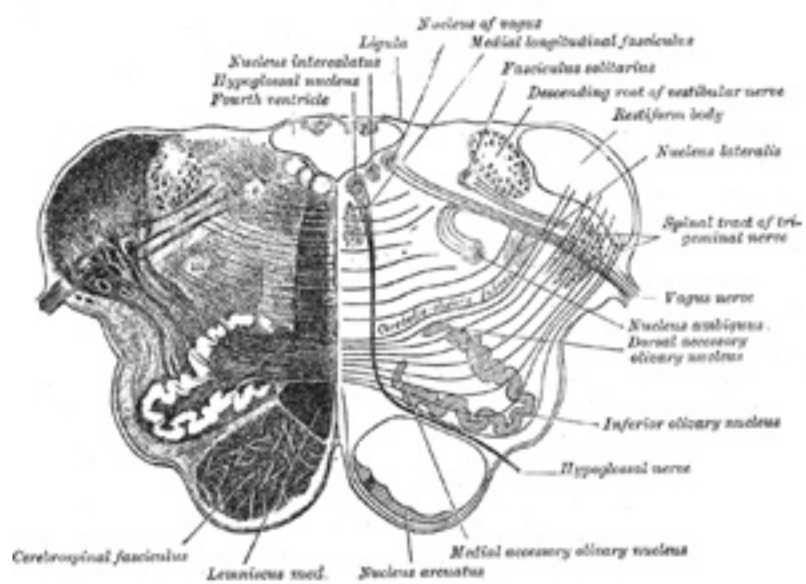


FIG. 695– Transverse section of medulla oblongata below the middle of the olive. (See enlarged image)

4. The **nuclei of the cochlear and vestibular nerves** are described on page 788. *27*

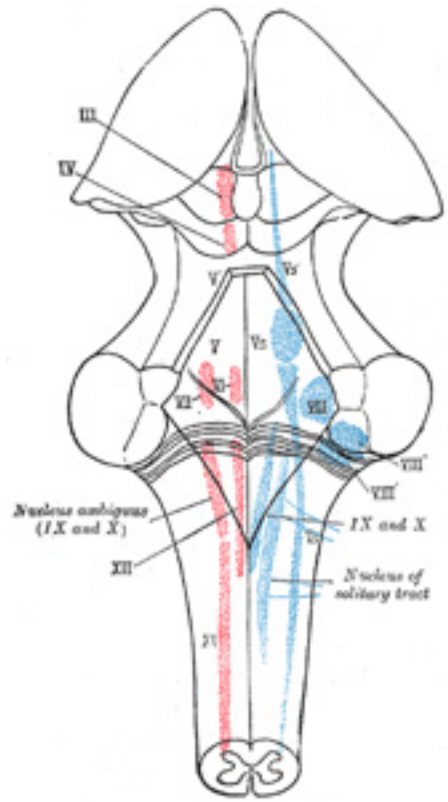


FIG. 696– The cranial nerve nuclei schematically represented; dorsal view. Motor nuclei in red; sensory in blue. (The olfactory and optic centers are not represented.) (See enlarged image)

5. The **olivary nuclei** (Fig. 694) are three in number on either side of the middle line, viz., the inferior olivary nucleus, and the medial and *28*
dorsal accessory olivary nuclei; they consist of small, round, yellowish cells and numerous fine nerve fibers. (*a*) The **inferior olivary nucleus** is the largest, and is situated within the olive. It consists of a gray folded lamina arranged in the form of an incomplete capsule, opening medially by an aperture called the **hilum** emerging from the hilum are numerous fibers which collectively constitute the **peduncle of the olive.** The axons, **olivocerebellar fibers,** which leave the olivary nucleus pass out through the hilum and decussate with those from the opposite olive in the raphé, then as internal arcuate fibers they pass partly through and partly around the opposite olive and enter the inferior peduncle to be

distributed to the cerebellar hemisphere of the opposite side from which they arise. The fibers are smaller than the internal arcuate fibers connected with the median lemniscus. Fibers passing in the opposite direction from the cerebellum to the olivary nucleus are often described but their existence is doubtful. Much uncertainty also exists in regard to the connections of the olive and the spinal cord. Important connections between the cerebrum and the olive of the same side exist but the exact pathway is unknown. Many collaterals from the reticular formation and from the pyramids enter the inferior olivary nucleus. Removal of one cerebellar hemisphere is followed by atrophy of the opposite olivary nucleus. (*b*) The **medial accessory olivary nucleus** lies between the inferior olivary nucleus and the pyramid, and forms a curved lamina, the concavity of which is directed laterally. The fibers of the hypoglossal nerve, as they traverse the medulla, pass between the medial accessory and the inferior olivary nuclei. (*c*) The **dorsal accessory olivary nucleus** is the smallest, and appears on transverse section as a curved lamina behind the inferior olivary nucleus.

6. The **nucleus arcuatus** is described below with the anterior external arcuate fibers. *29*

Inferior Peduncle (*restiform body*).—The position of the inferior peduncles has already been described (page 775). Each comprises: *30*

(1) Fibers from the **dorsal spinocerebellar fasciculus,** which ascends from the lateral funiculus of the medulla spinalis. *31*

(2) The **olivocerebellar fibers** from the opposite olivary nucleus. *32*

(3) **Internal arcuate fibers** from the gracile and cuneate nuclei of the opposite side; these fibers form the deeper and larger part of the inferior peduncle. *33*

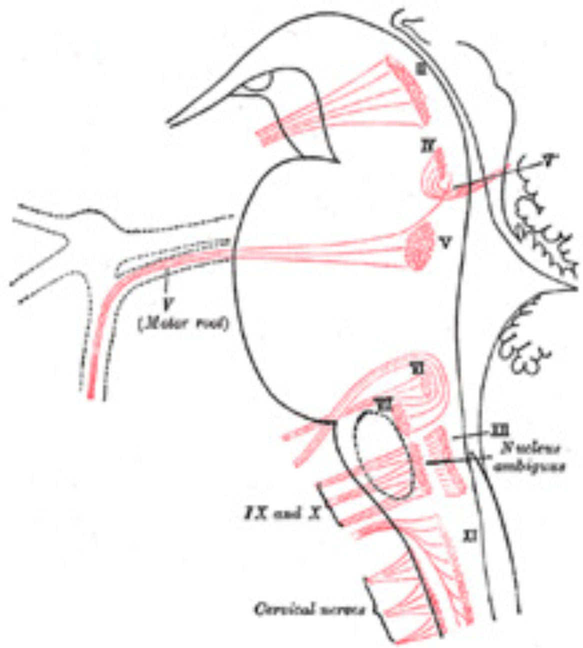


FIG. 697– Nuclei of origin of cranial motor nerves schematically represented; lateral view. (See enlarged image)

(4) The **anterior external arcuate fibers** vary as to their prominence in different cases: in some they form an almost continuous layer covering the pyramid and olive, while in others they are barely visible on the surface. They arise from the cells of the gracile and cuneate nuclei, and passing forward through the formatio reticularis, decussate in the middle line. Most of them reach the surface by way of the anterior median fissure, and arch backward over the pyramid. Reinforced by others which emerge between the pyramid and olive, they pass backward over the olive and lateral district of the medulla oblongata, and enter the inferior peduncle. They thus connect the cerebellum with the gracile and cuneate nuclei of the opposite side. As the fibers arch across the pyramid, they enclose a small nucleus which lies in front of and medial to the pyramid. This is named the**nucleus arcuatus,** and is serially continuous above with the nuclei pontis in the pons; it contains small fusiform cells, around which some of the arcuate fibers end, and from which others arise. *34*

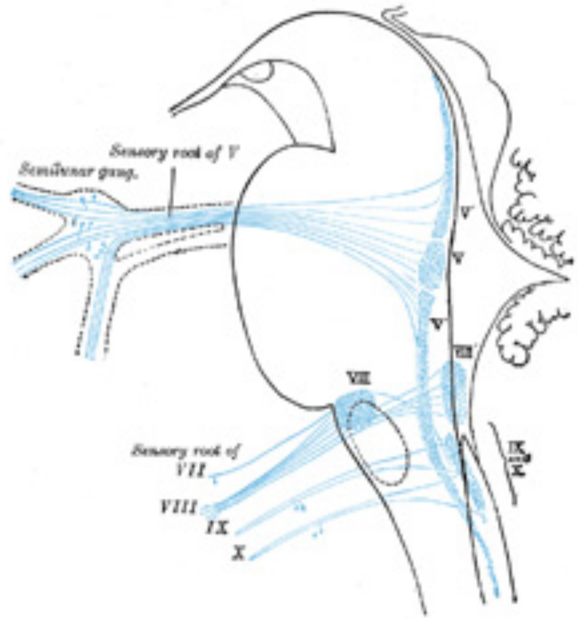


FIG. 698– Primary terminal nuclei of the afferent (sensory) cranial nerves schematically represented; lateral view. The olfactory and optic centers are not represented. (See enlarged image)

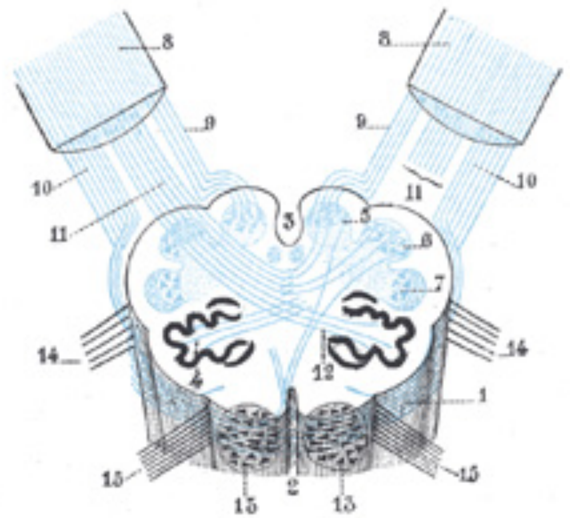


FIG. 699– Diagram showing the course of the arcuate fibers. (Testut.) 1. Medulla oblongata anterior surface. 2. Anterior median fissure. 3. Fourth ventricle. 4. Inferior olivary nucleus, with the accessory olivary nuclei. 5. Gracile nucleus. 6. Cuneate nucleus. 7. Trigeminal. 8. Inferior peduncles, seen from in front. 9. Posterior external arcuate fibers. 10. Anterior external arcuate fibers. 11. Internal arcuate fibers. 12. Peduncle of inferior olivary nucleus. 13. Nucleus arcuatus. 14. Vagus. 15. Hypoglossal. (See enlarged image)

(5) The **posterior external arcuate fibers** also take origin in the gracile and cuneate nuclei; they pass to the inferior peduncle of the same side. It is uncertain whether fibers are continued directly from the gracile and cuneate fasciculi into the inferior peduncle. 35

(6) Fibers from the **terminal sensory nuclei** of the cranial nerves, especially the vestibular. Some of the fibers of the vestibular nerve are thought to continue directly into the cerebellum. 36

(7) Fibers from the **ventral spinocerebellar fasciculus.** 37

(8) The existence of fibers from the **cerebellum** (cerebellobulbar, cerebelloölivary, and cerebellospinal) to the medulla and spinal cord is very uncertain. 38

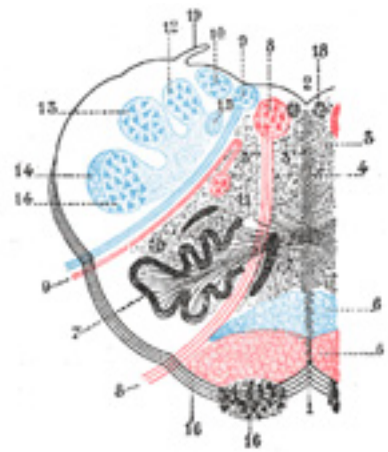


FIG. 700– The formatio reticularis of the medulla oblongata, shown by a transverse section passing through the middle of the olive. (Testut.) 1. Anterior median fissure. 2. Fourth ventricle. 3. Formatio reticularis, with 3', its internal part (reticularis alba), and 3'', its external part (reticularis grisea). 4. Raphé. 5. Pyramid. 6. Lemniscus. 7. Inferior olivary nucleus with the two accessory olivary nuclei. 8. Hypoglossal nerve, with 8', its nucleus of origin. 9. Vagus nerve, with 9', its nucleus of termination. 10. Lateral dorsal acoustic nucleus. 11. Nucleus ambiguus (nucleus of origin of motor fibers of glossopharyngeal, vagus, and cerebral portion of spinal accessory). 12. Gracile nucleus. 13. Cuneate nucleus. 14. Head of posterior column, with 14', the lower sensory root of trigeminal nerve. 15. Fasciculus solitarius. 16. Anterior external arcuate fibers, with 16', the nucleus arcuatus. 17. Nucleus lateralis 18. Nucleus of fasciculus teres. 19. Ligula. (See enlarged image)

Formatio Reticularis **(Fig. 700).**—This term is applied to the coarse reticulum which occupies the anterior and lateral districts of the medulla oblongata. It is situated behind the pyramid and olive, extending laterally as far as the inferior peduncles, and dorsally to within a short distance of the rhomboid fossa. The reticulum is caused by the intersection of bundles of fibers running at right angles to each other, some being longitudinal, others more or less transverse in direction. The formatio reticularis presents a different appearance in the anterior district from what it does in the lateral; in the former, there is an almost entire absence of nerve cells, and hence this part is known as the **reticularis alba;** whereas in the lateral district nerve cells are numerous, and as a consequence it presents a gray appearance, and is termed the **reticularis grisea.** 39

In the substance of the formatio reticularis are two small nuclei of gray matter: one, the**inferior central nucleus** (*nucleus of Roller*), near the dorsal aspect of the hilus of the inferior olivary nucleus; the other, the **nucleus lateralis,** between the olive and the spinal tract of the trigeminal nerve. 40

In the reticularis alba the longitudinal fibers form two well-defined fasciculi, viz.: (1) the**lemniscus,** which lies close to the raphé, immediately 41 behind the fibers of the pyramid; and (2) the **medial longitudinal fasciculus,** which is continued upward from the anterior and lateral proper fasciculi of the medulla spinalis, and, in the upper part of the medulla oblongata, lies between the lemniscus and the gray substance of the rhomboid fossa. The longitudinal fibers in the reticularis grisea are derived from the lateral funiculus of the medulla spinalis after the lateral cerebrospinal fasciculus has passed over to the opposite side, and the dorsal spinocerebellar fasciculus has entered the inferior peduncle. They form indeterminate fibers, with the exception of a bundle named the **fasciculus solitarius,** which is made up of descending fibers of the vagus and glossopharyngeal nerves. The transverse fibers of the formatio reticularis are the arcuate fibers already described (page 782).

The Pons (*pons Varoli*).—The pons or forepart of the hind-brain is situated in front of the cerebellum. From its superior surface the cerebral peduncles emerge, one on either side of the middle line. Curving around each peduncle, close to the upper surface of the pons, a thin white band, the **tænia pontis,** is frequently seen; it enters the cerebellum between the middle and superior peduncles. Behind and below, the pons is continuous with the medulla oblongata, but is separated from it in front by a furrow in which the abducent, facial, and acoustic nerves appear. *42*

Its **ventral** or **anterior surface** (*pars basilaris pontis*) is very prominent, markedly convex from side to side, less so from above downward. It consists of transverse fibers arched like a bridge across the middle line, and gathered on either side into a compact mass which forms the **middle peduncle.** It rests upon the clivus of the sphenoidal bone, and is limited above and below by well-defined borders. In the middle line is the **sulcus basilaris** for the lodgement of the basilar artery; this sulcus is bounded on either side by an eminence caused by the descent of the cerebrospinal fibers through the substance of the pons. Outside these eminences, near the upper border of the pons, the trigeminal nerves make their exit, each consisting of a smaller, medial, motor root, and a larger, lateral, sensory root; vertical lines drawn immediately beyond the trigeminal nerves, may be taken as the boundaries between the ventral surface of the pons and the middle cerebellar peduncle. *43*

Its **dorsal** or **posterior surface** (*pars dorsalis pontis*), triangular in shape, is hidden by the cerebellum, and is bounded laterally by the superior peduncle; it forms the upper part of the rhomboid fossa, with which it will be described. *44*

Structure (Fig. 701).—Transverse sections of the pons show it to be composed of two parts which differ in appearance and structure: thus, the basilar or ventral portion consists for the most part of fibers arranged in transverse and longitudinal bundles, together with a small amount of gray substance; while the dorsal tegmental portion is a continuation of the reticular formation of the medulla oblongata, and most of its constituents are continued into the tegmenta of the cerebral peduncles. *45*

The **basilar part** of the pons consists of—(*a*) superficial and deep transverse fibers, (*b*) longitudinal fasciculi, and (*c*) some small nuclei of gray substance, termed the nuclei pontis which give rise to the transverse fibers. *46*

The **superficial transverse fibers** (*fibræ pontis superficiales*) constitute a rather thick layer on the ventral surface of the pons, and are collected into a large rounded bundle on either side of the middle line. This bundle, with the addition of some transverse fibers from the deeper part of the pons, forms the greater part of the brachium pontis. *47*

The **deep transverse fibers** (*fibræ pontis profundæ*) partly intersect and partly lie on the dorsal aspect of the cerebrospinal fibers. They course to the lateral border of the pons, and form part of the middle peduncle; the further connections of this brachium will be discussed with the anatomy of the cerebellum. *48*

The **longitudinal fasciculi** (*fasciculi longitudinales*) are derived from the cerebral peduncles, and enter the upper surface of the pons. They stream downward on either side of the middle line in larger or smaller bundles, separated from each other by the deep transverse fibers; these *49* longitudinal bundles cause a forward projection of the superficial transverse fibers, and thus give rise to the eminences on the anterior surface. Some of these fibers end in, or give off collateral to, the nuclei pontis. An important pathway is thus formed between the cerebral cortex and the cerebellum, the first neuron having its cell body in the cortex and sending its axon through the internal capsule and cerebral peduncle to form synapses either by terminals or collaterals with cell bodies situated in the nuclei pontis. Axons from these cells form the transverse fibers which pass through the middle peduncle into the cerebellum. Others after decussating, terminate either directly or indirectly in the motor nuclei of the trigeminal, abducent, facial, and hypoglossal nerves; but most of them are carried through the pons, and at its lower surface are collected into the pyramids of the medulla. The fibers which end in the motor nuclei of the cranial nerves are derived from the cells of the cerebral cortex, and bear the same relation to the motor cells of the cranial nerves that the cerebrospinal fibers bear to the motor cells in the anterior column of the medulla spinalis. Probably none of the collaterals or terminals of the cerebrospinal and cerebrobulbar fibers end directly in the motor nuclei of the spinal and cranial nerves, one or more association neurons are probably interpolated in the pathway.

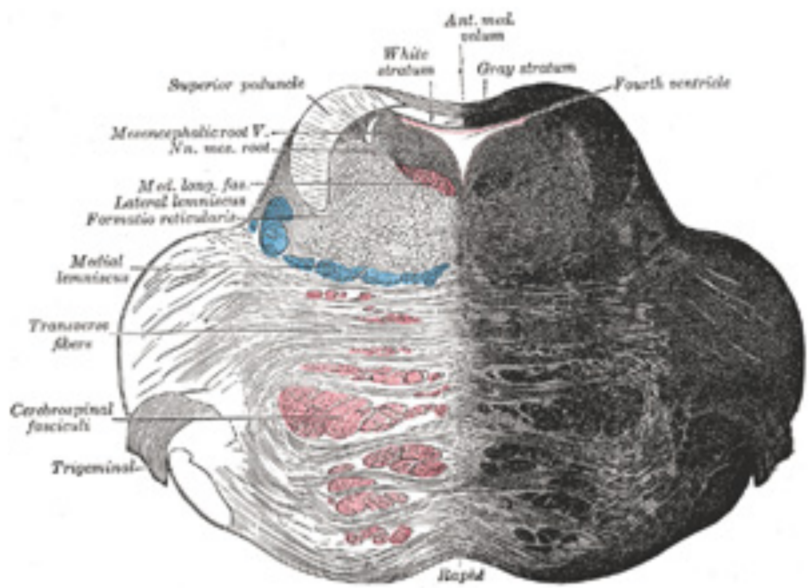


FIG. 701– Coronal section of the pons, at its upper part. (See enlarged image)

The **nuclei pontis** are serially continuous with the arcuate nuclei in the medulla, and consist of small groups of multipolar nerve cells which are scattered between the bundles of transverse fibers. *50*

The **dorsal** or **tegmental part** of the pons is chiefly composed of an upward continuation of the reticular formation and gray substance of the *51* medulla oblongata. It consists of transverse and longitudinal fibers and also contains important gray nuclei, and is subdivided by a median raphé, which, however, does not extend into the basilar part, being obliterated by the transverse fibers. The transverse fibers in the lower part of the pons are collected into a distinct strand, named the **trapezoid body.** This consists of fibers which arise from the cells of the cochlear nucleus, and will be referred to in connection with the cochlear division of the acoustic nerve. In the substance of the trapezoid body is a collection of nerve cells, which constitutes the **trapezoid nucleus.** The longitudinal fibers, which are continuous with those of the medulla oblongata, are mostly collected into two fasciculi on either side. One of these lies between the trapezoid body and the reticular formation, and forms the upward prolongation of the lemniscus; the second is situated near the floor of the fourth ventricle, and is the **medial longitudinal fasciculus.** Other longitudinal fibers, more diffusely distributed, arise from the cells of the gray substance of the pons.

The rest of the dorsal part of the pons is a continuation upward of the formatio reticularis of the medulla oblongata, and, like it, presents the appearance of a network, in the meshes of which are numerous nerve cells. Besides these scattered nerve cells, there are some larger masses of gray substance, viz., the superior olivary nucleus and the nuclei of the trigeminal, abducent, facial, and acoustic nerves (Fig. 696). *52*

1. The **superior olivary nucleus** (*nucleus olivaris superior*) is a small mass of gray substance situated on the dorsal surface of the lateral part of the trapezoid body. Rudimentary in man, but well developed in certain animals, it exhibits the same structure as the inferior olivary nucleus, and is situated immediately above it. Some of the fibers of the trapezoid body end by arborizing around the cells of this nucleus, while others arise from these cells. *53*

2. The **nuclei of the trigeminal nerve** (*nuclei n. trigemini*) in the pons are two in number: a motor and a sensory. The **motor nucleus** is situated in the upper part of the pons, close to its posterior surface and along the line of the lateral margin of the fourth ventricle. It is serially homologous with the nucleus ambiguus and the dorso-lateral cell group of the anterior column of the spinal cord. The axis-cylinder processes of its cells form the motor root of the trigeminal nerve. The **mesencephalic root** arises from the gray substance of the floor of the cerebral aqueduct, joins the motor root and probably conveys fibers of muscle sense from the temporal, masseter and pterygoid muscles. It is not altogether clear whether the mesencephalic root is motor or sensory. The **sensory nucleus**is lateral to the motor one, and beneath the superior peduncle. Some of the sensory fibers of the trigeminal nerve end in this nucleus; but the greater number descend, under the name of the spinal tract of the trigeminal nerve, to end in the substantia gelatinosa of Rolando. The roots, motor and sensory, of the trigeminal nerve pass through the substance of the pons and emerge near the upper margin of its anterior surface. *54*

3. The **nucleus of the abducent nerve** (*nucleus n. abducentis*) is a circular mass of gray substance situated close to the floor of the fourth ventricle, above the striæ medullares and subjacent to the medial eminence: it lies a little lateral to the ascending part of the facial nerve. The fibers of the abducent nerve pass forward through the entire thickness of the pons on the medial side of the superior olivary nucleus, and between the lateral fasciculi of the cerebrospinal fibers, and emerge in the furrow between the lower border of the pons and the pyramid of the medulla oblongata. *55*

4. The **nucleus of the facial nerve** (*nucleus n. fascialis*) is situated deeply in the reticular formation of the pons, on the dorsal aspect of the superior olivary nucleus, and the roots of the nerve derived from it pursue a remarkably tortuous course in the substance of the pons. At first they pass backward and medialward until they reach the rhomboid fossa, close to the median sulcus, where they are collected into a round bundle; this passes upward and forward, producing an elevation, the **colliculus facialis,** in the rhomboid fossa, and then takes a sharp bend, and arches lateralward through the substance of the pons to emerge at its lower border in the interval between the olive and the inferior peduncle of the medulla oblongata. *56*

5. The **nucleus of the cochlear nerve** consists of: (*a*) the **lateral cochlear nucleus,**corresponding to the tuberculum acusticum on the dorso- *57*

lateral surface of the inferior peduncle; and (*b*) the **ventral** or **accessory cochlear nucleus,** placed between the two divisions of the nerve, on the ventral aspect of the inferior peduncle.

The **nuclei of the vestibular nerve.** (*a*) The medial (**dorsal** or **chief vestibular nucleus**), corresponding to the lower part of the area acustica in the rhomboid fossa; the caudal end of this nucleus is sometimes termed the **descending** or **spinal vestibular nucleus.** (*b*) The **lateral** or **nucleus of Deiters,** consisting of large cells and situated in the lateral angle of the rhomboid fossa; the dorso-lateral part of this nucleus is sometimes termed the **nucleus of Bechterew.** 58

The fibers of the vestibular nerve enter the medulla oblongata on the medial side of those of the cochlear, and pass between the inferior peduncle and the spinal tract of the trigeminal. They then divide into ascending and descending fibers. The latter end by arborizing around the cells of the **medial nucleus,** which is situated in the **area acustica**of the rhomboid fossa. The ascending fibers either end in the same manner or in the **lateral nucleus,** which is situated lateral to the area acustica and farther from the ventricular floor. Some of the axons of the cells of the lateral nucleus, and possibly also of the medial nucleus, are continued upward through the inferior peduncle to the roof nuclei of the opposite side of the cerebellum, to which also other fibers of the vestibular root are prolonged without interruption in the nuclei of the medulla oblongata. A second set of fibers from the medial and lateral nuclei end partly in the tegmentum, while the remainder ascend in the medial longitudinal fasciculus to arborize around the cells of the nuclei of the oculomotor nerve. 59

The Cerebellum.—The cerebellum constitutes the largest part of the hindbrain. It lies behind the pons and medulla oblongata; between its central portion and these structures is the cavity of the fourth ventricle. It rests on the inferior occipital fossæ, while above it is the tentorium cerebelli, a fold of dura mater which separates it from the tentorial surface of the cerebrum. It is somewhat oval in form, but constricted medially and flattened from above downward, its greatest diameter being from side. Its surface is not convoluted like that of the cerebrum, but is traversed by numerous curved furrows or sulci, which vary in depth at different parts, and separate the laminæ of which it is composed. Its average weight in the male is about 150 gms. In the adult the proportion between the cerebellum and cerebrum is about 1 to 8, in the infant about 1 to 20. 60

Lobes of the Cerebellum.—The cerebellum consists of three parts, a median and two lateral, which are continuous with each other, and are substantially the same in structure. The median portion is constricted, and is called the **vermis,** from its annulated appearance which it owes to the transverse ridges and furrows upon it; the lateral expanded portions are named the **hemispheres.** On the upper surface of the cerebellum the vermis is elevated above the level of the hemispheres, but on the under surface it is sunk almost out of sight in the bottom of a deep depression between them; this depression is called the **vallecula cerebelli,** and lodges the posterior part of the medulla oblongata. The part of the vermis on the upper surface of the cerebellum is named the **superior vermis;** that on the lower surface, the **inferior vermis.** The hemispheres are separated below and behind by a deep notch, the **posterior cerebellar notch,** and in front by a broader shallower notch, the**anterior cerebellar notch.** The anterior notch lies close to the pons and upper part of the medullas, and its superior edge encircles the inferior colliculi and the superior cerebellar peduncle. The posterior notch contains the upper part of the falx cerebelli, a fold of dura mater. 61

The cerebellum is characterized by a laminated or foliated appearance; it is marked by deep, somewhat curved fissures, which extend for a considerable distance into its substance, and divide it into a series of layers or leaves. The largest and deepest fissure is named the **horizontal sulcus.** It commences in front of the pons, and passes horizontally around the free margin of the hemisphere to the middle line behind, and divides the cerebellum into an upper and a lower portion. Several secondary but deep fissures separate the cerebellum into lobes, and these are 62 further subdivided by shallower sulci, which separate the individual folia or laminæ from each other. Sections across the laminæ show that the folia, though differing in appearance from the convolutions of the cerebrum, are analogous to them, inasmuch as they consist of central white substance covered by gray substance.

The cerebellum is connected to the cerebrum, pons, and medulla oblongata; to the cerebrum by the superior peduncle, to the pons by the middle peduncle, and to the medulla oblongata by the inferior peduncles. 63

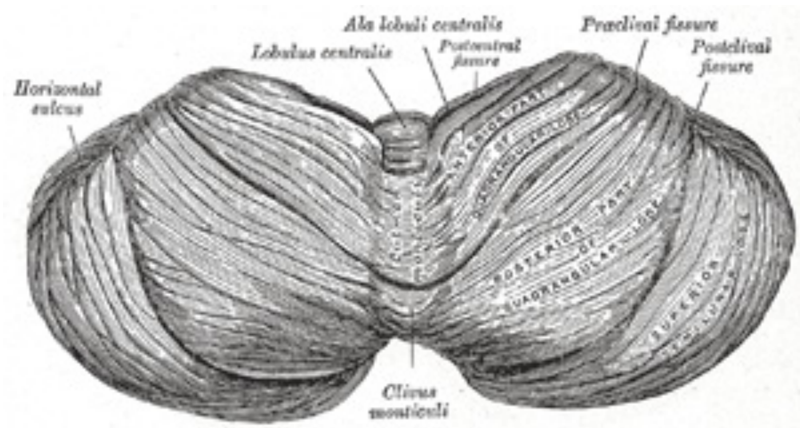


FIG. 702– Upper surface of the cerebellum. (Schäfer.) (See enlarged image)

The **upper surface of the cerebellum** (Fig. 702) is elevated in the middle and sloped toward the circumference, the hemispheres being connected together by the superior vermis, which assumes the form of a raised median ridge, most prominent in front, but not sharply defined from the hemispheres. The superior vermis is subdivided from before backward into the lingula, the lobulus centralis, the monticulus and the folium vermis, and each of these, with the exception of the lingula, is continuous with the corresponding parts of the hemispheres—the lobulus centralis with the alæ, the monticulus with the quadrangular lobules, and the folium vermis with the superior semilunar lobules. 64

The **lingula** (*lingula cerebelli*) is a small tongue-shaped process, consisting of four or five folia; it lies in front of the lobulus centralis, and is concealed by it. Anteriorly, it rests on the dorsal surface of the anterior medullary velum, and its white substance is continuous with that of the velum. 65

The **Lobulus Centralis and Alæ.**—The **lobulus centralis** is a small square lobule, situated in the anterior cerebellar notch. It overlaps the lingula, from which it is separated by the **precentral fissure;** laterally, it extends along the upper and anterior part of each hemisphere, where it forms a wing-like prolongation, the **ala lobuli centralis.** 66

The **Monticulus** and **Quadrangular Lobules.**—The **monticulus** is the largest part of the superior vermis. Anteriorly, it overlaps the lobulus 67 centralis, from which it is separated by the **postcentral fissure;** laterally, it is continuous with the **quadrangular lobule** in the hemispheres. It is divided by the **preclival fissure** into an anterior, raised part, the **culmen**or **summit,** and a posterior sloped part, the **clivus;** the quadrangular lobule is similarly divided. The culmen and the anterior parts of the quadrangular lobules form the **lobus culminis;** the clivus and the posterior parts, the **lobus clivi.**

The Folium Vermis and Superior Semilunar Lobule.—The **folium vermis** (*folium cacuminis; cacuminal lobe*) is a short, narrow, concealed 68
band at the posterior extremity of the vermis, consisting apparently of a single folium, but in reality marked on its upper and under surfaces by secondary fissures. Laterally, it expands in either hemisphere into a considerable lobule, the **superior semilunar lobule** (*lobulus semilunaris superior; postero-superior lobules*), which occupies the posterior third of the upper surface of the hemisphere, and is bounded below by the **horizontal sulcus.** The superior semilunar lobules and the folium vermis form the **lobus semilunaris.**

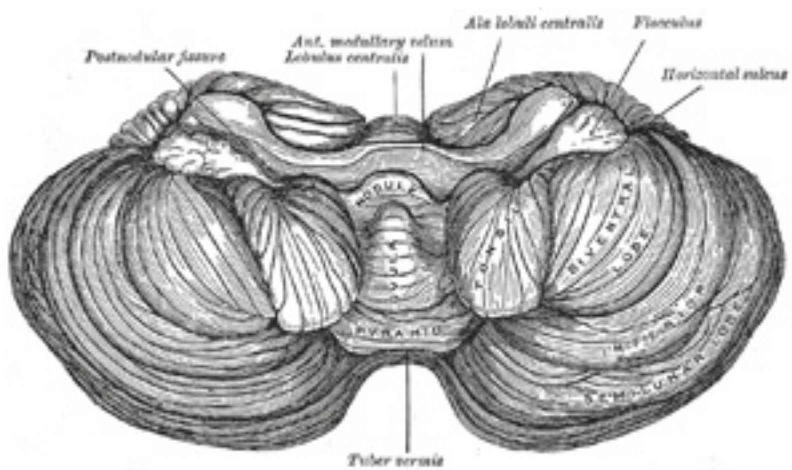


FIG. 703– Under surface of the cerebellum. (Schäfer.) (See enlarged image)

The **under surface of the cerebellum** (Fig. 703) presents, in the middle line, the**inferior vermis,** buried in the vallecula, and separated from 69
the hemisphere on either side by a deep groove, the **sulcus valleculæ.** Here, as on the upper surface, there are deep fissures, dividing it into separate segments or lobules; but the arrangement is more complicated, and the relation of the segments of the vermis to those of the hemispheres is less clearly marked. The inferior vermis is subdivided from before backward, into (1) the**nodule,** (2) the **uvula,** (3) the **pyramid,** and (4) the **tuber vermis;** the corresponding parts on the hemispheres are (1) the **flocculus,** (2) the **tonsilla cerebelli,** (3) the **biventral lobule,** and (4) the **inferior semilunar lobule.** The three main fissures are (1) the**postnodular fissure,** which runs transversely

across the vermis, between the nodule and the uvula. In the hemispheres this fissure passes in front of the tonsil, crosses between the flocculus in front and the biventral lobule behind, and joins the anterior end of the horizontal sulcus. (2) The **prepyramidal fissure** crosses the vermis between the uvula in front and the pyramid behind, then curves forward between the tonsil and the biventral lobe, to join the postnodular fissure. (3) The **postpyramidal fissure** passes across the vermis between the pyramid and the tuber vermis, and, in the hemispheres, courses behind the tonsil and biventral lobules, and then along the lateral border of the biventral lobule to the postnodular sulcus; in the hemisphere it forms the anterior boundary of the inferior semilunar lobule.

The **Nodule and Flocculus.**—The **nodule** (*nodulus vermis; nodular lobe*), or anterior end of the inferior vermis, abuts against the roof of the fourth ventricle, and can only be distinctly seen after the cerebellum has been separated from the medulla oblongata and pons. On either side of the nodule is a thin layer of white substance, named the **posterior medullary velum.** It is semilunar in form, its convex border being continuous with the white substance of the cerebellum; it extends on either side as far as the flocculus. The**flocculus** is a prominent, irregular lobule, situated in front of the biventral lobule, between it and the middle cerebellar peduncle. It is subdivided into a few small laminæ, and is connected to the inferior medullary velum by its central white core. The flocculi, together with the posterior medullary velum and nodule, constitute the **lobus noduli.** 70

The Uvula and Tonsilla.—The **uvula** (*uvula vermis; uvular lobe*) forms a considerable portion of the inferior vermis; it is separated on either side from the tonsil by the **sulcus valleculæ,** at the bottom of which it is connected to the tonsil by a ridge of gray matter, indented on its surface by shallow furrows, and hence called the **furrowed band.** The**tonsilla** (*tonsilla cerebelli; amygdaline nucleus*) is a rounded mass, situated in the hemispheres. Each lies in a deep fossa, termed the **bird's nest** (*nidus avis*), between the uvula and the biventral lobule. The uvula and tonsillæ form the **lobus uvulæ.** 71

The **Pyramid and Biventral lobules** constitute the **lobus pyramidis.** The **pyramid** is a conical projection, forming the largest prominence of the inferior vermis. It is separated from the hemispheres by the sulcus valleculæ, across which it is connected to the biventral lobule by an indistinct gray band, analogous to the furrowed band already described. The**biventral lobule** is triangular in shape; its apex points backward, and is joined by the gray band to the pyramid. The lateral border is separated from the inferior semilunar lobule by the postpyramidal fissure. The base is directed forward, and is on a line with the anterior border of the tonsil, and is separated from the flocculus by the postnodular fissure. 72

The **Tuber Vermis** (*tuber valvulæ*) and the **Inferior Semilunar Lobule** (*lobulus semilunaris inferior; postero-superior lobule*) collectively form the **lobus tuberus** (*tuberæ lobe*). The **tuber vermis,** the most posterior division of the inferior vermis, is of small size, and laterally spreads out into the large inferior semilunar lobules, which comprise at least two-thirds of the inferior surface of the hemisphere. 73

Internal Structure of the Cerebellum.—The cerebellum consists of white and gray substance. 74

White Substance.—If a sagittal section (Fig. 704) be made through either hemisphere, the interior will be found to consist of a central stem of white substance, in the middle of which is a gray mass, the **dentate nucleus.** From the surface of this central white stem a series of plates is prolonged; these are covered with gray substance and form the laminæ. In consequence of the main branches from the central stem dividing and subdividing, a characteristic appearance, named the **arbor vitæ,** is presented. If the sagittal section be made through the middle of the vermis, it 75 will be found that the central stem divides into a vertical and a horizontal branch. The *vertical* branch passes upward to the culmen monticuli, where it subdivides freely, one of its ramifications passing forward and upward to the central lobule. The *horizontal* branch passes backward to the folium vermis, greatly diminished in size in consequence of having given off large secondary branches; one, from its upper surface, ascends to the clivus monticuli; the others descend, and enter the lobes in the inferior vermis, viz., the tuber vermis, the pyramid, the uvula, and the nodule.

The white substance of the cerebellum includes two sets of nerve fibers: (1) **projection fibers,** (2) **fibræ propriæ.** 76

Projection Fibers.—The cerebellum is connected to the other parts of the brain by three large bundles of projection fibers, viz., to the cerebrum by the superior peduncle, to the pons by the middle peduncle, and to the medulla oblongata by the inferior peduncles (Fig. 705). 77

The **superior cerebellar peduncles** (*brachia conjunctiva*), two in number, emerge from the upper and medial part of the white substance of the hemispheres and are placed under cover of the upper part of the cerebellum. They are joined to each other across the middle line by the anterior medullary velum, and can be followed upward as far as the inferior colliculi, under which they disappear. Below, they form the upper lateral boundaries of the fourth ventricle, but as they ascend they converge on the dorsal aspect of the ventricle and thus assist in roofing it in. 78

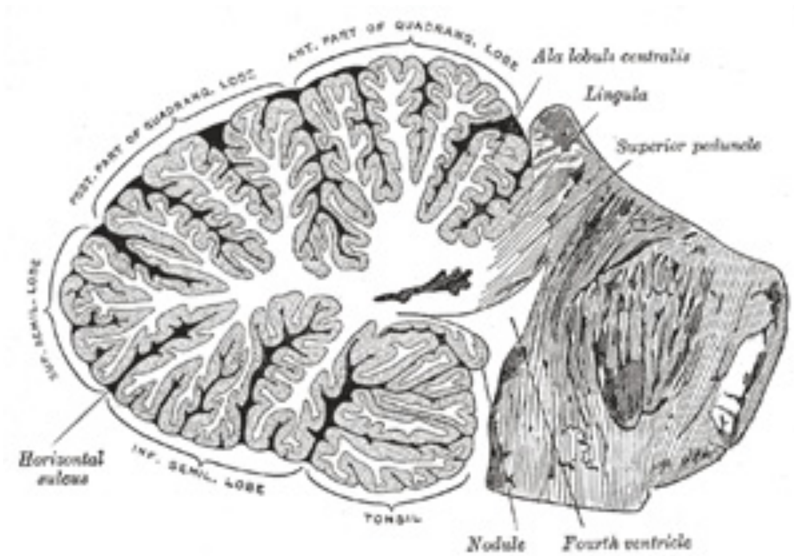


FIG. 704– Sagittal section of the cerebellum, near the junction of the vermis with the hemisphere. (Schäfer.) (See enlarged image)

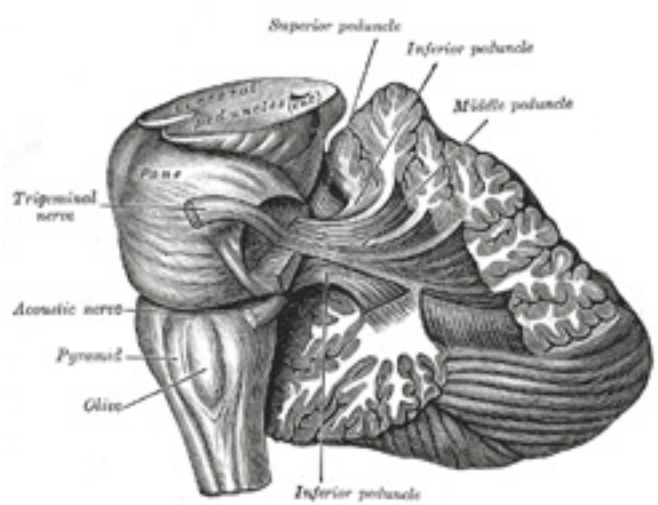


FIG. 705– Dissection showing the projection fibers of the cerebellum. (After E. B. Jamieson.) (See enlarged image)

The fibers of the superior peduncle are mainly derived from the cells of the dentate nucleus of the cerebellum and emerge from the hilus of this 79
nucleus; a few arise from the cells of the smaller gray nuclei in the cerebellar white substance, and others from the cells of the cerebellar cortex. They are continued upward beneath the corpora quadrigemina, and the fibers of the two peduncles undergo a complete decussation ventral to the Sylvian aqueduct. Having crossed the middle line they divide into ascending and descending groups of fibers, the former ending in the red nucleus, the thalamus, and the nucleus of the oculomotor nerve, while the descending fibers can be traced as far as the dorsal part of the pons; Cajal believes them to be continued into the anterior funiculus of the medulla spinalis.

As already stated (page 762), the majority of the fibers of the **ventral spinocerebellar fasciculus** of the medulla spinalis pass to the 80
cerebellum, which they reach by way of the superior peduncle.

The **middle cerebellar peduncles** (*brachia pontis*) (Fig. 705) are composed entirely of centripetal fibers, which arise from the cells of the 81
nuclei pontis of the opposite side and end in the cerebellar cortex; the fibers are arranged in three fasciculi, superior, inferior, and deep. The **superior fasciculus,** the most superficial, is derived from the upper transverse fibers of the pons; it is directed backward and lateralward superficial to the other two fasciculi, and is distributed mainly to the lobules on the inferior surface of the cerebellar hemisphere and to the parts of the superior surface adjoining the posterior and lateral margins. The **inferior fasciculus** is formed by the lowest transverse fibers of the pons; it passes under cover of the superior fasciculus and is continued downward and backward more or less parallel with it, to be distributed to the folia on the under surface close to the vermis.

The **deep fasciculus** comprises most of the deep transverse fibers of the pons. It is at first covered by the superior and inferior fasciculi, but 82
crosses obliquely and appears on the medial side of the superior, from which it receives a bundle; its fibers spread out and pass to the upper anterior cerebellar folia. The fibers of this fasciculus cover those of the restiform body. [121]

The **inferior cerebellar peduncles** (*restiform bodies*) pass at first upward and lateralward, forming part of the lateral walls of the fourth 83
ventricle, and then bend abruptly backward to enter the cerebellum between the superior and middle peduncles. Each contains the following fasciculi: (1) the dorsal spinocerebellar fasciculus of the medulla spinalis, which ends mainly in the superior vermis; (2) fibers from the gracile and cuneate nuclei of the same and of the opposite sides; (3) fibers from the opposite olivary nuclei; (4) crossed and uncrossed fibers from the reticular formation of the medulla oblongata; (5) vestibular fibers, derived partly from the vestibular division of the acoustic nerve and partly from the nuclei in which this division ends—these fibers occupy the medial segment of the inferior peduncle and divide into ascending and descending groups of fibers, the ascending fibers partly end in the roof nucleus of the opposite side of the cerebellum; (6) cerebellobulbar fibers which come from the opposite roof nucleus and probably from the dentate nucleus, and are said to end in the nucleus of Deiters and in the formatio reticularis of the medulla oblongata; (7) some fibers from the ventral spinocerebellar fasciculus are said to join the dorsal spinocerebellar fasciculus.

The **anterior medullary velum** (*velum medullare anterius; valve of Vieussens; superior medullary velum*) is a thin, transparent lamina of 84
white substance, which stretches between the superior peduncle; on the dorsal surface of its lower half the folia and lingula are prolonged. It forms, together with the superior peduncle, the roof of the upper part of the fourth ventricle; it is narrow above, where it passes beneath the inferior colliculi, and broader below, where it is continuous with the white substance of the superior vermis. A slightly elevated ridge, the **frænulum veli,** descends upon its upper part from between the inferior colliculi, and on either side of this the trochlear nerve emerges.

The **posterior medullary velum** (*velum medullare posterius; inferior medullary velum*) is a thin layer of white substance, prolonged from the 85
white center of the cerebellum, above and on either side of the nodule; it forms a part of the roof of the fourth ventricle. Somewhat semilunar in shape, its convex edge is continuous with the white substance of the cerebellum, while its thin concave margin is apparently free; in reality, however, it is continuous with the epithelium of the ventricle, which is prolonged downward from the posterior medullary velum to the ligulæ.

The two medullary vela are in contact with each other along their line of emergence from the white substance of the cerebellum; and this line 86
of contact forms the summit of the roof of the fourth ventricle, which, in a vertical section through the cavity, appears as a pointed angle.

The **Fibræ Propriæ** of the cerebellum are of two kinds: (1) **commissural fibers,** which cross the middle line at the anterior and posterior parts 87
of the vermis and connect the opposite halves of the cerebellum; (2) **arcuate** or **association fibers,** which connect adjacent laminæ with each other.

Gray Substance.—The gray substance of the cerebellum is found in two situations: (1) on the surface, forming the cortex; (2) as independent 88
masses in the anterior.

(1) The **gray substance of the cortex** presents a characteristic foliated appearance, due to the series of laminæ which are given off from the 89
central white substance; these in their turn give off secondary laminæ, which are covered by gray substance. Externally, the cortex is covered by pia mater; internally is the medullary center, consisting mainly of nerve fibers.

Microscopic Appearance of the Cortex (Fig. 706).—The cortex consists of two layers, viz., an external gray molecular layer, and an internal 90 rust-colored nuclear layer; between these is an incomplete stratum of cells which are characteristic of the cerebellum, viz., the**cells of Purkinje.**

The **external gray** or **molecular layer** consists of fibers and cells. The nerve fibers are delicate fibrillæ, and are derived from the following 91
sources: (*a*) the dendrites and axon collaterals of Purkinje's cells; (*b*) fibers from cells in the nuclear layer; (*c*) fibers from the central white substance of the cerebellum; (*d*) fibers derived from cells in the molecular layer itself. In addition to these are other fibers, which have a vertical direction, and are the processes of large neuroglia cells, situated in the nuclear layer. They pass outward to the periphery of the gray matter, where they expand into little conical enlargements which form a sort of limiting membrane beneath the pia mater, analogous to the membrana limitans interna in the retina, formed by the sustentacular fibers of Müller.

The **cells of the molecular layer** are small, and are arranged in two strata, an outer and an inner. They all possess branched axons; those of the 92
inner layer are termed **basket cells;** they run for some distance parallel with the surface of the folium—giving off collaterals which pass in a vertical direction toward the bodies of Purkinje's cells, around which they become enlarged, and form basket-like net-works.

The **cells of Purkinje** form a single stratum of large, flask-shaped cells at the junction of the molecular and nuclear layers, their bases resting 93
against the latter; in fishes and reptiles they are arranged in several layers. The cells are flattened in a direction transverse to the long axis of the folium, and thus appear broad in sections carried across the folium, and fusiform in sections parallel to the long axis of the folium. From the neck of the flask one or more dendrites arise and pass into the molecular layer, where they subdivide and form an extremely rich arborescence, the various subdivisions of the dendrites being covered by lateral spinelike processes. This arborescence is not circular, but, like the cell, is flattened at right angles to the long axis of the folium; in other words, it does not resemble a round bush, but has been aptly compared by Obersteiner to the branches of a fruit tree trained against a trellis or a wall. Hence, in sections carried across the folium the arborescence is broad and expanded; whereas in those which are parallel to the long axis of the folium, the arborescence, like the cell itself, is seen in profile, and is limited to a narrow area.

From the bottom of the flask-shaped cell the axon arises; this passes through the nuclear layer, and, becoming medullated, is continued as a 94
nerve fiber in the subjacent white substance. As this axon traverses the granular layer it gives off fine collaterals, some of which run back into the molecular layer.

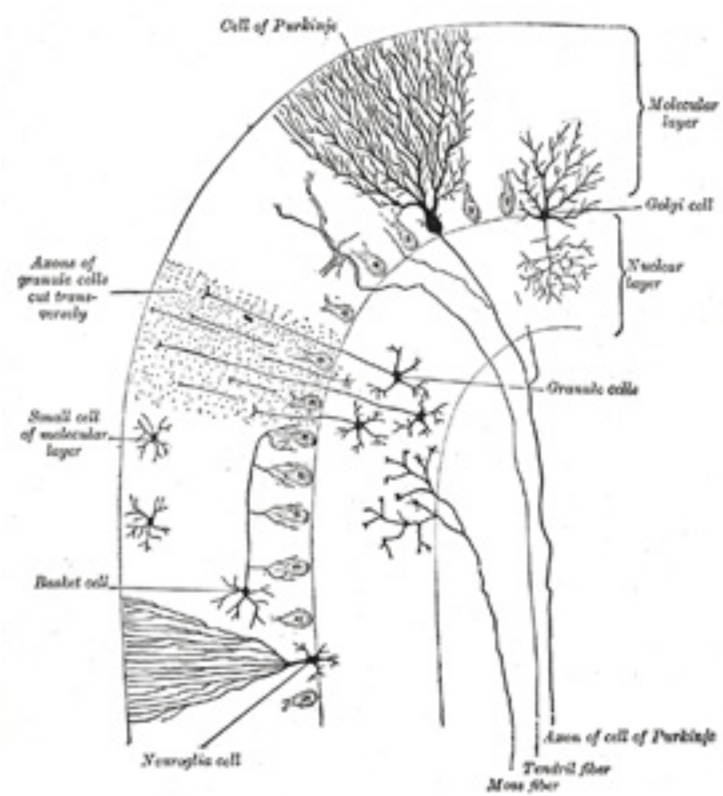


FIG. 706– Transverse section of a cerebellar folium. (Diagrammatic, after Cajal and Kölliker.) (See enlarged image)

The **internal rust-colored** or **nuclear layer** (Fig. 706) is characterized by containing numerous small nerve cells of a reddish-brown color, together with many nerve fibrils. Most of the cells are nearly spherical and provided with short dendrites which spread out in a spider-like manner in the nuclear layer. Their axons pass outward into the molecular layer, and, bifurcating at right angles, run for some distance parallel with the surface. In the outer part of the nuclear layer are some larger cells, of the type II of Golgi. Their axons undergo frequent division as soon as they leave the nerve cells, and pass into the nuclear layer; while their dendrites ramify chiefly in the molecular layer. *95*

Finally, in the gray substance of the cerebellar cortex there are fibers which come from the white center and penetrate the cortex. The cell-origin of these fibers is unknown, though it is believed that it is probably in the gray substance of the medulla spinalis. Some of these fibers end *96* in the nuclear layer by dividing into numerous branches, on which are to be seen peculiar moss-like appendages; hence they have been termed by Ramón y Cajal the **moss fibers;** they form an arborescence around the cells of the nuclear layer and are said to come from fibers in the inferior peduncle. Other fibers, the **clinging** or **tendril fibers,** derived from the medullary center can be traced into the molecular layer, where their branches cling around the dendrites of Purkinje's cells. They are said to come from fibers of the middle peduncle.

(2) The **independent centers of gray substance** in the cerebellum are four in number on either side: one is of large size, and is known as the **nucleus dentatus;** the other three, much smaller, are situated near the middle of the cerebellum, and are known as the**nucleus emboliformis, nucleus globosus,** and **nucleus fastigii.** 97

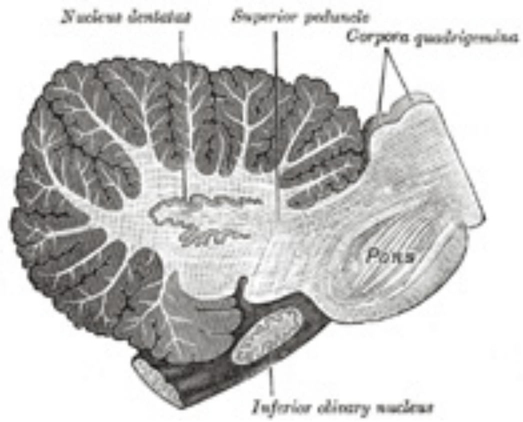


FIG. 707– Sagittal section through right cerebellar hemisphere. The right olive has also been cut sagitally. (See enlarged image)

The **nucleus dentatus** (Fig. 707) is situated a little to the medial side of the center of the stem of the white substance of the hemisphere. It consists of an irregularly folded lamina, of a grayish-yellow color, containing white fibers, and presenting on its antero-medial aspect an opening, the **hilus,** from which most of the fibers of the superior peduncle emerge (page 792). 98

The **nucleus emboliformis** lies immediately to the medial side of the nucleus dentatus, and partly covering its hilus. The **nucleus globosus** is an elongated mass, directed antero-posteriorly, and placed medial to preceding. The **nucleus fastigii** is somewhat larger than the other two, and is situated close to the middle line at the anterior end of the superior vermis, and immediately over the roof of the fourth ventricle, from which it is separated by a thin layer of white substance. 99

The cerebellum is concerned with the coördination of movements necessary in equilibration, locomotion and prehension. In it terminate pathways conducting impulses of muscle sense, tendon sense, joint sense and equilibratory disturbances. With the exception of the ventral spinocerebellar fasciculus these impulses enter through the inferior peduncle. The reflex arc is completed by fibers in the superior peduncle which pass to the red nucleus and the thalamus and thence by additional neurons (rubrospinal tract) to the motor centers. The exact functions of 100 its different parts are still quite uncertain, owing to the contradictory nature of the evidence furnished by (1) ablation experiments upon animals, and (2) clinical observations in man of the effects produced by abscesses or tumors affecting different portions of the organ.

The Fourth Ventricle (*ventriculus quartus*).—The fourth ventricle, or cavity of the hind-brain, is situated in front of the cerebellum and behind the pons and upper half of the medulla oblongata. Developmentally considered, the fourth ventricle consists of three parts: a **superior** belonging to the isthmus rhombencephali, an **intermediate,** to the metencephalon, and an **inferior,** to the myelencephalon. It is lined by ciliated epithelium, and is continuous below with the central canal of the medulla oblongata; 122 above, it communicates, by means of a passage termed the cerebral aqueduct, with the cavity of the third ventricle. It presents four **angles,** and possesses a **roof** or dorsal wall, a **floor** or ventral wall, and **lateral boundaries.** *101*

Angles.—The **superior angle** is on a level with the upper border of the pons, and is continuous with the lower end of the cerebral aqueduct. The **inferior angle** is on a level with the lower end of the olive, and opens into the central canal of the medulla oblongata. Each **lateral angle** corresponds with the point of meeting of the brachia and inferior peduncle. A little below the lateral angles, on a level with the striæ medullares, the ventricular cavity is prolonged outward in the form of two narrow **lateral recesses,** one on either side; these are situated between the inferior peduncles and the flocculi, and reach as far as the attachments of the glossopharyngeal and vagus nerves. *102*

Lateral Boundaries.—The lower part of each lateral boundary is constituted by the clava, the fasciculus cuneatus, and the inferior peduncle; the upper part by the middle and the superior peduncle. *103*

Roof or Dorsal Wall (Fig. 708).—The upper portion of the roof is formed by the superior peduncle and the anterior medullary velum; the lower portion, by the posterior medullary velum, the epithelial lining of the ventricle covered by the tela chorioidea inferior, the tæniæ of the fourth ventricle, and the obex. *104*

The **superior peduncle** (page 792), on emerging from the central white substance of the cerebellum, pass upward and forward, forming at first the lateral boundaries of the upper part of the cavity; on approaching the inferior colliculi, they converge, and their medial portions overlap the cavity and form part of its roof. *105*

The **anterior medullary velum** (page 793) fills in the angular interval between the superior peduncle, and is continuous behind with the central white substance of the cerebellum; it is covered on its dorsal surface by the lingula of the superior vermis. *106*

The **posterior medullary velum** (page 794) is continued downward and forward from the central white substance of the cerebellum in front of the nodule and tonsils, and ends inferiorly in a thin, concave, somewhat ragged margin. Below this margin the roof is devoid of nervous matter except in the immediate vicinity of the lower lateral boundaries of the ventricle, where two narrow white bands, the **tæniæ of the fourth ventricle**(*ligulæ*), appear; these bands meet over the inferior angle of the ventricle in a thin triangular lamina, the **obex.** The non-nervous part of the roof is formed by the **epithelial lining of the ventricle,** which is prolonged downward as a thin membrane, from the deep surface of the posterior medullary velum to the corresponding surface of the obex and tæniæ, and thence on to the floor of the ventricular cavity; it is covered and strengthened by a portion of the pia mater, which is named the **tela chorioidea of the fourth ventricle.** *107*

The **tæniæ of the fourth ventricle** (*tænia ventriculi quarti; ligula*) are two narrow bands of white matter, one on either side, which complete *108* the lower part of the roof of the cavity. Each consists of a vertical and a horizontal part. The vertical part is continuous below the obex with the clava, to which it is adherent by its lateral border. The horizontal portion extends transversely across the inferior peduncle, below the striæ medullares, and roofs in the lower and posterior part of the lateral recess; it is attached by its lower margin to the inferior peduncle, and partly encloses the choroid plexus, which, however, projects beyond it like a cluster of grapes; and hence this part of the tænia has been termed the**cornucopia** (Bochdalek). The **obex** is a thin, triangular, gray lamina, which roofs in the lower angle of the ventricle and is attached by its lateral margins to the clavæ. The **tela chorioidea of the fourth ventricle** is the name applied to the triangular fold of pia mater which is carried upward between the cerebellum and the medulla oblongata. It consists of two layers, which are continuous with each other in front, and are more or less adherent throughout. The posterior layer covers the antero-inferior surface of the cerebellum, while the anterior is applied to the structures which form the lower part of the roof of the ventricle, and is continuous inferiorly with the pia mater on the inferior peduncles and closed part of the medulla.

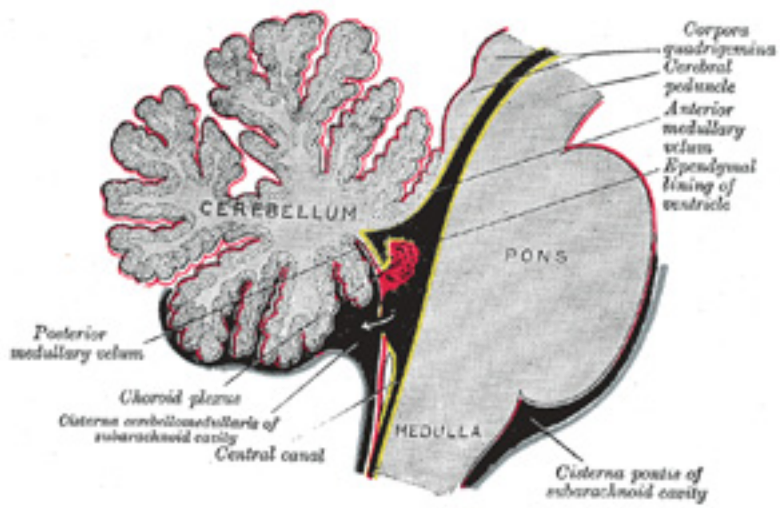


FIG. 708– Scheme of roof of fourth ventricle. The arrow is in the foramen of Majendie. (See enlarged image)

Choroid Plexuses.—These consist of two highly vascular inflexions of the tela chorioidea, which invaginate the lower part of the roof of the ventricle and are everywhere covered by the epithelial lining of the cavity. Each consists of a vertical and a horizontal portion: the former lies close to the middle line, and the latter passes into the lateral recess and projects beyond its apex. The vertical parts of the plexuses are distinct from each other, but the horizontal portions are joined in the middle line; and hence the entire structure presents the form of the letter T, the 109 vertical limb of which, however, is double.

Openings in the Roof.—In the roof of the fourth ventricle there are three openings, a medial and two lateral: the **medial aperture** (*foramen Majendii*), is situated immediately above the inferior angle of the ventricle; the **lateral apertures,** (*foramina of Luschka* are found at the extremities of the lateral recesses. By means of these three openings the ventricle communicates with the subarachnoid cavity, and the cerebrospinal fluid can circulate from the one to the other. *110*

Rhomboid Fossa (***fossa rhomboidea; "floor" of the fourth ventricle***) **(Fig. 709).**—The anterior part of the fourth ventricle is named, from its shape, the **rhomboid fossa,** and its anterior wall, formed by the back of the pons and medulla oblongata, constitutes the floor of the fourth ventricle. It is covered by a thin layer of gray substance continuous with that of the medulla spinalis; superficial to this is a thin lamina of neuroglia which constitutes the ependyma of the ventricle and supports a layer of ciliated epithelium. The fossa consists of three parts, superior, intermediate, and inferior. The **superior part** is triangular in shape and limited laterally by the superior cerebellar peduncle; its apex, directed upward, is continuous with the cerebral aqueduct; its base it represented by an imaginary line at the level of the upper ends of the superior foveæ. The **intermediate** part extends from this level to that of the horizontal portions of the tæniæ of the ventricle; it is narrow above where it is limited laterally by the middle peduncle, but widens below and is prolonged into the lateral recesses of the ventricle. The **inferior** part is triangular, and its downwardly directed apex, named the **calamus scriptorius,** is continuous with the central canal of the closed part of the medulla oblongata. *111*

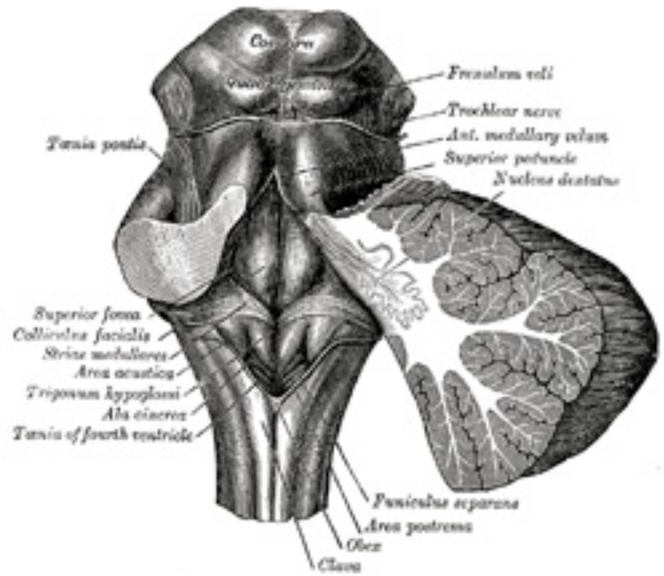


FIG. 709– Rhomboid fossa. (See enlarged image)

The rhomboid fossa is divided into symmetrical halves by a **median sulcus** which reaches from the upper to the lower angles of the fossa and 112 is deeper below than above. On either side of this sulcus is an elevation, the **medial eminence,** bounded laterally by a sulcus, the **sulcus limitans.** In the superior part of the fossa the medial eminence has a width equal to that of the corresponding half of the fossa, but opposite the superior fovea it forms an elongated swelling, the **colliculus facialis,** which overlies the nucleus of the abducent nerve, and is, in part at least, produced by the ascending portion of the root of the facial nerve. In the inferior part of the fossa the medial eminence assumes the form of a triangular area, the **trigonum hypoglossi.** When examined under water with a lens this trigone is seen to consist of a medial and a lateral area separated by a series of oblique furrows; the medial area corresponds with the upper part of the nucleus of the hypoglossal nerve, the lateral with a small nucleus, the **nucleus intercalatus.**

The **sulcus limitans** forms the lateral boundary of the medial eminence. In the superior part of the rhomboid fossa it corresponds with the 113 lateral limit of the fossa and presents a bluish-gray area, the **locus cæruleus,** which owes its color to an underlying patch of deeply pigmented nerve cells, termed the **substantia ferruginea.** At the level of the colliculus facialis the sulcus limitans widens into a flattened depression, the **superior fovea,** and in the inferior part of the fossa appears as a distinct dimple, the **inferior fovea.**Lateral to the foveæ is a rounded elevation named the **area acustica,** which extends into the lateral recess and there forms a feebly marked swelling, the **tuberculum acusticum.**Winding around the inferior peduncle and crossing the area acustica and the medial eminence are a number of white strands, the **striæ medullares,** which form a portion of the cochlear division of the acoustic nerve and disappear into the median sulcus. Below the inferior fovea, and between the trigonum hypoglossi and the lower part of the area acustica is a triangular dark field, the **ala cinerea,** which corresponds to the sensory nucleus of the vagus and glossopharyngeal nerves. The lower end of the ala cinerea is crossed by a narrow translucent ridge, the **funiculus separans,** and between this funiculus and the clava, is a small tongue-shaped area, the **area postrema.** On section it is seen that the funiculus separans is formed by a strip of thickened ependyma, and the area postrema by loose, highly vascular, neuroglial tissue containing nerve cells of moderate size.

Note 120. Essick, Am. Jour. Anat., 1907. [back]

Note 121. See article by E. B. Jamieson, Journal of Anatomy and Physiology, vol. xliv. [back]

Note 122. J. T. Wilson (Journal of Anatomy and Physiology, vol. xl) has pointed out that the central cana of the medulla oblongata, immediately below its entrance into the fourth ventricle, retains the cleft-like form presented by the fetal medulla spinalis, and that it is marked by dorso- and ventro-lateral sulci. [back]

4b. The Mid-brain or Mesencephalon

The **mid-brain** or **mesencephalon** (Fig. 681) is the short, constricted portion which connects the pons and cerebellum with the *1*
thalamencephalon and cerebral hemispheres. It is directed upward and forward, and consists of (1) a ventrolateral portion, composed of a pair of cylindrical bodies, named the **cerebral peduncles;** (2) a dorsal portion, consisting of four rounded eminences, named the **corpora quadrigemina;** and (3) an intervening passage or tunnel, the **cerebral aqueduct,** which represents the original cavity of the mid-brain and connects the third with the fourth ventricle (Fig. 710).

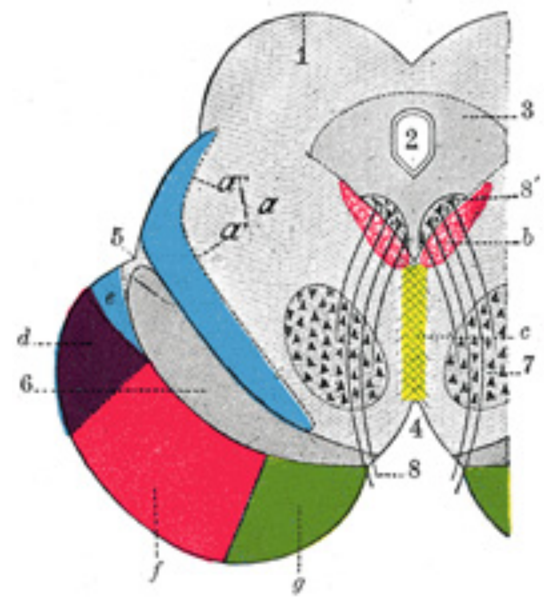


FIG. 710– Coronal section through mid-brain. (Schematic.) (Testut.) 1. Corpora quadrigemina. 2. Cerebral aqueduct. 3. Central gray stratum. 4. Interpeduncular space. 5. Sulcus lateralis. 6. Substantia nigra. 7. Red nucleus of tegmentum. 8. Oculomotor nerve, with 8', its nucleus of origin. *a*. Lemniscus (in blue) with *a'* the medial lemniscus and *a*"the lateral lemniscus. *b*. Medial longitudinal fasciculus. *c*. Raphé. *d*. Temporopontine fibers.*e*. Portion of medial lemniscus, which runs to the lentiform nucleus and insula. *f*.Cerebrospinal fibers. *g*. Frontopontine fibers. (See enlarged image)

The **cerebral peduncles** (*pedunculus cerebri; crus cerebri*) are two cylindrical masses situated at the base of the brain, and largely hidden by 2
the temporal lobes of the cerebrum, which must be drawn aside or removed in order to expose them. They emerge from the upper surface of the pons, one on either side of the middle line, and, diverging as they pass upward and forward, disappear into the substance of the cerebral hemispheres. The depressed area between the crura is termed the **interpeduncular fossa,** and consists of a layer of grayish substance, the **posterior perforated substance,** which is pierced by small apertures for the transmission of bloodvessels; its lower part lies on the ventral aspect of the medial portions of the tegmenta, and contains a nucleus named the **interpeduncular ganglion** (page 802); its upper part assists in forming the floor of the third ventricle. The ventral surface of each peduncle is crossed from the medial to the lateral side by the superior cerebellar and posterior cerebral arteries; its lateral surface is in relation to the gyrus hippocampi of the cerebral hemisphere and is crossed from behind forward by the trochlear nerve. Close to the point of disappearance of the peduncle into the cerebral hemisphere, the optic tract winds forward around its ventro-lateral surface. The medial surface of the peduncle forms the lateral boundary of the interpeduncular fossa, and is

marked by a longitudinal furrow, the **oculomotor sulcus,** from which the roots of the oculomotor nerve emerge. On the lateral surface of each peduncle there is a second longitudinal furrow, termed the **lateral sulcus;** the fibers of the lateral lemniscus come to the surface in this sulcus, and pass backward and upward, to disappear under the inferior colliculus.

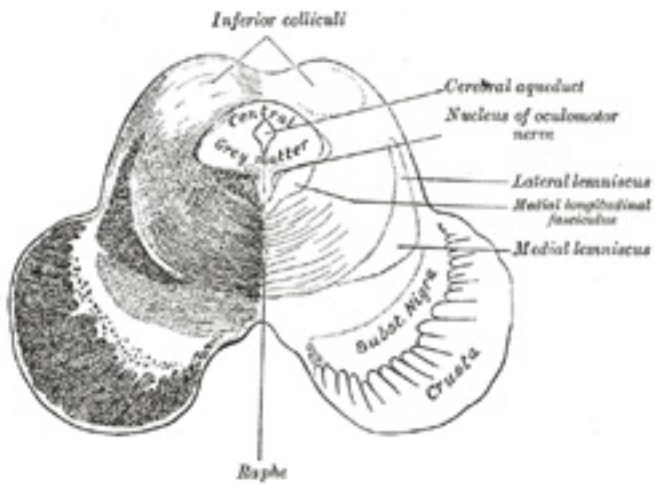


FIG. 711– Transverse section of mid-brain at level of inferior colliculi. (See enlarged image)

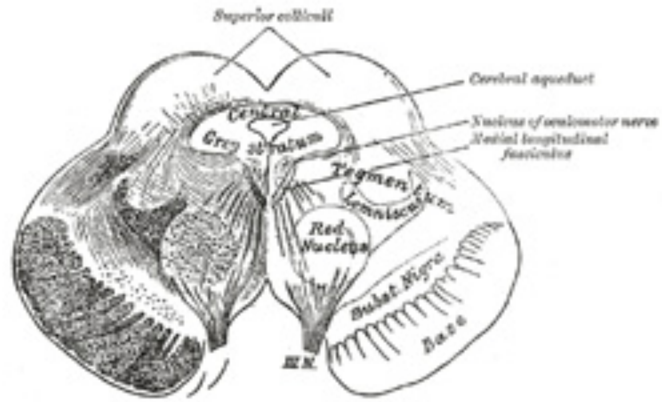


FIG. 712– Transverse section of mid-brain at level of superior colliculi. (See enlarged image)

Structure of the Cerebral Peduncles (Figs. 711, 712).—On transverse section, each peduncle is seen to consist of a dorsal and a ventral part, 3
separated by a deeply pigmented lamina of gray substance, termed the **substantia nigra.** The dorsal part is named the**tegmentum;** the ventral, the **base** or **crusta;** the two bases are separated from each other, but the tegmenta are joined in the median plane by a forward prolongation of the raphé of the pons. Laterally, the tegmenta are free; dorsally, they blend with the corpora quadrigemina.

The **base** (*basis pedunculi; crusta or pes*) is semilunar on transverse section, and consists almost entirely of longitudinal bundles of efferent 4
fibers, which arise from the cells of the cerebral cortex and are grouped into three principal sets, viz., cerebrospinal, frontopontine, and temporopontine (Fig. 710). The **cerebrospinal fibers,** derived from the cells of the motor area of the cerebral cortex, occupy the middle three-fifths of the base; they are continued partly to the nuclei of the motor cranial nerves, but mainly into the pyramids of the medulla oblongata. The **frontopontine fibers** are situated in the medial fifth of the base; they arise from the cells of the frontal lobe and end in the nuclei of the pons. The**temporopontine fibers** are lateral to the cerebrospinal fibers; they originate in the temporal lobe and end in the nuclei pontis. 123

The **substantia nigra** (*intercalatum*) is a layer of gray substance containing numerous deeply pigmented, multipolar nerve cells. It is semilunar 5
on transverse section, its concavity being directed toward the tegmentum; from its convexity, prolongations extend between the fibers of the base of the peduncle. Thicker medially than laterally, it reaches from the oculomotor sulcus to the lateral sulcus, and extends from the upper surface of the pons to the subthalamic region; its medial part is traversed by the fibers of the oculomotor nerve as these stream forward to reach the oculomotor sulcus. The connections of the cells of the substantia nigra have not been definitely established. It receives collaterals from the medial lemniscus and the pyramidal bundles. Bechterew is of the opinion that the fibers from the motor area of the cerebral cortex form synapses with cells whose axons pass to the motor nucleus of the trigeminal nerve and serve for the coördination of the muscles of mastication.

The **tegmentum** is continuous below with the reticular formation of the pons, and, like it, consists of longitudinal and transverse fibers, 6 together with a considerable amount of gray substance. The principal gray masses of the tegmentum are the red nucleus and the interpeduncular ganglion; of its fibers the chief longitudinal tracts are the superior peduncle, the medial longitudinal fasciculus, and the lemniscus.

GRAY SUBSTANCE.—The **red nucleus** is situated in the anterior part of the tegmentum, and is continued upward into the posterior part of the subthalamic region. In sections at the level of the superior colliculus it appears as a circular mass which is traversed by the fibers of the oculomotor nerve. It receives many terminals and collaterals from the superior cerebellar peduncle also collaterals from the ventral longitudinal bundle, from Gudden's bundle and the median lemniscus. The axons of its larger cells cross the middle line and are continued downward into the lateral funiculus of the medulla spinalis as the rubrospinal tract (page 761); those of its smaller cells end mainly in the thalamus. The rubrospinal tract forms an important part of the pathway from the cerebellum to the lower motor centers. *7*

The **interpeduncular ganglion** is a median collection of nerve cells situated in the ventral part of the tegmentum. The fibers of the fasciculus retroflexus of Meynert, which have their origin in the cells of the ganglion habenulæ (page 812), end in it. *8*

Besides the two nuclei mentioned, there are small collections of cells which form the dorsal and ventral nuclei and the central nucleus or nucleus of the raphé. *9*

WHITE SUBSTANCE.—(1) The origin and course of the *superior peduncle* have already been described (page 792). *10*

(2) The **medial** (*posterior*) **longitudinal fasciculus** is continuous below with the proper fasciculi of the anterior and lateral funiculi of the medulla spinalis. In the medulla oblongata and pons it runs close to the middle line, near the floor of the fourth ventricle; in the mid-brain it is situated on the ventral aspect of the cerebral aqueduct, below the nuclei of the oculomotor and trochlear nerves. Its connections are imperfectly known, but it consists largely of ascending and descending intersegmental or association fibers, which connect the nuclei of the hind-brain and mid-brain to each other. Many of the fibers arise in **Deiters's nucleus** (*lateral vestibular nucleus*) and divide into ascending and descending branches which send terminals and collaterals to the motor nuclei of the cranial and spinal nerves. Its spinal portion is located in the anterior funiculus and is known as the **vestibulospinal fasciculus.** Other fibers pass to the median longitudinal bundle from cells in the reticular formation of the medulla, pons and mid-brain and also from certain large cells in the terminal nucleus of the trigeminal nerve. According to Edinger it extends to the so-called nucleus of the posterior longitudinal bundle in the hypothalamic region, but this is uncertain and the fibers above the nucleus of the oculomotor are smaller in diameter than the rest of the bundle. According to Held fibers from the posterior commissure can be traced into the posterior longitudinal bundle, and according to the same author many of the descending fibers arise in the superior colliculus, and, after decussating in the middle line, end in the motor nuclei of the pons and medulla oblongata. These fibers from the superior colliculus probably pass into the ventral longitudinal bundle. Fibers are said to pass through the medial longitudinal fasciculus from the nucleus of the abducent nerve into the oculomotor nerve of the opposite side, and through this nerve to the Rectus medialis oculi. Fraser, however, denies the existence of such fibers. Again, fibers are said to be prolonged through this fasciculus from the nucleus of the oculomotor nerve into the facial nerve, and are distributed to the Orbicularis oculi, the Corrugator, and the Frontalis. 124 *11*

The **ventral longitudinal bundle** consists for the most part of the **tectospinal fasciculus,** and arises from the superior colliculus, the fibers arch ventrally around the central gray matter and cross the midline in the fountain-decussation of Meynert. They then descend in the tegmentum, part of them passing through the red nucleus ventral to the medial longitudinal bundle. In the medulla oblongata and spinal cord its fibers are more or less intermingled with the medial longitudinal bundle and the rubrospinal tract. It descends in the adjoining region of the ventral and lateral funiculi. Collaterals and terminals are given off to the red nucleus and probably other nuclei of the brain stem and to the anterior column of the spinal cord. It is probably concerned in optic reflexes. *12*

(3) The **medial lemniscus** or **medial fillet** (Fig. 713).—The fibers of the medial lemniscus take origin in the gracile and cuneate nuclei of the *13*

medulla oblongata, and as internal arcuate fibers they cross to the opposite side in the sensory decussation (page 777). They then pass in the interolivary stratum upward through the medulla oblongata, in which they are situated behind the cerebrospinal fibers and between the olives. In the pons and lower part of the mid-brain it occupies the ventral part of the reticular formation and tegmentum close to the raphé, while above it gradually shifts to the dorso-lateral part of the tegmentum in the angle between the red nucleus and the substantia nigra. In the pons it assumes a flattened ribbon-like appearance, and is placed dorsal to the trapezium. As the lemniscus ascends, it receives additional fibers from the terminal sensory nuclei of the cranial nerves of the opposite side. Many of the fibers which arise from the terminal sensory nuclei of the cranial nerves pass upward in the formatio reticularis as a separate bundle, known as the**central tract of the cranial nerves,** to the thalamus.

Many fibers either terminate in or send off collaterals to the gray matter of the medulla, the pons, and the mid-brain. Large numbers of fibers *14*
pass to or from the substantia nigra. Many collaterals enter the red nucleus and other fibers are said to run to the superior colliculus. The great bulk of the fibers, however, enter the ventro-lateral portion of the thalamus, give off collaterals to the posterior semilunar nucleus and then terminate in the principal sensory nucleus of the thalamus.

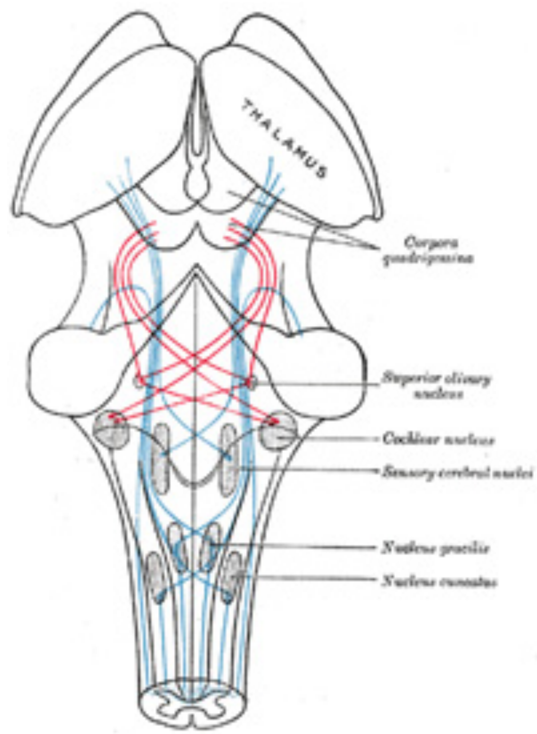


FIG. 713– Scheme showing the course of the fibers of the lemniscus; medial lemniscus in blue, lateral in red. (See enlarged image)

In the cerebral peduncle, a few of its fibers pass upward in the lateral part of the base of the peduncle, on the dorsal aspect of the 15
temporopontine fibers, and reach the lentiform nucleus and the insula. The greater part of the medial lemniscus, on the other hand, is prolonged through the tegmentum, and most of its fibers end in the thalamus; probably some are continued directly through the occipital part of the internal capsule to the cerebral cortex. From the cells of the thalamus a relay of fibers is prolonged to the cerebral cortex.

The medial lemniscus may be considered as the upward continuation of the posterior funiculus of the spinal cord and to convey conscious 16
impulses of muscle sense and tactile discrimination.

The **central** or **thalamic tract of the cranial nerves** is closely associated with the medial lemniscus. The fibers of the spinothalamic fasciculi 17
are continued from the spinal cord into this tract which passes upward in the reticular formation and the tegmentum to the thalamus along the dorsal side of the median lemniscus. It receives fibers from the opposite terminal sensory nuclei of the vagus, glossopharyngeal, facial, trigeminal and probably the vestibular nerves. Many of the secondary sensory fibers of the trigeminal cross the raphé from its terminal nucleus and pass upward to the thalamus by a more or less separate but closely associated pathway known as the **central tract of the trigeminal nerve** which also lies on the dorsal aspect of the lemniscus. These two tracts give off collaterals to the posterior semilunar nucleus of the thalamus and terminate in the anterior semilunar nucleus of the ventro-lateral region of the thalamus sending collaterals into the zona incerta.

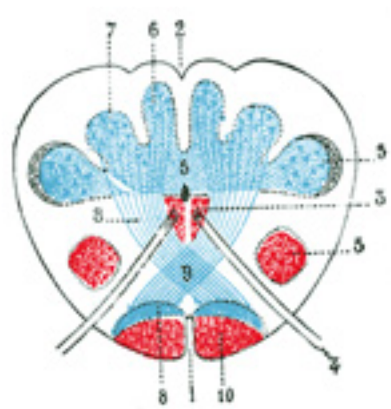


FIG. 714– Transverse section passing through the sensory decussation. Schematic. (Testut.) 1. Anterior median fissure. 2. Posterior median sulcus. 3, 3’. Head and base of anterior column (in red). 4. Hypoglossal nerve. 5. Bases of posterior column. 6. Gracile nucleus. 7. Cuneate nucleus. 8, 8. Lemniscus. 9. Sensory decussation. 10. Cerebrospinal fasciculus. (See enlarged image)

The fibers of the **rubrospinal tract** (*bundle of Monakow*) arise in the red nucleus, cross the midline in the decussation of Forel and pass downward in the formatio reticularis of the brainstem into the lateral funiculus of the spinal cord ventral to the crossed pyramidal tract. *18*

The **lateral lemniscus** (*lemniscus lateralis*) comes to the surface of the mid-brain along its lateral sulcus, and disappears under the inferior colliculus. It consists of fibers from the terminal nuclei of the cochlear division of the acoustic nerve, together with others from the superior olivary and trapezoid nuclei. Most of these fibers are crossed, but some are uncrossed. Many of them pass to the inferior colliculus of the same or opposite side, but others are prolonged to the thalamus, and thence through the occipital part of the internal capsule to the middle and superior temporal gyri. *19*

The **corpora quadrigemina** (Fig. 720) are four rounded eminences which form the dorsal part of the mid-brain. They are situated above and in front of the anterior medullary velum and superior peduncle, and below and behind the third ventricle and posterior commissure. They are covered by the splenium of the corpus callosum, and are partly overlapped on either side by the medial angle, or **pulvinar,** of the posterior end of the thalamus; on the lateral aspect, under cover of the pulvinar, is an oval eminence, named the**medial geniculate body.** The corpora quadrigemina are arranged in pairs (**superior and inferior colliculi**), and are separated from one another by a crucial sulcus. The longitudinal part of this sulcus expands superiorly to form a slight depression which supports the **pineal body,** a cone-like structure which projects backward from the thalamencephalon and partly obscures the superior colliculi. From the inferior end of the longitudinal sulcus, a white band, termed the **frenulum veli,** is prolonged downward to the anterior medullary velum; on either side of this band the trochlear nerve emerges, and passes forward on the lateral aspect of the cerebral peduncle to reach the base of the brain. The **superior colliculi** are larger and darker in color than the inferior, and are oval in shape. The **inferior colliculi** are hemispherical, and somewhat more prominent than the superior. The superior colliculi are associated with the sense of sight, the inferior with that of hearing. *20*

From the lateral aspect of each colliculus a white band, termed the **brachium,** is prolonged upward and forward. The **superior brachium** extends lateralward from the superior colliculus, and, passing between the pulvinar and medial geniculate body, is partly continued into an eminence called the **lateral geniculate body,** and partly into the optic tract. The **inferior brachium** passes forward and upward from the inferior colliculus and disappears under cover of the **medial geniculate body.** *21*

In close relationship with the corpora quadrigemina are the superior peduncles, which emerge from the upper and medial parts of the cerebellar hemispheres. They run upward and forward, and, passing under the inferior colliculi, enter the tegmenta as already described (page 792). *22*

Structure of the Corpora Quadrigemina.—The **inferior colliculus** (*colliculus inferior; inferior quadrigeminal body; postgemina*) consists of a compact nucleus of gray substance containing large and small multipolar nerve cells, and more or less completely surrounded by white fibers derived from the lateral lemniscus. Most of these fibers end in the gray nucleus of the same side, but some cross the middle line and end in that of the opposite side. From the cells of the gray nucleus, fibers are prolonged through the inferior brachium into the tegmentum of the cerebral peduncle, and are carried to the thalamus and the cortex of the temporal lobe; other fibers cross the middle line and end in the opposite colliculus. *23*

The **superior colliculus** (*colliculus superior; superior quadrigeminal body; pregemina*) is covered by a thin stratum (**stratum zonale**) of white fibers, the majority of which are derived from the optic tract. Beneath this is the **stratum cinereum,** a cap-like layer of gray substance, thicker in the center than at the circumference, and consisting of numerous small multipolar nerve cells, imbedded in a fine network of nerve fibers. Still deeper is the**stratum opticum,** containing large multipolar nerve cells, separated by numerous fine nerve fibers. Finally, there is the **stratum lemnisci,** consisting of fibers derived partly from the lemniscus and partly from the cells of the stratum opticum; interspersed among these fibers *24* are many large multipolar nerve cells. The two last-named strata are sometimes termed the **gray-white layers,** from the fact that they consist of both gray and white substance. Of the afferent fibers which reach the superior colliculus, some are derived from the lemniscus, but the majority have their origins in the retina and are conveyed to it through the superior brachium; all of them end by arborizing around the cells of the gray substance. Of the efferent fibers, some cross the middle line to the opposite colliculus; many ascend through the superior brachium, and finally reach the cortex of the occipital lobe of the cerebrum; while others, after undergoing decussation (**fountain decussation of Meynert**) form the tectospinal fasciculus which descends through the formatio reticularis of the midbrain, pons, and medulla oblongata into the medulla spinalis, where it is found partly in the anterior funiculus and partly intermingled with the fibers of the rubrospinal tract.

The corpora quadrigemina are larger in the lower animals than in man. In fishes, reptiles, and birds they are hollow, and only two in number (corpora bigemina); they represent the superior colliculi of mammals, and are frequently termed the optic lobes, because of their intimate connection with the optic tracts. *25*

The **cerebral aqueduct** (*aqueductus cerebri; aqueduct of Sylvius*) is a narrow canal, about 15 mm. long, situated between the corpora quadrigemina and tegmenta, and connecting the third with the fourth ventricle. Its shape, as seen in transverse section, varies at different levels, being T-shaped, triangular above, and oval in the middle; the central part is slightly dilated, and was named by Retzius the **ventricle of the mid-brain.** It is lined by ciliated columnar epithelium, and is surrounded by a layer of gray substance named the**central gray stratum:** this is continuous below with the gray substance in the rhomboid fossa, and above with that of the third ventricle. Dorsally, it is partly separated from the gray substance of the quadrigeminal bodies by the fibers of the lemniscus; ventral to it are the medial longitudinal fasciculus, and the formatio reticularis of the tegmentum. Scattered throughout the central gray stratum are numerous nerve cells of various sizes, interlaced, by a net-work of fine fibers. Besides these scattered cells it contains three groups which constitute the nuclei of the oculomotor and trochlear nerves, and the nucleus of the mesencephalic root of the trigeminal nerve. The **nucleus of the trigeminal nerve** extends along the entire length of the aqueduct, and occupies the lateral part of the gray stratum, while the nuclei of the oculomotor and trochlear nerves are situated in its ventral part. The**nucleus of the oculomotor nerve** is about 10 cm. long, and lies under the superior colliculus, beyond which, however, it extends for a short distance into the gray substance of the third ventricle. The **nucleus of the trochlear nerve** is small and nearly circular, and is on a level with a plane carried transversely through the upper part of the inferior colliculus. *26*

Note 123. A band of fibers, the *tractus peduncularis transversus,* is sometimes seen emerging from in front of the superior colliculus; it passes around the ventral aspect of the peduncle about midway between the pons and the optic tract, and dips into the oculomotor sulcus. This band is a constant structure in many mammals, but is only present in about 30 per cent. of human brains. Since it undergoes atrophy after enucleation of the eyeballs, it may be considered as forming a path for visual sensations. [back]

Note 124. A. Bruce and J. H. Harvey Pirrie, “On the Origin of the Facial Nerve,” Review of Neurology and Psychiatry, December, 1908, No. 12, vol. vi, produce weighty evidence against the view that the facial nerve derives fibers from the nucleus of the oculomotor nerve. [back]

4c. The Fore-brain or Prosencephalon

The **fore-brain** or **prosencephalon** consists of: (1) the **diencephalon,** corresponding in a large measure to the third ventricle and the structures which bound it; and (2) the**telencephalon,** comprising the largest part of the brain, viz., the cerebral hemispheres; these hemispheres are *1* intimately connected with each other across the middle line, and each contains a large cavity, named the lateral ventricle. The lateral ventricles communicate through the interventricular foramen with the third ventricle, but are separated from each other by a medial septum, the **septum pellucidum;** this contains a slit-like cavity, which does not communicate with the ventricles.

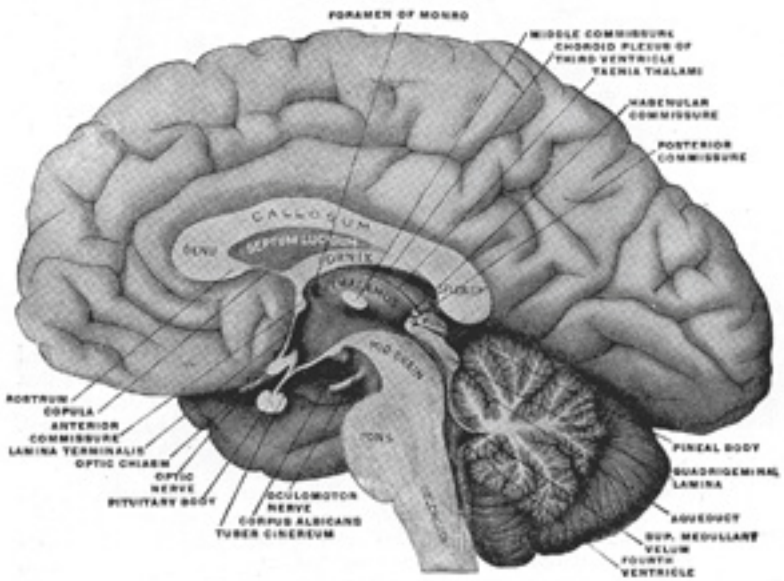


FIG. 715– Mesal aspect of a brain sectioned in the median sagittal plane. (See enlarged image)

The Diencephalon.—The diencephalon is connected above and in front with the cerebral hemispheres; behind with the mid-brain. Its upper surface is concealed by the corpus callosum, and is covered by a fold of pia mater, named the tela chorioidea of the third ventricle; inferiorly it reaches to the base of the brain. 2

The diencephalon comprises: (1) the **thalamencephalon;** (2) the **pars mamillarishypothalami;** and (3) the **posterior part of the third ventricle.** For descriptive purposes, however, it is more convenient to consider the whole of the third ventricle and its boundaries together; this necessitates the inclusion, under this heading, of the pars optica hypothalami and the corresponding part of the third ventricle—structures which properly belong to the telencephalon. 3

The Thalamencephalon.—The thalamencephalon comprises: (1) the **thalamus;** (2) the**metathalamus** or **corpora geniculata;** and (3) the **epithalamus,** consisting of the trigonum habenulæ, the pineal body, and the posterior commissure. *4*

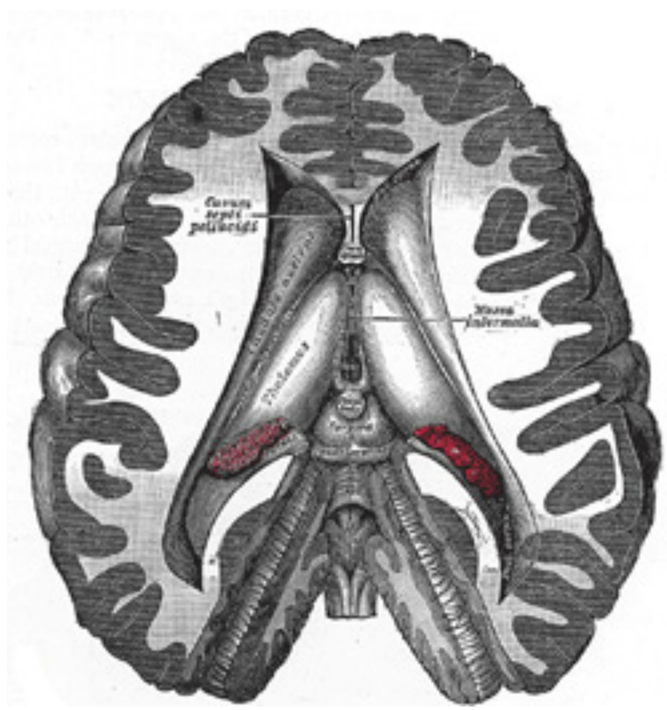


FIG. 716– Dissection showing the ventricles of the brain. (See enlarged image)

The **Thalami** (*optic thalamus*) (Figs. 716, 717) are two large ovoid masses, situated one on either side of the third ventricle and reaching for some distance behind that cavity. Each measures about 4 cm. in length, and presents two extremities, an anterior and a posterior, and four surfaces, superior, inferior, medial, and lateral. *5*

The **anterior extremity** is narrow; it lies close to the middle line and forms the posterior boundary of the interventricular foramen. *6*

The **posterior extremity** is expanded, directed backward and lateralward, and overlaps the superior colliculus. Medially it presents an angular prominence, the **pulvinar,** which is continued laterally into an oval swelling, the **lateral geniculate body,** while beneath the pulvinar, but separated from it by the superior brachium, is a second oval swelling, the**medial geniculate body.** *7*

The **superior surface** is free, slightly convex, and covered by a layer of white substance, termed the **stratum zonale.** It is separated laterally from the caudate nucleus by a white band, the **stria terminalis,** and by the terminal vein. It is divided into a medial and a lateral portion by an oblique shallow furrow which runs from behind forward and medialward and corresponds with the lateral margin of the fornix; the lateral part forms a portion of the floor of the lateral ventricle, and is covered by the epithelial lining of this cavity; the medial part is covered by the tela chorioidea of the third ventricle, and is destitute of an epithelial covering. In front, the superior is separated from the medial surface by a salient margin, the**tænia thalami,** along which the epithelial lining of the third ventricle is reflected on to the under surface of the tela chorioidea. Behind, it is limited medially by a groove, the **sulcus habenulæ,** which intervenes between it and a small triangular area, termed the **trigonum habenulæ.** *8*

The **inferior surface** rests upon and is continuous with the upward prolongation of the tegmentum (**subthalamic tegmental region**), in front of which it is related to the**substantia innominata of Meynert.** *9*

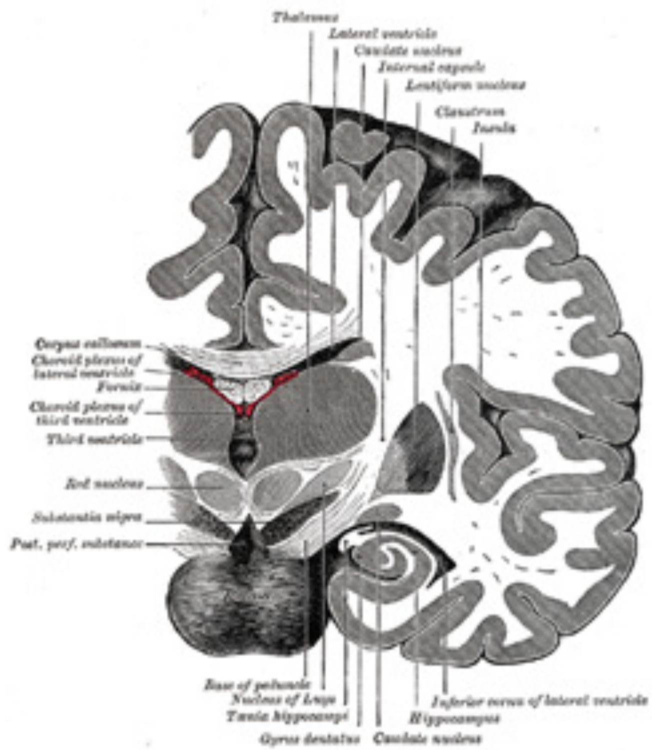


FIG. 717– Coronal section of brain immediately in front of pons. (See enlarged image)

The **medial surface** constitutes the upper part of the lateral wall of the third ventricle, and is connected to the corresponding surface of the 10
opposite thalamus by a flattened gray band, the **massa intermedia** (*middle* or *gray commissure*). This mass averages about 1 cm. in its antero-posterior diameter: it sometimes consists of two parts and occasionally is absent. It contains nerve cells and nerve fibers; a few of the latter may cross the middle line, but most of them pass toward the middle line and then curve lateralward on the same side.

The **lateral surface** is in contact with a thick band of white substance which forms the occipital part of the internal capsule and separates the 11
thalamus from the lentiform nucleus of the corpus striatum.

Structure.—The thalamus consists chiefly of gray substance, but its upper surface is covered by a layer of white substance, named the **stratum** 12
zonale, and its lateral surface by a similar layer termed the **lateral medullary lamina.** Its gray substance is incompletely subdivided into three parts—anterior, medial, and lateral—by a white layer, the **medial medullary lamina.** The anterior part comprises the anterior tubercle, the medial part lies next the lateral wall of the third ventricle while the lateral and largest part is interposed between the medullary laminæ and includes the pulvinar. The lateral part is traversed by numerous fibers which radiate from the thalamus into the internal capsule, and pass through the latter to the cerebral cortex. These three parts are built up of numerous nuclei, the connections of many of which are imperfectly known.

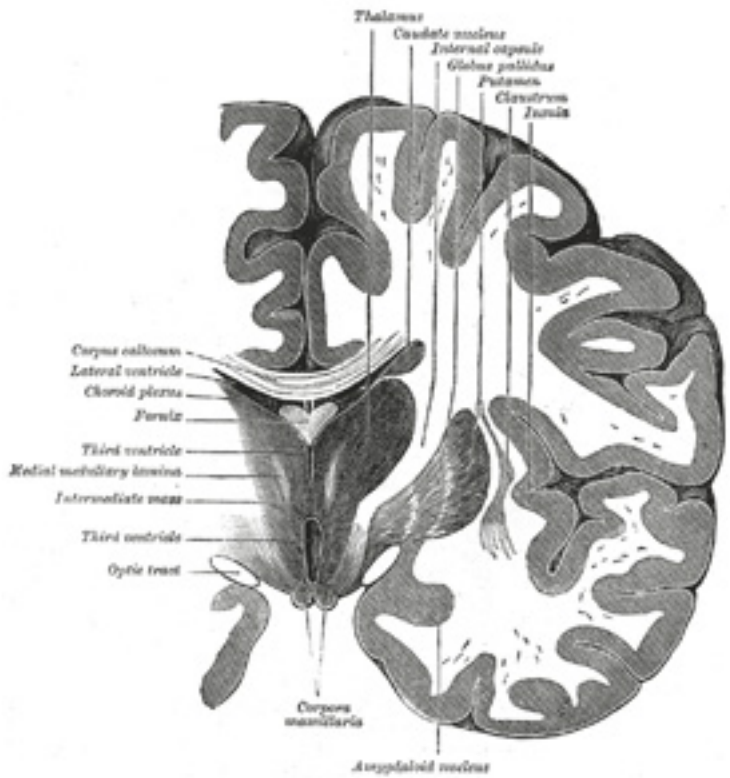


FIG. 718– Coronal section of brain through intermediate mass of third ventricle. (See enlarged image)

Connections.—The thalamus may be regarded as a large ganglionic mass in which the ascending tracts of the tegmentum and a considerable proportion of the fibers of the optic tract end, and from the cells of which numerous fibers (thalamocortical) take origin, and radiate to almost every part of the cerebral cortex. The lemniscus, together with the other longitudinal strands of the tegmentum, enters its ventral part: the **thalamomammillary fasciculus** (*bundle of Vicq d'Azyr*), from the corpus mammillare, enters in its anterior tubercle, while many of the fibers of the optic tract terminate in its posterior end. The thalamus also receives numerous fibers (corticothalamic) from the cells of the cerebral cortex. The fibers that arise from the cells of the thalamus form four principal groups or stalks: (*a*) those of the **anterior stalk** pass through the 13 frontal part of the internal capsule to the frontal lobe; (*b*) the fibers of the **posterior stalk** (*optic radiations*) arise in the pulvinar and are conveyed through the occipital part of the internal capsule to the occipital lobe; (*c*) the fibers of the **inferior stalk** leave the under and medial surfaces of the thalamus, and pass beneath the lentiform nucleus to the temporal lobe and insula; (*d*) those of the**parietal stalk** pass from the lateral nucleus of the thalamus to the parietal lobe. Fibers also extend from the thalamus into the corpus striatum—those destined for the caudate nucleus leave the lateral surface, and those for the lentiform nucleus, the inferior surface of the thalamus.

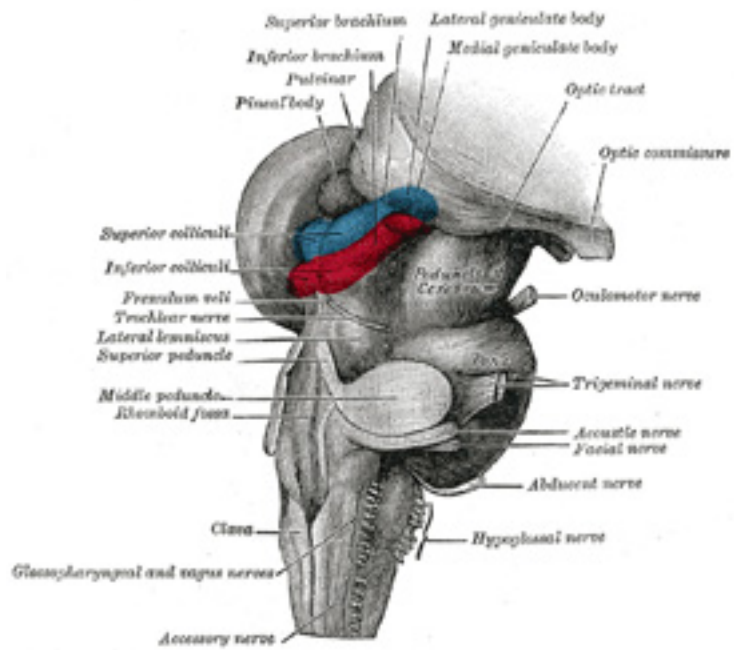


FIG. 719– Hind- and mid-brains; postero-lateral view. (See enlarged image)

The **Metathalamus** (Fig. 719) comprises the **geniculate bodies,** which are two in number—a **medial** and a **lateral**—on each side. *14*

The **medial geniculate body** (*corpus geniculatum mediale; internal geniculate body; postgeniculatum*) lies under cover of the pulvinar of the *15*
thalamus and on the lateral aspect of the corpora quadrigemina. Oval in shape, with its long axis directed forward and lateralward, it is lighter in color and smaller in size than the lateral. The inferior brachium from the inferior colliculus disappears under cover of it while from its lateral extremity a strand of fibers passes to join the optic tract. Entering it are many acoustic fibers from the lateral lemniscus. The medial geniculate

bodies are connected with one another by the commissure of Gudden, which passes through the posterior part of the optic chiasma.

The **lateral geniculate body** (*corpus geniculatum laterale; external geniculate body; pregeniculatum*) is an oval elevation on the lateral part 16
of the posterior end of the thalamus, and is connected with the superior colliculus by the superior brachium. It is of a dark color, and presents a laminated arrangement consisting of alternate layers of gray and white substance. It receives numerous fibers from the optic tract, while other fibers of this tract pass over or through it into the pulvinar. Its cells are large and pigmented; their axons pass to the visual area in the occipital part of the cerebral cortex.

The superior colliculus, the pulvinar, and the lateral geniculate body receive many fibers from the optic tracts, and are therefore intimately 17
connected with sight, constituting what are termed the **lower visual centers.** Extirpation of the eyes in a newly born animal entails an arrest of the development of these centers, but has no effect on the medial geniculate bodies or on the inferior colliculi. Moreover, the latter are well-developed in the mole, an animal in which the superior colliculi are rudimentary.

The **Epithalamus** comprises the **trigonum habenulæ,** the **pineal body,** and the**posterior commissure.** 18

The **trigonum habenulæ** is a small depressed triangular area situated in front of the superior colliculus and on the lateral aspect of the 19
posterior part of the tænia thalami. It contains a group of nerve cells termed the **ganglion habenulæ.** Fibers enter it from the stalk of the pineal body, and others, forming what is termed the **habenular commissure,**pass across the middle line to the corresponding ganglion of the opposite side. Most of its fibers are, however, directed downward and form a bundle, the **fasciculus retroflexus** of Meynert, which passes medial to the red nucleus, and, after decussating with the corresponding fasciculus of the opposite side, ends in the interpeduncular ganglion.

The **pineal body** (*corpus pineale; epiphysis*) is a small, conical, reddish-gray body which lies in the depression between the superior colliculi. 20
It is placed beneath the splenium of the corpus callosum, but is separated from this by the tela chorioidea of the third ventricle, the lower layer of which envelops it. It measures about 8 mm. in length, and its base, directed forward, is attached by a stalk or peduncle of white substance. The **stalk** of the pineal body divides anteriorly into two laminæ, a dorsal and a ventral, separated from one another by the pineal recess of the third ventricle. The ventral lamina is continuous with the posterior commissure; the dorsal lamina is continuous with the habenular commissure and divides into two strands the medullary striæ, which run forward, one on either side, along the junction of the medial and upper surfaces of the thalamus to blend in front with the columns of the fornix.

The **posterior commissure** is a rounded band of white fibers crossing the middle line on the dorsal aspect of the upper end of the cerebral 21
aqueduct. Its fibers acquire their medullary sheaths early, but their connections have not been definitely determined. Most of them have their origin in a nucleus, the **nucleus of the posterior commissure** (*nucleus of Darkschewitsch*), which lies in the central gray substance of the upper end of the cerebral aqueduct, in front of the nucleus of the oculomotor nerve. Some are probably derived from the posterior part of the thalamus and from the superior colliculus, while others are believed to be continued downward into the medial longitudinal fasciculus.

The **Hypothalamus** (Fig. 720) includes the **subthalamic tegmental region** and the structures forming the greater part of the floor of the third 22
ventricle, viz., the **corpora mammillaria, tuber cinereum, infundibulum, hypophysis,** and **optic chiasma.**

The **subthalamic tegmental region** consists of the upward continuation of the tegmentum; it lies on the ventro-lateral aspect of the thalamus 23
and separates it from the fibers of the internal capsule. The red nucleus and the substantia nigra are prolonged into its lower part; in front it is continuous with the substantia innominata of Meynert, medially with the gray substance of the floor of the third ventricle.

It consists from above downward of three strata: (1) **stratum dorsale,** directly applied to the under surface of the thalamus and consisting of 24
fine longitudinal fibers; (2) **zona incerta,** a continuation forward of the formatio reticularis of the tegmentum; and (3) the**corpus**

subthalamicum (*nucleus of Luys*), a brownish mass presenting a lenticular shape on transverse section, and situated on the dorsal aspect of the fibers of the base of the cerebral peduncle; it is encapsuled by a lamina of nerve fibers and contains numerous medium-sized nerve cells, the connections of which are as yet not fully determined.

The **corpora mammillaria** (*corpus albicantia*) are two round white masses, each about the size of a small pea, placed side by side below the 25
gray substance of the floor of the third ventricle in front of the posterior perforated substance. They consist of white substance externally and of gray substance internally, the cells of the latter forming two nuclei, a **medial** of smaller and a **lateral** of larger cells. The white substance is mainly formed by the fibers of the columns of the fornix, which descend to the base of the brain and end partly in the corpora mammillaria. From the cells of the gray substance of each mammillary body two fasciculi arise: one, the **thalamomammillary fasciculus** (*bundle of Vicq d'Azyr*), passes upward into the anterior nucleus of the thalamus; the other is directed downward into the tegmentum. Afferent fibers are believed to reach the corpus mammillare from the medial lemniscus and from the tegmentum.

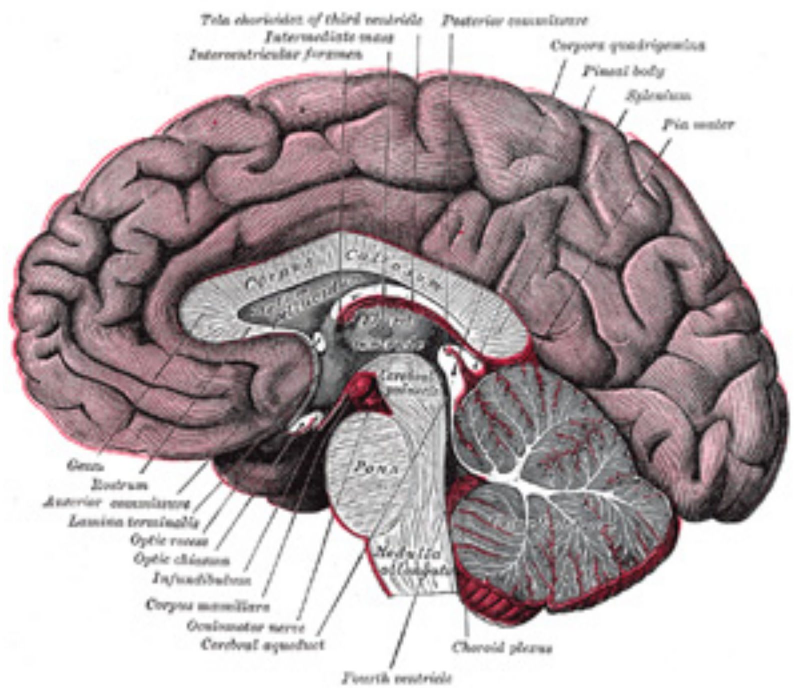


FIG. 720– Median sagittal section of brain. The relations of the pia mater are indicated by the red color. (See enlarged image)

The **tuber cinereum** is a hollow eminence of gray substance situated between the corpora mammillaria behind, and the optic chiasma in front. 26
Laterally it is continuous with the anterior perforated substances and anteriorly with a thin lamina, the **lamina terminalis.**From the under surface of the tuber cinereum a hollow conical process, the **infundibulum,**projects downward and forward and is attached to the posterior lobe of the hypophysis.

In the lateral part of the tuber cinereum is a nucleus of nerve cells, the **basal optic nucleus of Meynert,** while close to the cavity of the third 27
ventricle are three additional nuclei. Between the tuber cinereum and the corpora mammillaria a small elevation, with a corresponding depression in the third ventricle, is sometimes seen. Retzius has named it the **eminentia saccularis,** and regards it as a representative of the saccus vasculosus found in this situation in some of the lower vertebrates.

The **hypophysis** (*pituitary body*) (Fig. 721) is a reddish-gray, somewhat oval mass, measuring about 12.5 mm. in its transverse, and about 8 28
mm. in its antero-posterior diameter. It is attached to the end of the infundibulum, and is situated in the fossa hypophyseos of the sphenoidal bone, where it is retained by a circular fold of dura mater, the **diaphragma sella;** this fold almost completely roofs in the fossa, leaving only a small central aperture through which the infundibulum passes.

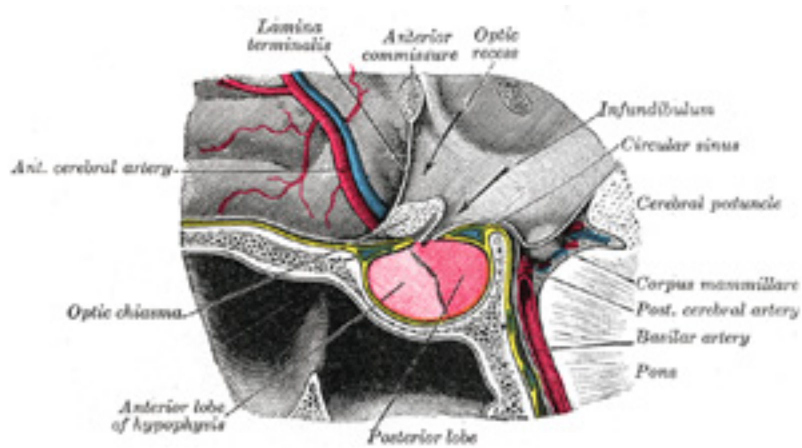


FIG. 721– The hypophysis cerebri, in position. Shown in sagittal section. (See enlarged image)

Optic Chiasma (***chiasma opticum; optic commissure***)**.**—The optic chiasma is a flattened, somewhat quadrilateral band of fibers, situated at the 29
junction of the floor and anterior wall of the third ventricle. Most of its fibers have their origins in the retina, and reach the chiasma through the optic nerves, which are continuous with its antero-lateral angles. In the chiasma, they undergo a partial decussation (Fig. 722); the fibers from

the nasal half of the retina decussate and enter the optic tract of the opposite side, while the fibers from the temporal half of the retina do not undergo decussation, but pass back into the optic tract of the same side. Occupying the posterior part of the commissure, however, is a strand of fibers, the **commissure of Gudden,** which is not derived from the optic nerves; it forms a connecting link between the medial geniculate bodies.

Optic Tracts.—The optic tracts are continued backward and lateralward from the postero-lateral angles of the optic chiasma. Each passes 30
between the anterior perforated substance and the tuber cinereum, and, winding around the ventrolateral aspect of the cerebral peduncle, divides into a medial and a lateral root. The former comprises the fibers of Gudden's commissure. The lateral root consists mainly of afferent fibers which arise in the retina and undergo partial decussation in the optic chiasma, as described; but it also contains a few fine efferent fibers which have their origins in the brain and their terminations in the retina. When traced backward, the afferent fibers of the lateral root are found to end in the lateral geniculate body and pulvinar of the thalamus, and in the superior colliculus; and these three structures constitute the **lower visual centers.** Fibers arise from the nerve cells in these centers and pass through the occipital part of the internal capsule, under the name of the **optic radiations,** to the cortex of the occipital lobe of the cerebrum, where the **higher** or **cortical visual center** is situated. Some of the fibers of the optic radiations take an opposite course, arising from the cells of the occipital cortex and passing to the lower visual centers. Some fibers are detached from the optic tract, and pass through the cerebral peduncle to the nucleus of the oculomotor nerve. These may be regarded as the afferent branches for the Sphincter pupillæ and Ciliaris muscles. Other fibers have been described as reaching the cerebellum through the superior peduncle; while others, again, are lost in the pons.

The Third Ventricle (*ventriculus tertius*) (Figs. 716, 720).—The third ventricle is a median cleft between the two thalami. Behind, it 31
communicates with the fourth ventricle through the cerebral aqueduct, and in front with the lateral ventricles through the interventricular foramen. Somewhat triangular in shape, with the apex directed backward, it has a **roof,** a **floor,** an **anterior** and a **posterior boundary** and a pair of **lateral walls.**

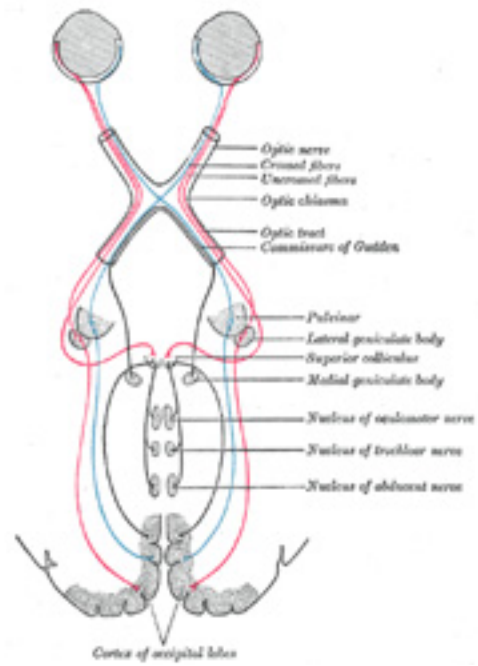


FIG. 722– Scheme showing central connections of the optic nerves and optic tracts. (See enlarged image)

The **roof** (Fig. 723) is formed by a layer of epithelium, which stretches between the upper edges of the lateral walls of the cavity and is continuous with the epithelial lining of the ventricle. It is covered by and adherent to a fold of pia mater, named the tela chorioidea of the third ventricle, from the under surface of which a pair of vascular fringed processes, the **choroid plexuses of the third ventricle,** project downward, one on either side of the middle line, and invaginate the epithelial roof into the ventricular cavity. *32*

The **floor** slopes downward and forward and is formed mainly by the structures which constitute the hypothalamus: from before backward these are: the optic chiasma, the tuber cinereum and infundibulum, and the corpora mammillaria. Behind the last, the floor is formed by the interpeduncular fossa and the tegmenta of the cerebral peduncles. The ventricle is prolonged downward as a funnel-shaped recess, the **recessus infundibuli,** into the infundibulum, and to the apex of the latter the hypophysis is attached. *33*

The **anterior boundary** is constituted below by the **lamina terminalis,** a thin layer of gray substance stretching from the upper surface of the optic chiasma to the rostrum of the corpus callosum; above by the columns of the fornix and the anterior commissure. At the junction of the floor and anterior wall, immediately above the optic chiasma, the ventricle presents a small angular recess or diverticulum, the **optic** *34*

recess. Between the columns of the fornix, and above the anterior commissure, is a second recess termed the **vulva.** At the junction of the roof and anterior wall of the ventricle, and situated between the thalami behind and the columns of the fornix in front, is the **interventricular foramen** (*foramen of Monro*) through which the third communicates with the lateral ventricles.

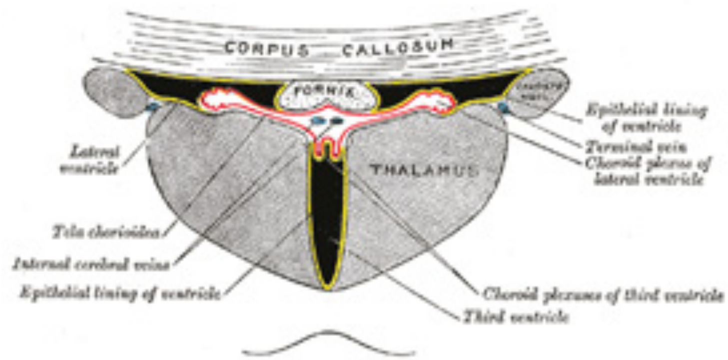


FIG. 723– Coronal section of lateral and third ventricles. (Diagrammatic.) (See enlarged image)

The **posterior boundary** is constituted by the pineal body, the posterior commissure and the cerebral aqueduct. A small recess, the **recessus pinealis,** projects into the stalk of the pineal body, while in front of and above the pineal body is a second recess, the **recessus suprapinealis,** consisting of a diverticulum of the epithelium which forms the ventricular roof. *35*

Each **lateral wall** consists of an upper portion formed by the medial surface of the anterior two-thirds of the thalamus, and a lower consisting of an upward continuation of the gray substance of the ventricular floor. These two parts correspond to the alar and basal laminæ respectively of the lateral wall of the fore-brain vesicle and are separated from each other by a furrow, the **sulcus of Monro,** which extends from the interventricular foramen to the cerebral aqueduct (pages 741 and 742). The lateral wall is limited above by the tænia thalami. The columns of the fornix curve downward in front of the interventricular foramen, and then run in the lateral walls of the ventricle, where, at first, they form distinct prominences, but subsequently are lost to sight. The lateral walls are joined to each other across the cavity of the ventricle by a band of gray matter, the**massa intermedia** (page 809). *36*

Interpeduncular Fossa (Fig. 724).—This is a somewhat lozenge-shaped area of the base of the brain, limited in front by the optic chiasma, behind by the antero-superior surface of the pons, antero-laterally by the converging optic tracts, and postero-laterally by the diverging cerebral peduncles. The structures contained in it have already been described; from behind forward, they are the posterior perforated substance, corpora mamillaria, tuber cinereum, infundibulum, and hypophysis. *37*

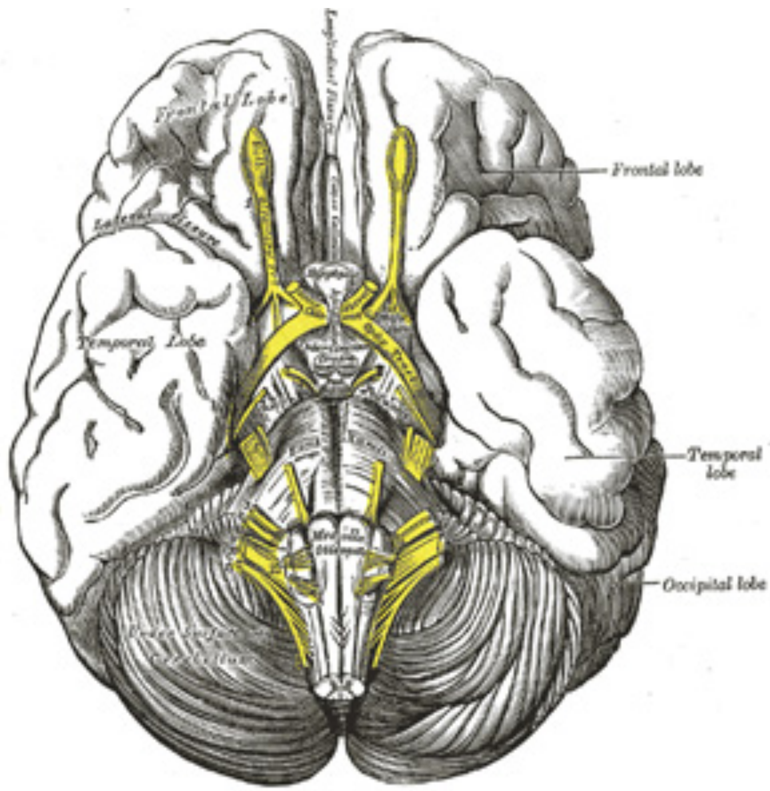


FIG. 724– Base of brain. (See enlarged image)

The Telencephalon.—The telencephalon includes: (1) the **cerebral hemispheres** with their cavities, the lateral ventricles; and (2) the **pars optica hypothalami** and the anterior portion of the third ventricle (already described under the diencephalon). As previously stated (see page 744), each cerebral hemisphere may be divided into three fundamental parts, viz., the rhinencephalon, the corpus striatum, and the neopallium. The rhinencephalon, associated with the sense of smell, is the oldest part of the telencephalon, and forms almost the whole of the hemisphere in some of the lower animals, *e. g.,* fishes, amphibians, and reptiles. In man it is rudimentary, whereas the neopallium undergoes great development and forms the chief part of the hemisphere. 38

The Cerebral Hemispheres.—The cerebral hemispheres constitute the largest part of the brain, and, when viewed together from above, assume the form of an ovoid mass broader behind than in front, the greatest transverse diameter corresponding with a line connecting the two parietal eminences. The hemispheres are separated medially by a deep cleft, named the **longitudinal cerebral fissure,** and each possesses a central cavity, the lateral ventricle. 39

The **Longitudinal Cerebral Fissure** (*fissura cerebri longitudinalis; great longitudinal fissure*) contains a sickle-shaped process of dura mater, the **falx cerebri.** It front and behind, the fissure extends from the upper to the under surfaces of the hemispheres and completely separates them, but its middle portion separates them for only about one-half of their vertical extent; for at this part they are connected across the middle line by a great central white commissure, the **corpus callosum.** 40

In a median sagittal section (Fig. 720) the cut corpus callosum presents the appearance of a broad, arched band. Its thick posterior end, termed the **splenium,** overlaps the mid-brain, but is separated from it by the tela chorioidea of the third ventricle and the pineal body. Its anterior curved end, termed the **genu,** gradually tapers into a thinner portion, the **rostrum,**which is continued downward and backward in front of the anterior commissure to join the lamina terminalis. Arching backward from immediately behind the anterior commissure to the under surface of the splenium is a second white band named the **fornix:**between this and the corpus callosum are the laminæ and cavity of the septum pellucidum. 41

Surfaces of the Cerebral Hemispheres.—Each hemisphere presents three surfaces:**lateral, medial,** and **inferior.** 42

The **lateral surface** is convex in adaptation to the concavity of the corresponding half of the vault of the cranium. The **medial surface** is flat and vertical, and is separated from that of the opposite hemisphere by the great longitudinal fissure and the falx cerebri. The**inferior surface** is of an irregular form, and may be divided into three areas: anterior, middle, and posterior. The anterior area, formed by the orbital surface of the frontal lobe, is concave, and rests on the roof of the orbit and nose; the middle area is convex, and consists of the under surface of the temporal lobe: it is adapted to the corresponding half of the middle cranial fossa. The posterior area is concave, directed medialward as well as downward, and is named the **tentorial surface,** since it rests upon the tentorium cerebelli, which intervenes between it and the upper surface of the cerebellum. 43

FIG. 725– Lateral surface of left cerebral hemisphere, viewed from above. (See enlarged image)

These three surfaces are separated from each other by the following **borders:** (*a*)**supero-medial,** between the lateral and medial surfaces; 44
(*b*) **infero-lateral,** between the lateral and inferior surfaces; the anterior part of this border separating the lateral from the orbital surface, is known as the **superciliary border;** (*c*) **medial occipital,** separating the medial and tentorial surfaces; and (*d*) **medial orbital,** separating the orbital from the medial surface. The anterior end of the hemisphere is named the **frontal pole;** the posterior, the **occipital pole;** and the anterior end of the temporal lobe, the **temporal pole.**About 5 cm. in front of the occipital pole on the infero-lateral border is an indentation or notch, named the **preoccipital notch.**

The surfaces of the hemispheres are moulded into a number of irregular eminences,named **gyri** or **convolutions,** and separated by furrows 45 termed **fissures** and **sulci.** The furrows are of two kinds, *complete* and *incomplete*. The former appear early in fetal life, are few in number, and are produced by infoldings of the entire thickness of the brain wall, and give rise to corresponding elevations in the interior of the ventricle. They comprise the hippocampal fissure, and parts of the calcarine and collateral fissures. The incomplete furrows are very numerous, and only indent the subjacent white substance, without producing any corresponding elevations in the ventricular cavity.

The gyri and their intervening fissures and the sulci are fairly constant in their arrangement; at the same time they vary within certain limits, not only in different individuals, but on the two hemispheres of the same brain. The convoluted condition of the surface permits of a great increase of the gray matter without the sacrifice of much additional space. The number and extent of the gyri, as well as the depth of the intervening furrows, appear to bear a direct relation to the intellectual powers of the individual. 46

Certain of the fissures and sulci are utilized for the purpose of dividing the hemisphere into lobes, and are therefore termed **interlobular;** included under this category are the lateral cerebral, parietoöccipital, calcarine, and collateral fissures, the central and cingulate sulci, and the sulcus circularis. 47

FIG. 726– Lateral surface of left cerebral hemisphere, viewed from the side. (See enlarged image)

The **Lateral Cerebral Fissure** (*fissura cerebri lateralis* [*Sylvii*]; *fissure of Sylvius*) (Fig. 726) is a well-marked cleft on the inferior and lateral surfaces of the hemisphere, and consists of a short stem which divides into three rami. The **stem** is situated on the base of the brain, and commences in a depression at the lateral angle of the anterior perforated substance. From this point it extends between the anterior part of the 48 temporal lobe and the orbital surface of the frontal lobe, and reaches the lateral surface of the hemisphere. Here it divides into three rami: an anterior horizontal, an anterior ascending, and a posterior. The**anterior horizontal ramus** passes foward for about 2.5 cm. into the inferior frontal gyrus, while the **anterior ascending ramus** extends upward into the same convolution for about an equal distance. The **posterior ramus** is the longest; it runs backward and slightly upward for about 7 cm., and ends by an upward inflexion in the parietal lobe.

The **Central Sulcus** (*sulcus centralis* [*Rolandi*]; *fissure of Rolando; central fissure*)(Figs. 725, 726) is situated about the middle of the lateral surface of the hemisphere, and begins in or near the longitudinal cerebral fissure, a little behind its mid-point. It runs sinuously downward and forward, and ends a little above the posterior ramus of the lateral fissure, and about 2.5 cm. behind the anterior ascending ramus of the same fissure. It described two chief curves: **a superior genu** with its concavity directed forward, and an**inferior genu** with its concavity directed backward. The central sulcus forms an angle opening forward of about 70° with the median plane. *49*

The Parietoöccipital Fissure (*fissura parietoöccipitalis*).—Only a small part of this fissure is seen on the lateral surface of the hemisphere, its chief part being on the medial surface. *50*

The **lateral part** of the parietoöccipital fissure (Fig. 726) is situated about 5 cm. in front of the occipital pole of the hemisphere, and measures about 1.25 cm. in length. *51*

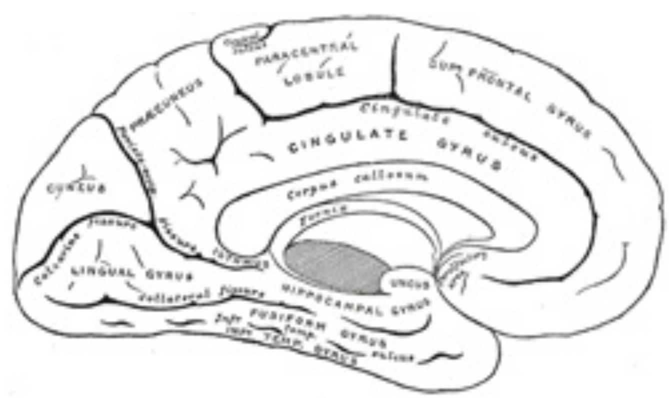


FIG. 727– Medial surface of left cerebral hemisphere. (See enlarged image)

The **medial part** of the parietoöccipital fissure (Fig. 727) runs downward and forward as a deep cleft on the medial surface of the hemisphere, and joins the calcarine fissure below and behind the posterior end of the corpus callosum. In most cases it contains a submerged gyrus. *52*

The **Calcarine Fissure** (*fissura calcarina*) (Fig. 727) is on the medial surface of the hemisphere. It begins near the occipital pole in two converging rami, and runs forward to a point a little below the splenium of the corpus callosum, where it is joined at an acute angle by the medial part of the parietoöccipital fissure. The anterior part of this fissure gives rise to the prominence of the **calcar avis** in the posterior cornu *53* of the lateral ventricle.

The **Cingulate Sulcus** (*sulcus cinguli; callosomarginal fissure*) (Fig. 727) is on the medial surface of the hemisphere; it begins below the anterior end of the corpus callosum and runs upward and forward nearly parallel to the rostrum of this body and, curving in front of the genu, is continued backward above the corpus callosum, and finally ascends to the supero-medial border of the hemisphere a short distance behind the upper end of the central sulcus. It separates the superior frontal from the cingulate gyrus. *54*

The **Collateral Fissure** (*fissura collateralis*) (Fig. 727) is on the tentorial surface of the hemisphere and extends from near the occipital pole to within a short distance of the temporal pole. Behind, it lies below and lateral to the calcarine fissure, from which it is separated by the lingual gyrus; in front, it is situated between the hippocampal gyrus and the anterior part of the fusiform gyrus. *55*

The **Sulcus Circularis** (*circuminsular fissure*) (Fig. 731) is on the lower and lateral surfaces of the hemisphere: it surrounds the insula and separates it from the frontal, parietal, and temporal lobes. *56*

Lobes of the Hemispheres.—By means of these fissures and sulci, assisted by certain arbitrary lines, each hemisphere is divided into the following lobes: the **frontal,** the**parietal,** the **temporal,** the **occipital,** the **limbic,** and the **insula.** *57*

Frontal Lobe (*lobus frontalis*).—On the lateral surface of the hemisphere this lobe extends from the frontal pole to the central sulcus, the latter separating it from the parietal lobe. Below, it is limited by the posterior ramus of the lateral fissure, which intervenes between it and the central lobe. On the medial surface, it is separated from the cingulate gyrus by the cingulate sulcus; and on the inferior surface, it is bounded behind by the stem of the lateral fissure. *58*

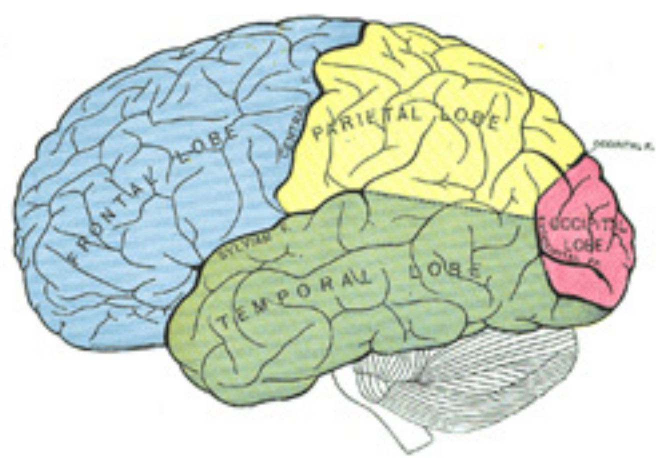


FIG. 728– Principal fissures and lobes of the cerebrum viewed laterally. (See enlarged image)

The **lateral surface** of the frontal lobe (Fig. 726) is tranversed by three sulci which divide it into four gyri: the sulci are named the precentral, 59
and the superior and inferior frontal; the gyri are the anterior central, and the superior, middle, and inferior frontal. The**precentral sulcus** runs parallel to the central sulcus, and is usually divided into an upper and a lower part; between it and the central sulcus is the **anterior central gyrus.** From the precentral sulcus, the **superior** and **inferior frontal sulci** run forward and downward, and divide the remainder of the lateral surface of the lobe into three parallel gyri, named, respectively the **superior, middle,** and **inferior frontal gyri.**

The **anterior central gyrus** (*gyrus centralis anterior; ascending frontal convolution; precentral gyre*) is bounded in front by the precentral 60
sulcus, behind by the central sulcus; it extends from the supero-medial border of the hemisphere to the posterior ramus of the lateral fissure.

The **superior frontal gyrus** (*gyrus frontalis superior; superfrontal gyre*) is situated above the superior frontal sulcus and is continued on to 61
the medial surface of the hemisphere. The portion on the lateral surface of the hemisphere is usually more or less completely subdivided into an upper and a lower part by an antero-posterior sulcus, the**paramedial sulcus,** which, however, is frequently interrupted by bridging gyri.

The **middle frontal gyrus** (*gyrus frontalis medius; medifrontal gyre*), between the superior and inferior frontal sulci, is continuous with the 62
anterior orbital gyrus on the inferior surface of the hemisphere; it is frequently subdivided into two by a horizontal sulcus, the **medial frontal sulcus** of Eberstaller, which ends anteriorly in a wide bifurcation.

The **inferior frontal gyrus** (*gyrus frontalis inferior; subfrontal gyre*) lies below the inferior frontal sulcus, and extends forward from the lower 63
part of the precentral sulcus; it is continuous with the lateral and posterior orbital gyri on the under surface of the lobe. It is subdivided by the anterior horizontal and ascending rami of the lateral fissure into three parts, viz., (1) the **orbital part,** below the anterior horizontal ramus of the fissure; (2) the**triangular part** (*cap of Broca*), between the ascending and horizontal rami; and (3) the**basilar part,** behind the anterior ascending ramus. The left inferior frontal gyrus is, as a rule, more highly developed than the right, and is named the **gyrus of Broca,** from the fact that Broca described it as the center for articulate speech.

The **inferior** or **orbital surface** of the frontal lobe is concave, and rests on the orbital plate of the frontal bone (Fig. 729). It is divided into four 64
orbital gyri by a well-marked H-shaped **orbital sulcus.** These are named, from their position, the **medial, anterior, lateral,**and **posterior orbital gyri.** The medial orbital gyrus presents a well-marked antero-posterior sulcus, the **olfactory sulcus,** for the olfactory tract; the portion medial to this is named the **straight gyrus,** and is continuous with the superior frontal gyrus on the medial surface.

The **medial surface** of the frontal lobe is occupied by the medial part of the superior frontal gyrus (*marginal gyrus*) (Fig. 727). It lies between 65
the cingulate sulcus and the supero-medial margin of the hemisphere. The posterior part of this gyrus is sometimes marked off by a vertical sulcus, and is distinguished as the **paracentral lobule,** because it is continuous with the anterior and posterior central gyri.

Parietal Lobe (*lobus parietalis*).—The parietal lobe is separated from the frontal lobe by the central sulcus, but its boundaries below and 66
behind are not so definite. Posteriorly, it is limited by the parietoöccipital fissure, and by a line carried across the hemisphere from the end of this fissure toward the preoccipital notch. Below, it is separated from the temporal lobe by the posterior ramus of the lateral fissure, and by a line carried backward from it to meet the line passing downward to the preoccipital notch.

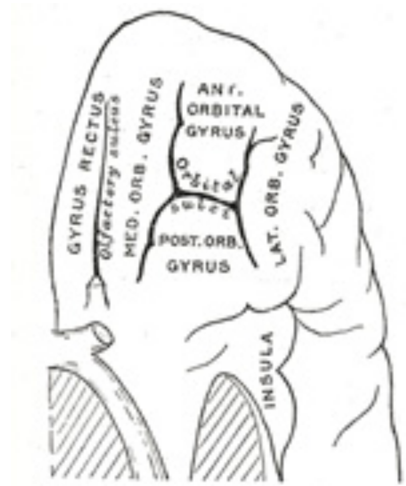


FIG. 729– Orbital surface of left frontal lobe. (See enlarged image)

The **lateral surface** of the parietal lobe (Fig. 726) is cleft by a well-marked furrow, the**intraparietal sulcus** of Turner, which consists of an 67
oblique and a horizontal portion. The oblique part is named the **postcentral sulcus,** and commences below, about midway between the lower end of the central sulcus and the upturned end of the lateral fissure. It runs upward and backward, parallel to the central sulcus, and is sometimes divided into an*upper* and a *lower* ramus. It forms the hinder limit of the posterior central gyrus.

From about the middle of the postcentral sulcus, or from the upper end of its inferior ramus, the **horizontal portion** of the intraparietal sulcus 68
is carried backward and slightly upward on the parietal lobe, and is prolonged, under the name of the **occipital ramus,** on to the occipital lobe, where it divides into two parts, which form nearly a right angle with the main stem and constitute the **transverse occipital sulcus.** The part of the parietal lobe above the horizontal portion of the intraparietal sulcus is named the **superior parietal lobule;** the part below, the **inferior parietal lobule.**

The **posterior central gyrus** (*gyrus centralis posterior; ascending parietal convolution; postcentral gyre*) extends from the longitudinal 69
fissure above to the posterior ramus of the lateral fissure below. It lies parallel with the anterior central gyrus, with which it is connected below, and also, sometimes, above, the central sulcus.

The **superior parietal lobule** (*lobulus parietalis superior*) is bounded in front by the upper part of the postcentral sulcus, but is usually 70
connected with the posterior central gyrus above the end of the sulcus; behind it is the lateral part of the parietoöccipital fissure, around the end of which it is joined to the occipital lobe by a curved gyrus, the **arcus parietoöccipitalis;** below, it is separated from the inferior parietal lobule by the horizontal portion of the intraparietal sulcus.

The **inferior parietal lobule** (*lobulus parietalis inferior; subparietal district or lobule*) lies below the horizontal portion of the intraparietal 71 sulcus, and behind the lower part of the postcentral sulcus. It is divided from before backward into two gyri. One, the**supramarginal,** arches over the upturned end of the lateral fissure; it is continuous in front with the postcentral gyrus, and behind with the superior temporal gyrus. The second, the**angular,** arches over the posterior end of the superior temporal sulcus, behind which it is continuous with the middle temporal gyrus.

The **medial surface** of the parietal lobe (Fig. 727) is bounded behind by the medial part of the parietoöccipital fissure; in front, by the posterior end of the cingulate sulcus; and below, it is separated from the cingulate gyrus by the **subparietal sulcus.** It is of small size, and consists of a square-shaped convolution, which is termed the **precuneus** or**quadrate lobe.** *72*

Occipital Lobe (*lobus occipitalis*).—The occipital lobe is small and pyramidal in shape; it presents three surfaces: **lateral, medial,** and **tentorial.** *73*

The **lateral surface** is limited in front by the lateral part of the parietoöccipital fissure, and by a line carried from the end of this fissure to the preoccipital notch; it is traversed by the transverse occipital and the lateral occipital sulci. The **transverse occipital sulcus** is continuous with the posterior end of the occipital ramus of the intraparietal sulcus, and runs across the upper part of the lobe, a short distance behind the parietoöccipital fissure. The **lateral occipital sulcus** extends from behind forward, and divides the lateral surface of the occipital lobe into a **superior** and an **inferior gyrus,** which are continuous in front with the parietal and temporal lobes. 125 *74*

The **medial surface** of the occipital lobe is bounded in front by the medial part of the parietoöccipital fissure, and is traversed by the calcarine fissure, which subdivides it into the cuneus and the lingual gyrus. The cuneus is a wedge-shaped area between the calcarine fissure and the medial part of the parietoöccipital fissure. The **lingual gyrus** lies between the calcarine fissure and the posterior part of the collateral fissure; behind, it reaches the occipital pole; in front, it is continued on to the tentorial surface of the temporal lobe, and joins the hippocampal gyrus. *75*

The **tentorial surface** of the occipital lobe is limited in front by an imaginary transverse line through the preoccipital notch, and consists of the posterior part of the **fusiform gyrus**(*occipitotemporal convolution*) and the lower part of the lingual gyrus, which are separated from each other by the posterior segment of the collateral fissure. *76*

Temporal Lobe (*lobus temporalis*).—The temporal lobe presents **superior, lateral,** and**inferior surfaces.** *77*

The **superior surface** forms the lower limit of the lateral fissure and overlaps the insula. On opening out the lateral fissure, three or four gyri will be seen springing from the depth of the hinder end of the fissure, and running obliquely forward and outward on the posterior part of the upper surface of the superior temporal gyrus; these are named the**transverse temporal gyri** (Heschl) (Fig. 730). *78*

The **lateral surface** (Fig. 726) is bounded above by the posterior ramus of the lateral fissure, and by the imaginary line continued backward from it; below, it is limited by the infero-lateral border of the hemisphere. It is divided into superior, middle, and inferior gyri by the superior and middle temporal sulci. The **superior temporal sulcus** runs from before backward across the temporal lobe, some little distance below, but parallel with, the posterior ramus of the lateral fissure; and hence it is often termed the **parallel sulcus.** The**middle temporal sulcus** takes the same direction as the superior, but is situated at a lower level, and is usually subdivided into two or more parts. The **superior temporal gyrus** lies between the posterior ramus of the lateral fissure and the superior temporal sulcus, and is continuous behind with the supramarginal and angular gyri. The **middle temporal gyrus**is placed between the superior and middle temporal sulci, and is joined posteriorly with the angular gyrus. The **inferior temporal gyrus** is placed below the middle temporal sulcus, and is connected behind with the inferior occipital *79* gyrus; it also extends around the infero-lateral border on to the inferior surface of the temporal lobe, where it is limited by the inferior sulcus.

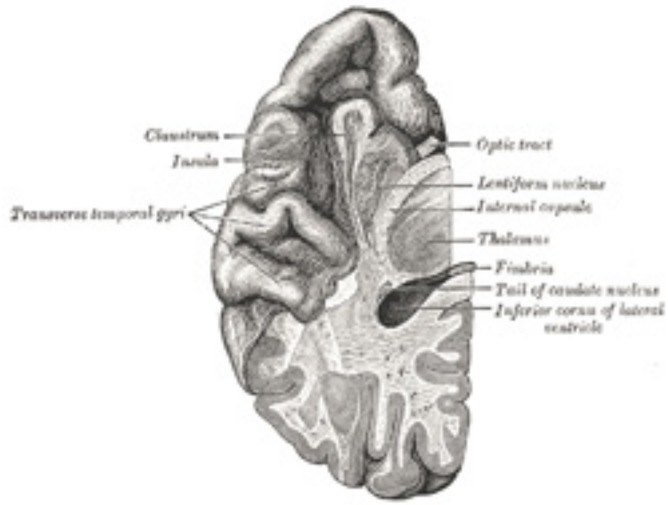


FIG. 730– Section of brain showing upper surface of temporal lobe. (See enlarged image)

The **inferior surface** is concave, and is continuous posteriorly with the tentorial surface of the occipital lobe. It is traversed by the **inferior temporal sulcus,** which extends from near the occipital pole behind, to within a short distance of the temporal pole in front, but is frequently subdivided by bridging gyri. Lateral to this fissure is the narrow tentorial part of the inferior temporal gyrus, and medial to it the **fusiform gyrus,** which extends from the occipital to the temporal pole; this gyrus is limited medially by the collateral fissure, which separates it from the lingual gyrus behind and from the hippocampal gyrus in front. *80*

The **Insula** (*island of Reil; central lobe*) (Fig. 731) lies deeply in the lateral or Sylvian fissure, and can only be seen when the lips of that fissure are widely separated, since it is overlapped and hidden by the gyri which bound the fissure. These gyri are termed the**opercula of the insula;** they are separated from each other by the three rami of the lateral fissure, and are named the orbital, frontal, frontoparietal, and temporal opercula. The**orbital operculum** lies below the anterior horizontal ramus of the fissure, the **frontal**between this and the anterior ascending ramus, the **parietal** between the anterior ascending ramus and the upturned end of the posterior ramus, and the **temporal** below the posterior ramus. The frontal operculum is of small size in those cases where the anterior horizontal and ascending rami of the lateral fissure arise from a common stem. The insula is surrounded by a deep **circular sulcus** which separates it from the frontal, parietal, and temporal lobes. When the opercula have been removed, the insula is seen as a triangular eminence, the apex of which is directed toward the anterior perforated substance. It is divided into a larger anterior and a smaller posterior part by a deep sulcus, which runs backward and upward from the apex of the insula. *81*

The anterior part is subdivided by shallow sulci into three or four **short gyri,** while the posterior part is formed by one **long gyrus,** which is often bifurcated at its upper end. The cortical gray substance of the insula is continuous with that of the different opercula, while its deep surface corresponds with the lentiform nucleus of the corpus striatum.

FIG. 731– The insula of the left side, exposed by removing the opercula. (See enlarged image)

Limbic Lobe (Fig. 727).—The term limbic lobe was introduced by Broca, and under it he included the cingulate and hippocampal gyri, which *82*
together arch around the corpus callosum and the hippocampal fissure. These he separated on the morphological ground that they are well-developed in animals possessing a keen sense of smell (osmatic animals), such as the dog and fox. They were thus regarded as a part of the rhinencephalon, but it is now recognized that they belong to the neopallium; the cingulate gyrus is therefore sometimes described as a part of the frontal lobe, and the hippocampal as a part of the temporal lobe.

The **cingulate gyrus** (*gyrus cinguli; callosal convolution*) is an arch-shaped convolution, lying in close relation to the superficial surface of the *83*
corpus callosum, from which it is separated by a slit-like fissure, the **callosal fissure.** It commences below the rostrum of the corpus callosum, curves around in front of the genu, extends along the upper surface of the body, and finally turns downward behind the splenium, where it is connected by a narrow**isthmus** with the hippocampal gyrus. It is separated from the medial part of the superior frontal gyrus by the cingulate sulcus, and from the precuneus by the subparietal sulcus.

The **hippocampal gyrus** (*gyrus hippocampi*) is bounded above by the hippocampal fissure, and below by the anterior part of the collateral *84*
fissure. Behind, it is continuous superiorly, through the isthmus, with the cingulate gyrus and inferiorly with the lingual gyrus. Running in the substance of the cingulate and hippocampal gyri, and connecting them together, is a tract of arched fibers, named the **cingulum** (page 843). The

anterior extremity of the hippocampal gyrus is recurved in the form of a hook (**uncus**), which is separated from the apex of the temporal lobe by a slight fissure, the **incisura temporalis.**Although superficially continuous with the hippocampal gyrus, the uncus forms morphologically a part of the rhinencephalon.

The **Hippocampal Fissure** (*fissura hippocampi; dentate fissure*) begins immediately behind the splenium of the corpus callosum, and runs 85
forward between the hippocampal and dentate gyri to end in the uncus. It is a complete fissure (page 819), and gives rise to the prominence of the hippocampus in the inferior cornu of the lateral ventricle.

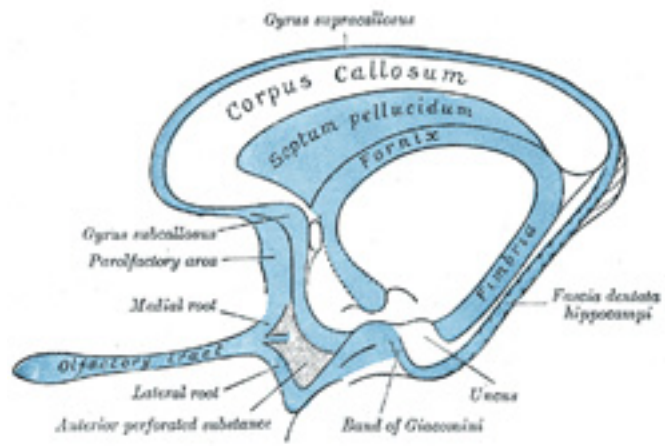


FIG. 732– Scheme of rhinencephalon. (See enlarged image)

Rhinencephalon (Fig. 732).—The rhinencephalon comprises the **olfactory lobe,** the**uncus,** the **subcallosal** and **supracallosal gyri,** the **fascia** 86
dentata hippocampi, the**septum pellucidum,** the **fornix,** and the **hippocampus.**

1. The **Olfactory Lobe** (*lobus olfactorius*) is situated under the inferior or orbital surface of the frontal lobe. In many vertebrates it constitutes 87
a well-marked portion of the hemisphere and contains an extension of the lateral ventricle; but in man and some other mammals it is rudimentary. It consists of the **olfactory bulb** and **tract,** the **olfactory trigone,** the **parolfactory area of Broca,** and the **anterior perforated substance.**

(*a*) The **olfactory bulb** (*bulbus olfactorius*) is an oval, reddish-gray mass which rests on the cribriform plate of the ethmoid and forms the 88
anterior expanded extremity of the olfactory tract. Its under surface receives the olfactory nerves, which pass upward through the cribriform plate from the olfactory region of the nasal cavity. Its minute structure is described on page 848.

(*b*) The **olfactory tract** (*tractus olfactorius*) is a narrow white band, triangular on coronal section, the apex being directed upward. It lies in the olfactory sulcus on the inferior surface of the frontal lobe, and divides posteriorly into two striæ, a medial and a lateral. The **lateral stria** is directed across the lateral part of the anterior perforated substance and then bends abruptly medialward toward the uncus of the hippocampal gyrus. The **medial stria** turns medialward behind the parolfactory area and ends in the subcallosal gyrus; in some cases a small **intermediate stria** is seen running backward to the anterior perforated substance. *89*

(*c*) The **olfactory trigone** (*trigonum olfactorium*) is a small triangular area in front of the anterior perforated substance. Its apex, directed forward, occupies the posterior part of the olfactory sulcus, and is brought into view by throwing back the olfactory tract. *90*

(*d*) The **parolfactory area of Broca** (*area parolfactoria*) is a small triangular field on the medial surface of the hemisphere in front of the subcallosal gyrus, from which it is separated by the posterior parolfactory sulcus; it is continuous below with the olfactory trigone, and above and in front with the cingulate gyrus; it is limited anteriorly by the anterior parolfactory sulcus. *91*

(*e*) The **anterior perforated substance** (*substantia perforata anterior*) is an irregularly quadrilateral area in front of the optic tract and behind the olfactory trigone, from which it is separated by the **fissure prima;** medially and in front it is continuous with the subcallosal gyrus; laterally it is bounded by the lateral stria of the olfactory tract and is continued into the uncus. Its gray substance is confluent above with that of the corpus striatum, and is perforated anteriorly by numerous small bloodvessels. *92*

2. The **Uncus** has already been described (page 826) as the recurved, hook-like portion of the hippocampal gyrus. *93*

3. The **Subcallosal, Supracallosal,** and **Dentate Gyri** form a rudimentary arch-shaped lamina of gray substance extending over the corpus callosum and above the hippocampal gyrus from the anterior perforated substance to the uncus. *94*

(*a*) The **subcallosal gyrus** (*gyrus subcallosus; peduncle of the corpus callosum*) is a narrow lamina on the medial surface of the hemisphere in front of the lamina terminalis, behind the parolfactory area, and below the rostrum of the corpus callosum. It is continuous around the genu of the corpus callosum with the supracallosal gyrus. *95*

(*b*) The **supracallosal gyrus** (*indusium griseum; gyrus epicallosus*) consists of a thin layer of gray substance in contact with the upper surface of the corpus callosum and continuous laterally with the gray substance of the cingulate gyrus. It contains two longitudinally directed strands of fibers termed respectively the **medial** and **lateral longitudinal striæ.** The supracallosal gyrus is prolonged around the splenium of the corpus callosum as a delicate lamina, the **fasciola cinerea,** which is continuous below with the fascia dentata hippocampi. *96*

(*c*) The **fascia dentata hippocampi** (*gyrus dentatus*) is a narrow band extending downward and forward above the hippocampal gyrus but separated from it by the hippocampal fissure; its free margin is notched and overlapped by the fimbria—the**fimbriodentate fissure** intervening. Anteriorly it is continued into the notch of the uncus, where it forms a sharp bend and is then prolonged as a delicate band, the **band of Giacomini,** over the uncus, on the lateral surface of which it is lost. *97*

The remaining parts of the rhinencephalon, viz., the septum pellucidum, fornix, and hippocampus, will be described in connection with the lateral ventricle. *98*

Interior of the Cerebral Hemispheres.—If the upper part of either hemisphere be removed, at a level about 1.25 cm. above the corpus callosum, the central white substance will be exposed as an oval-shaped area, the **centrum ovale minus,** surrounded by a narrow convoluted margin of gray substance, and studded with numerous minute red dots (**puncta vasculosa**), produced by the escape of blood from divided bloodvessels. If the remaining portions of the hemispheres be slightly drawn apart a broad band of white substance, the **corpus callosum,** will *99* be observed, connecting them at the bottom of the longitudinal fissure; the margins of the hemispheres which overlap the corpus callosum are called the **labia cerebri.** Each labrium is part of the cingulate gyrus already described; and the slit-like interval between it and the upper surface of the corpus callosum is termed the**callosal fissure** (Fig. 727). If the hemispheres be sliced off to a level with the upper surface of the corpus callosum, the white substance of that structure will be seen connecting the two hemispheres. The large expanse of medullary matter now exposed, surrounded by the convoluted margin of gray substance, is called the **centrum ovale majus.**

The **Corpus Callosum** (Fig. 733) is the great transverse commissure which unites the cerebral hemispheres and roofs in the lateral ventricles. *100*
A good conception of its position and size is obtained by examining a median sagittal section of the brain (Fig. 720), when it is seen to form an arched structure about 10 cm. long. Its anterior end is about 4 cm. from the frontal pole, and its posterior end about 6 cm. from the occipital pole of the hemisphere.

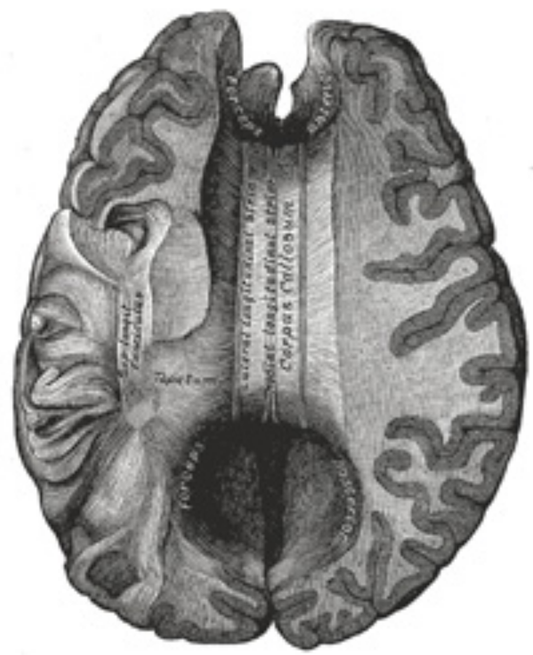


FIG. 733– Corpus callosum from above. (See enlarged image)

The **anterior end** is named the **genu,** and is bent downward and backward in front of the septum pellucidum; diminishing rapidly in thickness, *101* it is prolonged backward under the name of the **rostrum,** which is connected below with the lamina terminalis. The anterior cerebral arteries are in contact with the under surface of the rostrum; they then arch over the front of the genu, and are carried backward above the body of the corpus callosum.

The **posterior end** is termed the **splenium** and constitutes the thickest part of the corpus callosum. It overlaps the tela chorioidea of the third ventricle and the mid-brain, and ends in a thick, convex, free border. A sagittal section of the splenium shows that the posterior end of the corpus callosum is acutely bent forward, the upper and lower parts being applied to each other. *102*

The **superior surface** is convex from before backward, and is about 2.5 cm. wide. Its medial part forms the bottom of the longitudinal fissure, and is in contact posteriorly with the lower border of the falx cerebri. Laterally it is overlapped by the cingulate gyrus, but is separated from it by the slit-like callosal fissure. It is traversed by numerous transverse ridges and furrows, and is covered by a thin layer of gray matter, the **supracallosal gyrus,**which exhibits on either side of the middle line the medial and lateral longitudinal striæ, already described (page 827). *103*

The **inferior surface** is concave, and forms on either side of the middle line the roof of the lateral ventricle. Medially, this surface is attached in front to the septum pellucidum; behind this it is fused with the upper surface of the body of the fornix, while the splenium is in contact with the tela chorioidea. *104*

On either side, the fibers of the corpus callosum radiate in the white substance and pass to the various parts of the cerebral cortex; those curving forward from the genu into the frontal lobe constitute the **forceps anterior,** and those curving backward into the occipital lobe, the **forceps posterior.** Between these two parts is the main body of the fibers which constitute the **tapetum** and extend laterally on either side into the temporal lobe, and cover in the central part of the lateral ventricle. *105*

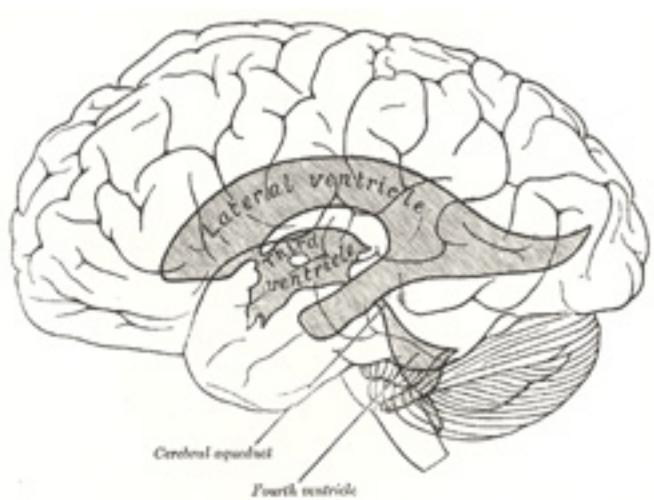


FIG. 734– Scheme showing relations of the ventricles to the surface of the brain. (See enlarged image)

The Lateral Ventricles (***ventriculus lateralis***) **(Fig. 734).**—The two lateral ventricles are irregular cavities situated in the lower and medial parts of the cerebral hemispheres, one on either side of the middle line. They are separated from each other by a median vertical partition, the **septum pellucidum,** but communicate with the third ventricle and indirectly with each other through the **interventricular foramen.** They are lined by a thin, diaphanous membrane, the **ependyma,** covered by ciliated epithelium, and contain cerebrospinal fluid, which, even in health, may be secreted in considerable amount. Each lateral ventricle consists of a **central part** or **body,** and three prolongations from it, termed**cornua** (Figs. 735, 736). *106*

The **central part** (*pars centralis ventriculi lateralis; cella*) (Fig. 737) of the lateral ventricle extends from the interventricular foramen to the splenium of the corpus callosum. It is an irregularly curved cavity, triangular on transverse section, with a roof, a floor, and a medial wall. The roof is formed by the under surface of the corpus callosum; the floor by the following parts, enumerated in their order of position, from before backward: the caudate nucleus of the corpus striatum, the stria terminalis and the terminal vein, the lateral portion of the upper surface of the thalamus, the choroid plexus, and the lateral part of the fornix; the medial wall is the posterior part of the septum pellucidum, which separates it from the opposite ventricle. *107*

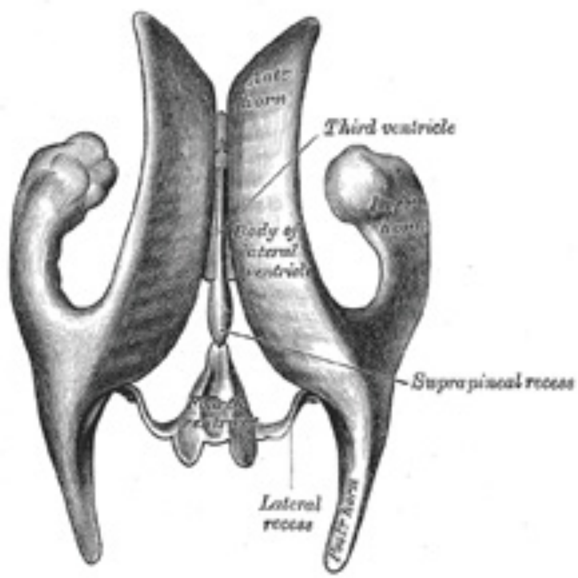


FIG. 735– Drawing of a cast of the ventricular cavities, viewed from above. (Retzius.) (See enlarged image)

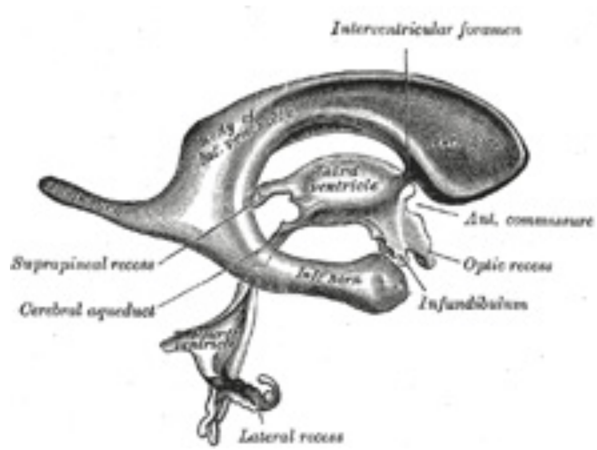


FIG. 736– Drawing of a cast of the ventricular cavities, viewed from the side. (Retzius.) (See enlarged image)

The **anterior cornu** (*cornu anterius; anterior horn; precornu*) (Fig. 736) passes forward and lateralward, with a slight inclination downward, *108*
from the interventricular foramen into the frontal lobe, curving around the anterior end of the caudate nucleus. Its floor is formed by the upper surface of the reflected portion of the corpus callosum, the **rostrum.** It is bounded medially by the anterior portion of the septum pellucidum, and laterally by the head of the caudate nucleus. Its apex reaches the posterior surface of the genu of the corpus callosum.

The **posterior cornu** (*cornu posterius; postcornu*) (Figs. 737, 788) passes into the occipital lobe, its direction being backward and lateralward, *109*
and then medialward. Its roof is formed by the fibers of the corpus callosum passing to the temporal and occipital lobes. On its medial wall is a longitudinal eminence, the **calcar avis** (*hippocampus minor*), which is an involution of the ventricular wall produced by the calcarine fissure. Above this the forceps posterior of the corpus callosum, sweeping around to enter the occipital lobe, causes another projection, termed the **bulb of the posterior cornu.** The calcar avis and bulb of the posterior cornu are extremely variable in their degree of development; in some cases they are ill-defined, in others prominent.

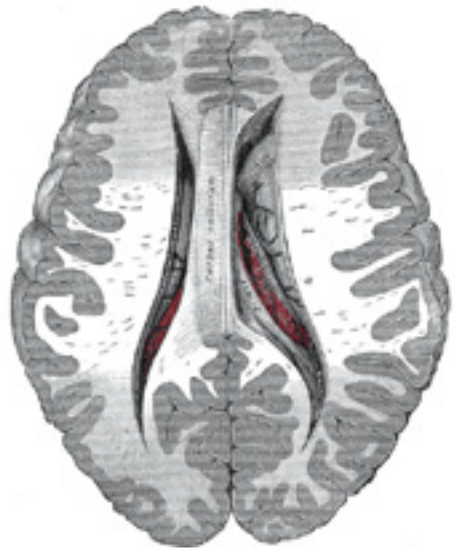


FIG. 737– Central part and anterior and posterior cornua of lateral ventricles exposed from above. (See enlarged image)

The **inferior cornu** (*cornu inferior; descending horn; middle horn; medicornu*) (Fig. 739), the largest of the three, traverses the temporal lobe 110
of the brain, forming in its course a curve around the posterior end of the thalamus. It passes at first backward, lateralward, and downward, and then curves forward to within 2.5 cm. of the apex of the temporal lobe, its direction being fairly well indicated on the surface of the brain by that of the superior temporal sulcus. Its roof is formed chiefly by the inferior surface of the tapetum of the corpus callosum, but the tail of the caudate nucleus and the stria terminalis also extend forward in the roof of the inferior cornu to its extremity; the tail of the caudate nucleus joins the putamen. Its floor presents the following parts: the hippocampus, the fimbria hippocampi, the collateral eminence, and the choroid plexus. When the choroid plexus is removed, a cleft-like opening is left along the medial wall of the inferior cornu; this cleft constitutes the lower part of the choroidal fissure.

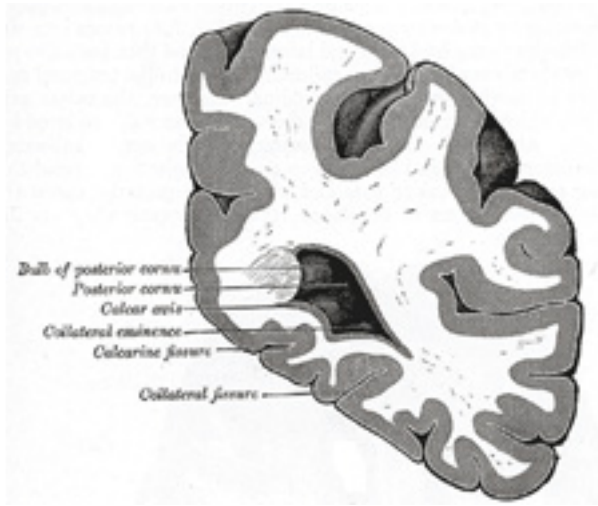


FIG. 738– Coronal section through posterior cornua of lateral ventricle. (See enlarged image)

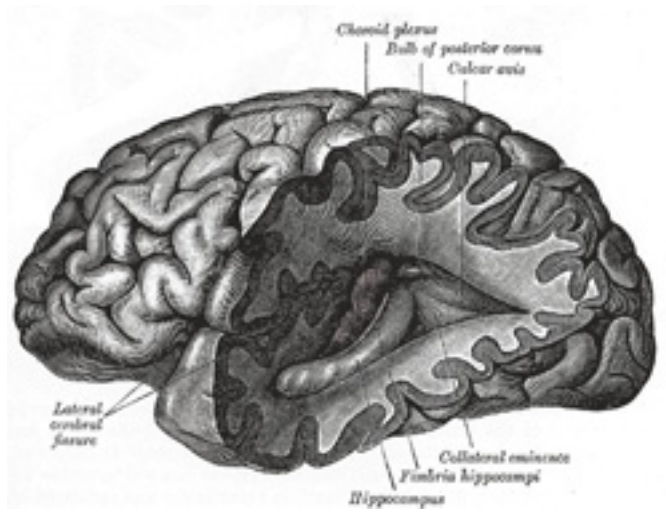


FIG. 739– Posterior and inferior cornua of left lateral ventricle exposed from the side. (See enlarged image)

The **hippocampus** (*hippocampus major*) (Figs. 739, 740) is a curved eminence, about 5 cm. long, which extends throughout the entire length *111*
of the floor of the inferior cornu. Its lower end is enlarged, and presents two or three rounded elevations or digitations which give it a paw-like appearance, and hence it is named the **pes hippocampi.** If a transverse section be made through the hippocampus, it will be seen that this eminence is produced by the folding of the wall of the hemisphere to form the hippocampal fissure. The main mass of the hippocampus consists of gray substance, but on its ventricular surface is a thin white layer, the **alveus,** which is continuous with the fimbria hippocampi.

The **collateral eminence** (*eminentia collateralis*) (Fig. 740) is an elongated swelling lying lateral to and parallel with the hippocampus. It *112*
corresponds with the middle part of the collateral fissure, and its size depends on the depth and direction of this fissure. It is continuous behind with a flattened triangular area, the **trigonum collaterale,** situated between the posterior and inferior cornua.

The fimbria hippocampi is a continuation of the crus of the fornix, and will be discussed with that body; a description of the choroid plexus *113*
will be found on page 840.

FIG. 740– Inferior and posterior cornua, viewed from above. (See enlarged image)

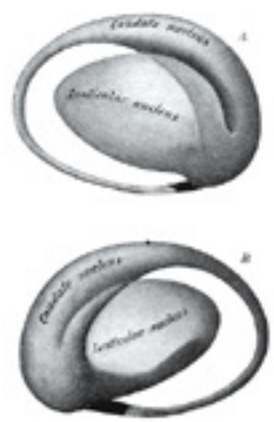


FIG. 741– Two views of a model of the striatum: *A,* lateral aspect; *B,* mesal aspect. (See enlarged image)

The **corpus striatum** has received its name from the striped appearance which a section of its anterior part presents, in consequence of diverging white fibers being mixed with the gray substance which forms its chief mass. A part of the corpus striatum is imbedded in the white substance of the hemisphere, and is therefore external to the ventricle; it is termed the **extraventricular portion,** or the **lentiform nucleus;** the remainder, however, projects into the ventricle, and is named the **intraventricular portion,** or the **caudate nucleus**(Fig. 737). *114*

The **caudate nucleus** (*nucleus caudatus; caudatum*) (Figs. 741, 742) is a pear-shaped, highly arched gray mass; its broad extremity, or **head,** is directed forward into the anterior cornu of the lateral ventricle, and is continuous with the anterior perforated substance and with the anterior end of the lentiform nucleus; its narrow end, **or tail,** is directed backward on the lateral side of the thalamus, from which it is separated by the stria terminalis and the terminal vein. It is then continued downward into the roof of the inferior cornu, and ends in the putamen near the apex of the temporal lobe. It is covered by the lining of the ventricle, and crossed by some veins of considerable size. It is separated from the lentiform nucleus, in the greater part of its extent, by a thick lamina of white substance, called the**internal capsule,** but the two portions of the corpus striatum are united in front (Figs. 743,744). *115*

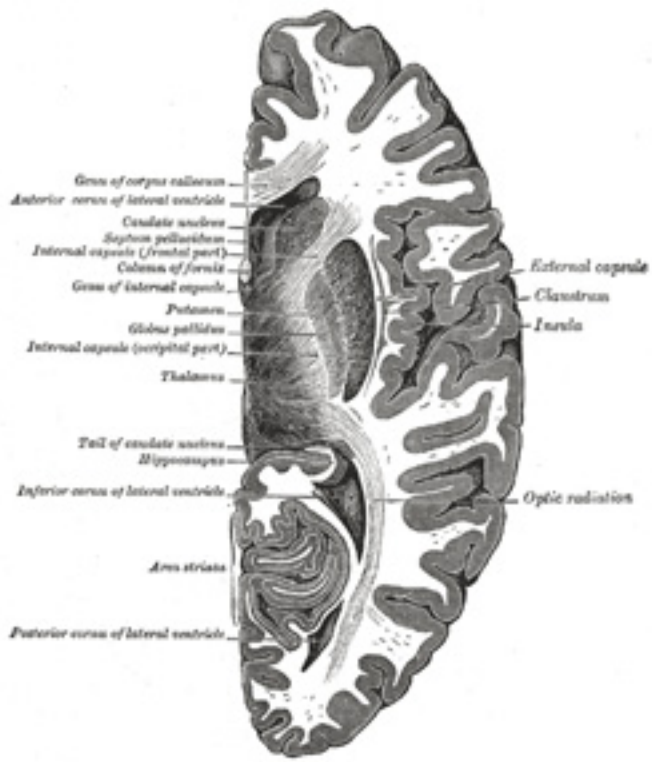


FIG. 742– Horizontal section of right cerebral hemisphere. (See enlarged image)

The **lentiform nucleus** (*nucleus lentiformis; lenticular nucleus; lenticula*) (Fig. 741) is lateral to the caudate nucleus and thalamus, and is seen only in sections of the hemisphere. When divided horizontally, it exhibits, to some extent, the appearance of a biconvex lens(Fig. 742), while a coronal section of its central part presents a somewhat triangular outline. It is shorter than the caudate nucleus and does not extend as far forward. It is bounded laterally by a lamina of white substance called the **external capsule,** and lateral to this is a thin layer of gray substance termed the **claustrum.** Its anterior end is continuous with the lower part of the head of the caudate nucleus and with the anterior perforated substance. *116*

In a coronal section through the middle of the lentiform nucleus, two **medullary laminæ**are seen dividing it into three parts. The lateral and largest part is of a reddish color, and is known as the **putamen,** while the medial and intermediate are of a yellowish tint, and together constitute the **globus pallidus;** all three are marked by fine radiating white fibers, which are most distinct in the putamen (Fig. 744). *117*

The gray substance of the corpus striatum is traversed by nerve fibers, some of which originate in it. The cells are multipolar, both large and small; those of the lentiform nucleus contain yellow pigment. The caudate and lentiform nuclei are not only directly continuous with each other anteriorly, but are connected to each other by numerous fibers. The corpus striatum is also connected: (1) to the cerebral cortex, by what are termed the **corticostriate fibers;** (2) to the thalamus, by fibers which pass through the internal capsule, and by a strand named the **ansa lentiformis;** (3) to the cerebral peduncle, by fibers which leave the lower aspect of the caudate and lentiform nuclei. *118*

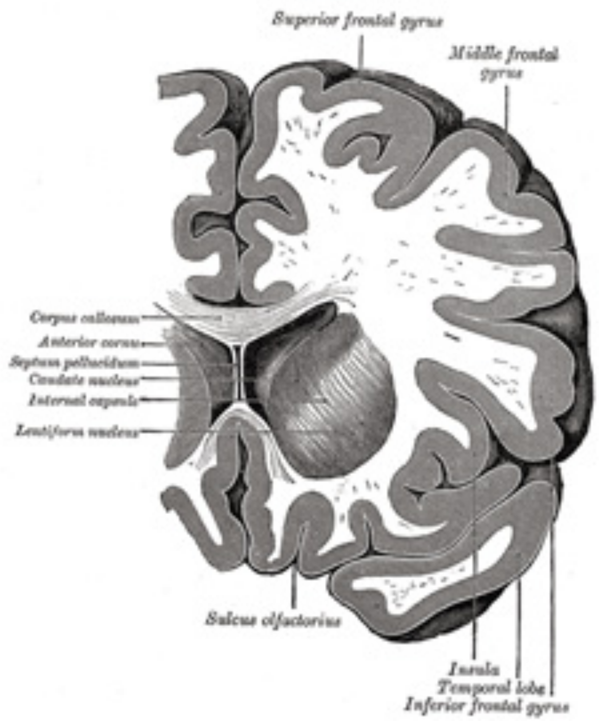


FIG. 743– Coronal section through anterior cornua of lateral ventricles. (See enlarged image)

The **claustrum** (Figs. 742, 744) is a thin layer of gray substance, situated on the lateral surface of the external capsule. Its transverse section is *119*
triangular, with the apex directed upward. Its medial surface, contiguous to the external capsule, is smooth, but its lateral surface presents ridges and furrows corresponding with the gyri and sulci of the insula, with which it is in close relationship. The claustrum is regarded as a detached portion of the gray substance of the insula, from which it is separated by a layer of white fibers, the**capsula extrema** (*band of Baillarger*). Its cells are small and spindle-shaped, and contain yellow pigment; they are similar to those of the deepest layer of the cortex.

The **nucleus amygdalæ** (*amygdala*) (Fig. 741), is an ovoid gray mass, situated at the lower end of the roof of the inferior cornu. It is merely a *120*
localized thickening of the gray cortex, continuous with that of the uncus; in front it is continuous with the putamen, behind with the stria terminalis and the tail of the caudate nucleus.

The **internal capsule** (*capsula interna*) (Figs. 745, 746) is a flattened band of white fibers, between the lentiform nucleus on the lateral side *121* and the caudate nucleus and thalamus on the medial side. In horizontal section (Figs. 742) it is seen to be somewhat abruptly curved, with its convexity inward; the prominence of the curve is called the **genu,**and projects between the caudate nucleus and the thalamus. The portion in front of the genu is termed the frontal part, and separates the lentiform from the caudate nucleus; the portion behind the genu is the occipital part, and separates the lentiform nucleus from the thalamus.

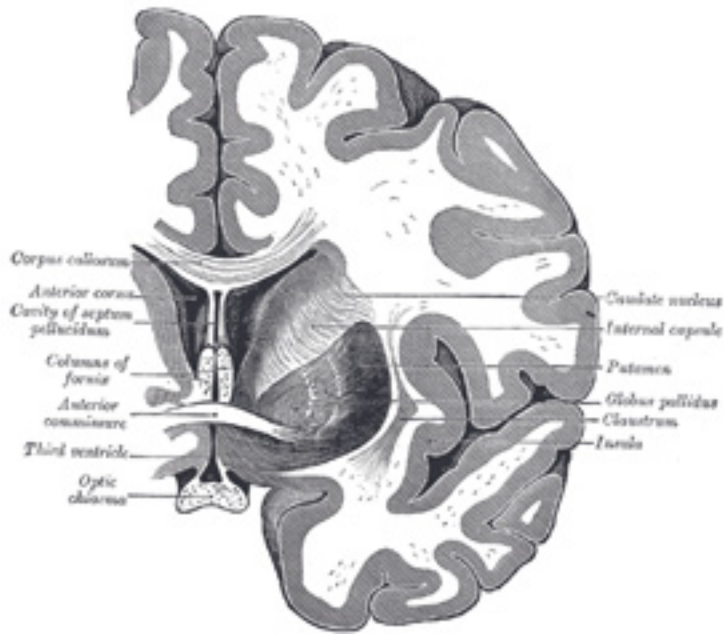


FIG. 744– Coronal section of brain through anterior commissure. (See enlarged image)

The *frontal part* of the internal capsule contains: (1) fibers running from the thalamus to the frontal lobe; (2) fibers connecting the lentiform 122
and caudate nuclei; (3) fibers connecting the cortex with the corpus striatum; and (4) fibers passing from the frontal lobe through the medial fifth of the base of the cerebral peduncle to the nuclei pontis. The fibers in the region of the genu are named the **geniculate fibers;** they originate in the motor part of the cerebral cortex, and, after passing downward through the base of the cerebral peduncle with the cerebrospinal fibers, undergo decussation and end in the motor nuclei of the cranial nerves of the opposite side. The anterior two-thirds of the occipital part of the internal capsule contains the **cerebrospinal fibers,** which arise in the motor area of the cerebral cortex and, passing downward through the middle three-fifths of the base of the cerebral peduncle, are continued into the pyramids of the medulla oblongata. The posterior third of the

occipital part contains: (1) sensory fibers, largely derived from the thalamus, though some may be continued upward from the medial lemniscus; (2) the fibers of optic radiation, from the lower visual centers to the cortex of the occipital lobe; (3) acoustic fibers, from the lateral lemniscus to the temporal lobe; and (4) fibers which pass from the occipital and temporal lobes to the nuclei pontis.

The fibers of the internal capsule radiate widely as they pass to and from the various parts of the cerebral cortex, forming the **corona** 123
radiata (Fig. 745) and intermingling with the fibers of the corpus callosum.

The **external capsule** (*capsula externa*) (Fig. 742) is a lamina of white substance, situated lateral to the lentiform nucleus, between it and the 124
claustrum, and continuous with the internal capsule below and behind the lentiform nucleus. It probably contains fibers derived from the thalamus, the anterior commissure, and the subthalamic region.

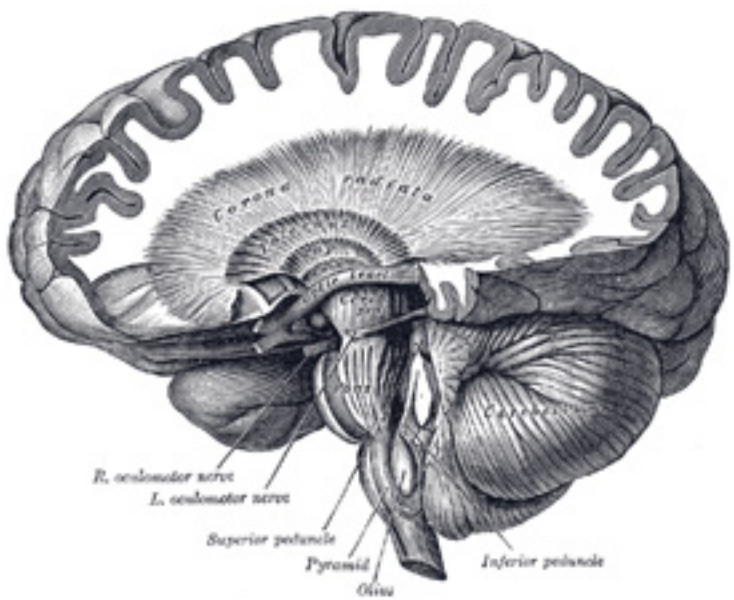


FIG. 745– Dissection showing the course of the cerebrospinal fibers. (E. B. Jamieson.) (See enlarged image)

The **substantia innominata of Meynert** is a stratum consisting partly of gray and partly of white substance, which lies below the anterior part 125
of the thalamus and lentiform nucleus. It consists of three layers, superior, middle, and inferior. The *superior* layer is named the **ansa lentiformis,** and its fibers, derived from the medullary lamina of the lentiform nucleus, pass medially to end in the thalamus and subthalamic region, while others are said to end in the tegmentum and red nucleus. The *middle* layer consists of nerve cells and nerve fibers; fibers enter it

from the parietal lobe through the external capsule, while others are said to connect it with the medial longitudinal fasciculus. The*inferior* layer forms the main part of the inferior stalk of the thalamus, and connects this body with the temporal lobe and the insula.

The **stria terminalis** (*tænia semicircularis*) is a narrow band of white substance situated in the depression between the caudate nucleus and the thalamus. Anteriorly, its fibers are partly continued into the column of the fornix; some, however, pass over the anterior commissure to the gray substance between the caudate nucleus and septum pellucidum, while others are said to enter the caudate nucleus. Posteriorly, it is continued into the roof of the inferior cornu of the lateral ventricle, at the extremity of which it enters the nucleus amygdalæ. Superficial to it is a large vein, the **terminal vein** (*vein of the corpus striatum*), which receives numerous tributaries from the corpus striatum and thalamus; it runs forward to the interventricular foramen and there joins with the vein of the choroid plexus to form the corresponding internal cerebral vein. On the surface of the terminal vein is a narrow white band, named the **lamina affixa.** *126*

The **Fornix** (Figs. 720, 747, 748) is a longitudinal, arch-shaped lamella of white substance, situated below the corpus callosum, and continuous with it behind, but separated from it in front by the septum pellucidum. It may be described as consisting of two symmetrical bands, one for either hemisphere. The two portions are not united to each other in front and behind, but their central parts are joined together in the middle line. The anterior parts are called the **columns** of the fornix; the intermediate united portions, the**body;** and the posterior parts, the **crura.** *127*

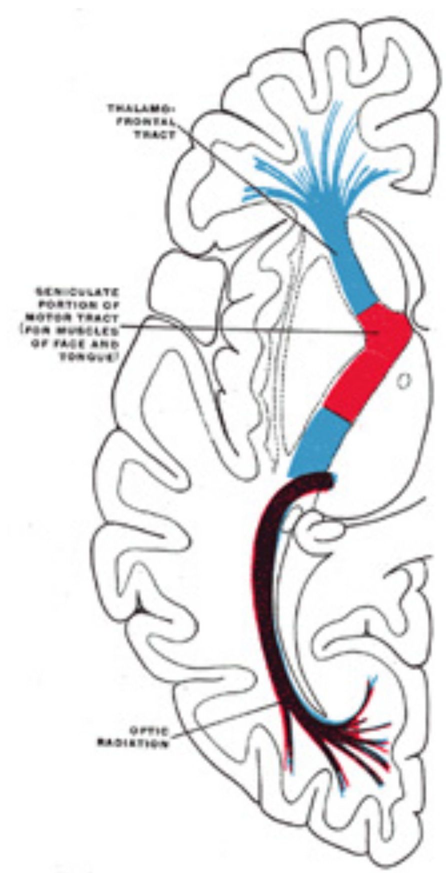


FIG. 746– Diagram of the tracts in the internal capsule. Motor tract red. The sensory tract (blue) is not direct, but formed of neurons receiving impulses from below in the thalamus and transmitting them to the cortex. The optic radiation (occipitothalamic) is shown in violet. (See enlarged image)

The **body** (*corpus fornicis*) of the fornix is triangular, narrow in front, and broad behind. The medial part of its upper surface is connected to the septum pellucidum in front and to the corpus callosum behind. The lateral portion of this surface forms part of the floor of the lateral ventricle, and is covered by the ventricular epithelium. Its lateral edge overlaps the choroid plexus, and is continuous with the epithelial 128 covering of this structure. The under surface rests upon the tela chorioidea of the third ventricle, which separates it from the epithelial roof of that cavity, and from the medial portions of the upper surfaces of the thalami. Below, the lateral portions of the body of the fornix are joined by a thin triangular lamina, named the **psalterium** (*lyra*). This lamina contains some transverse fibers which connect the two hippocampi across the middle line and constitute the **hippocampal commissure.** Between the psalterium and the corpus callosum a horizontal cleft, the so-called **ventricle of the fornix** (*ventricle of Verga*), is sometimes found.

The **columns** (*columna fornicis; anterior pillars; fornicolumns*) of the fornix arch downward in front of the interventricular foramen and *129*
behind the anterior commissure,and each descends through the gray substance in the lateral wall of the third ventricle to the base of the brain, where it ends in the corpus mammillare. From the cells of the corpus mammillare the **thalamomammillary fasciculus** (*bundle of Vicq d'Azyr*) takes origin and is prolonged into the anterior nucleus of the thalamus. The column of the fornix and the thalamomammillary fasciculus together form a loop resembling the figure 8, but the continuity of the loop is broken in the corpus mammillare. The column of the fornix is joined by the stria medullaris of the pineal body and by the superficial fibers of the stria terminalis, and is said to receive also fibers from the septum pellucidum. Zuckerkandl describes an **olfactory fasciculus** which becomes detached from the main portion of the column of the fornix, and passes downward in front of the anterior commissure to the base of the brain, where it divides into two bundles, one joining the medial stria of the olfactory tract; the other joins the subcallosal gyrus, and through it reaches the hippocampal gyrus.

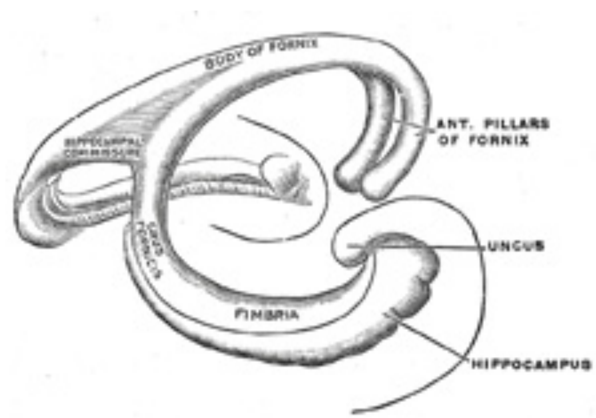


FIG. 747– Diagram of the fornix. (Spitzka.) (See enlarged image)

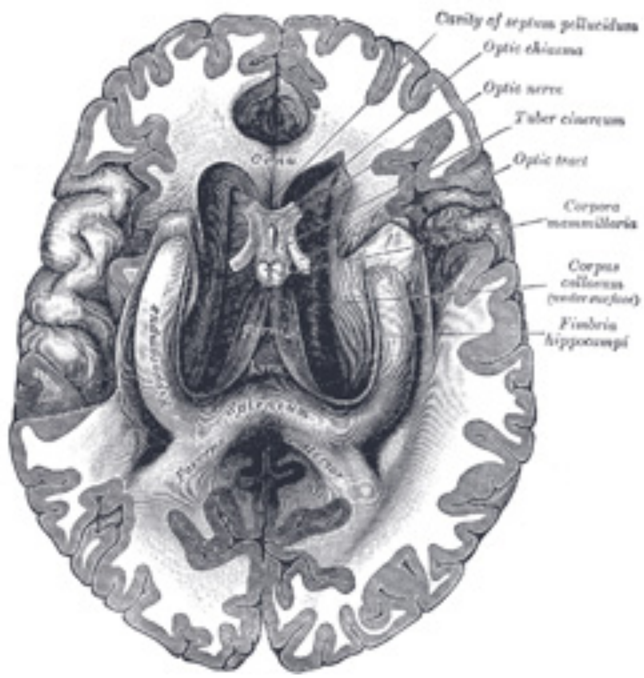


FIG. 748– The fornix and corpus callosum from below. (From a specimen in the Department of Human Anatomy of the University of Oxford.)
(See enlarged image)

The **crura** (*crus fornicis; posterior pillars*) of the fornix are prolonged backward from the body. They are flattened bands, and at their 130
commencement are intimately connected with the under surface of the corpus callosum. Diverging from one another, each curves around the posterior end of the thalamus, and passes downward and forward into the inferior cornu of the lateral ventricle (Fig. 750). Here it lies along the concavity of the hippocampus, on the surface of which some of its fibers are spread out to form the **alveus,**while the remainder are continued as a narrow white band, the **fimbria hippocampi,**which is prolonged into the uncus of the hippocampal gyrus. The inner edge of the fimbria overlaps the **fascia dentata hippocampi** (*dentate gyrus*) (page 827), from which it is separated by the **fimbriodentate fissure;** from its lateral margin, which is thin and ragged, the ventricular epithelium is reflected over the choroid plexus as the latter projects into the chorioidal fissure.

Interventricular Foramen (*foramen of Monro*).—Between the columns of the fornix and the anterior ends of the thalami, an oval aperture is 131
present on either side: this is the interventricular foramen, and through it the lateral ventricles communicate with the third ventricle. Behind the

epithelial lining of the foramen the choroid plexuses of the lateral ventricles are joined across the middle line.

The **Anterior Commissure** (*precommissure*) is a bundle of white fibers, connecting the two cerebral hemispheres across the middle line, and placed in front of the columns of the fornix. On sagittal section it is oval in shape, its long diameter being vertical and measuring about 5 mm. Its fibers can be traced lateralward and backward on either side beneath the corpus striatum into the substance of the temporal lobe. It serves in this way to connect the two temporal lobes, but it also contains decussating fibers from the olfactory tracts. 132

The **Septum Pellucidum** (*septum lucidum*) (Fig. 720) is a thin, vertically placed partition consisting of two laminæ, separated in the greater part of their extent by a narrow chink or interval, the **cavity of the septum pellucidum.** It is attached, above, to the under surface of the corpus callosum; below, to the anterior part of the fornix behind, and the reflected portion of the corpus callosum in front. It is triangular in form, broad in front and narrow behind; its inferior angle corresponds with the upper part of the anterior commissure. The lateral surface of each lamina is directed toward the body and anterior cornu of the lateral ventricle, and is covered by the ependyma of that cavity. 133

The **cavity of the septum pellucidum** (*cavum septi pellucidi; pseudocele; fifth ventricle*) is generally regarded as part of the longitudinal cerebral fissure, which has become shut off by the union of the hemispheres in the formation of the corpus callosum above and the fornix below. Each half of the septum therefore forms part of the medial wall of the hemisphere, and consists of a medial layer of gray substance, derived from that of the cortex, and a lateral layer of white substance continuous with that of the cerebral hemispheres. This cavity is not developed from the cavity of the cerebral vesicles, and never communicates with the ventricles of the brain. 134

The **Choroid Plexus of the Lateral Ventricle** (*plexus chorioideus ventriculus lateralis; paraplexus*) (Fig. 750) is a highly vascular, fringe-like process of pia mater, which projects into the ventricular cavity. The plexus, however, is everywhere covered by a layer of epithelium continuous with the epithelial lining of the ventricle. It extends from the interventricular foramen, where it is joined with the plexus of the opposite ventricle, to the end of the inferior cornu. The part in relation to the body of the ventricle forms the vascular fringed margin of a triangular process of pia mater, named the **tela chorioidea of the third ventricle,** and projects from under cover of the lateral edge of the fornix. It lies upon the upper surface of the thalamus, from which the epithelium is reflected over the plexus on to the edge of the fornix (Fig. 723). The portion in relation to the inferior cornu lies in the concavity of the hippocampus and overlaps the fimbria hippocampi: from the lateral edge of the fimbria the epithelium is reflected over the plexus on to the roof of the cornu (Fig. 749). It consists of minute and highly vascular villous processes, each with an afferent and an efferent vessel. The *arteries* of the plexus are: (*a*) the anterior choroidal, a branch of the internal carotid, which enters the plexus at the end of the inferior cornu; and (*b*) the posterior choroidal, one or two small branches of the posterior cerebral, which pass forward under the splenium. The *veins* of the choroid plexus unite to form a tortuous vein, which courses from behind forward to the interventricular foramen and there joins with the terminal vein to form the corresponding internal cerebral vein. 135

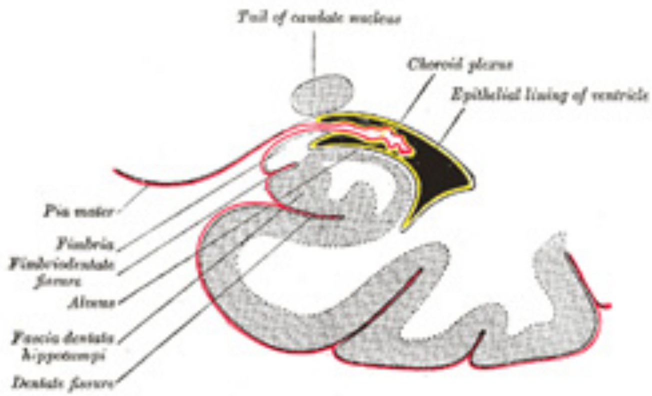


FIG. 749– Coronal section of inferior horn of lateral ventricle. (Diagrammatic.) (See enlarged image)

When the choroid plexus is pulled away, the continuity between its epithelial covering and the epithelial lining of the ventricle is severed, and a cleft-like space is produced. This is named the **choroidal fissure;** like the plexus, it extends from the interventricular foramen to the end of the inferior cornu. The upper part of the fissure, *i.e.,* the part nearest the interventricular foramen is situated between the lateral edge of the fornix and the upper surface of the thalamus; farther back at the beginning of the inferior cornu it is between the commencement of the fimbria hippocampi and the posterior end of the thalamus, while in the inferior cornu it lies between the fimbria in the floor and the stria terminalis in the roof of the cornu. *136*

The **tela chorioidea of the third ventricle** (*tela chorioidea ventriculi tertii; velum interpositum*) (Fig. 750) is a double fold of pia mater, triangular in shape, which lies beneath the fornix. The lateral portions of its lower surface rest upon the thalami, while its medial portion is in contact with the epithelial roof of the third ventricle. Its apex is situated at the interventricular foramen; its base corresponds with the splenium of the corpus callosum, and occupies the interval between that structure above and the corpora quadrigemina and pineal body below. *137*
This interval, together with the lower portions of the choroidal fissures, is sometimes spoken of as the **transverse fissure of the brain.** At its base the two layers of the velum separate from each other, and are continuous with the pia mater investing the brain in this region. Its lateral margins are modified to form the highly vascular choroid plexuses of the lateral ventricles. It is supplied by the anterior and posterior choroidal arteries already described, The veins of the tela chorioidea are named the **internal cerebral veins** (*venæ Galeni*); they are two in number, and run backward between its layers, each being formed at the interventricular foramen by the union of the terminal vein with the choroidal vein. The internal cerebral veins unite posteriorly in a single trunk, the **great cerebral vein** (*vena magna Galeni*), which passes backward beneath the splenium and ends in the straight sinus.

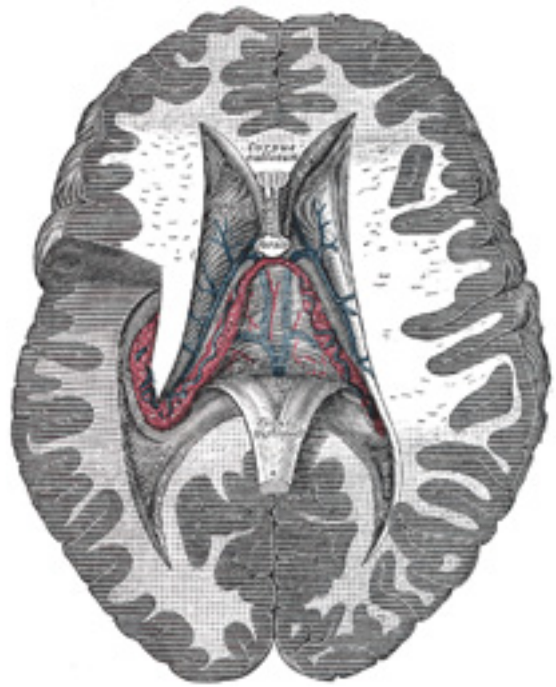


FIG. 750– Tela chorioidea of the third ventricle, and the choroid plexus of the left lateral ventricle, exposed from above. (See enlarged image)

Structure of the Cerebral Hemispheres.—The cerebral hemispheres are composed of gray and white substance: the former covers their surface, and is termed the **cortex;** the latter occupies the interior of the hemispheres. 138

The **white substance** consists of medullated fibers, varying in size, and arranged in bundles separated by neuroglia. They may be divided, according to their course and connections, into three distinct systems. (1) **Projection fibers** connect the hemisphere with the lower parts of the brain and with the medulla spinalis. (2) **Transverse** or **commissural fibers** unite the two hemispheres. (3) **Association fibers** connect different structures in the same hemisphere; these are, in many instances, collateral branches of the projection fibers, but others are the axons of independent cells. 139

1. The **projection fibers** consist of efferent and afferent fibers uniting the cortex with the lower parts of the brain and with the medulla spinalis. The principal efferent strands are: (1) the *motor tract,* occupying the genu and anterior two-thirds of the occipital part of the internal 140

capsule, and consisting of (*a*) the geniculate fibers, which decussate and end in the motor nuclei of the cranial nerves of the opposite side; and (*b*) the cerebrospinal fibers, which are prolonged through the pyramid of the medulla oblongata into the medulla spinalis: (2) the *corticopontine fibers,* ending in the nuclei pontis. The chief afferent fibers are: (1) those of the lemniscus which are not interrupted in the thalamus; (2) those of the superior cerebellar peduncle which are not interrupted in the red nucleus and thalamus; (3) numerous fibers arising within the thalamus, and passing through its stalks to the different parts of the cortex (page 810); (4) optic and acoustic fibers, the former passing to the occipital, the latter to the temporal lobe.

2. The **transverse** or **commissural fibers** connect the two hemispheres. They include: (*a*) the *transverse fibers* of the corpus callosum, (*b*) the anterior commissure, (*c*) the posterior commissure, and (*d*) the lyra or hippocampal commissure; they have already been described. *141*

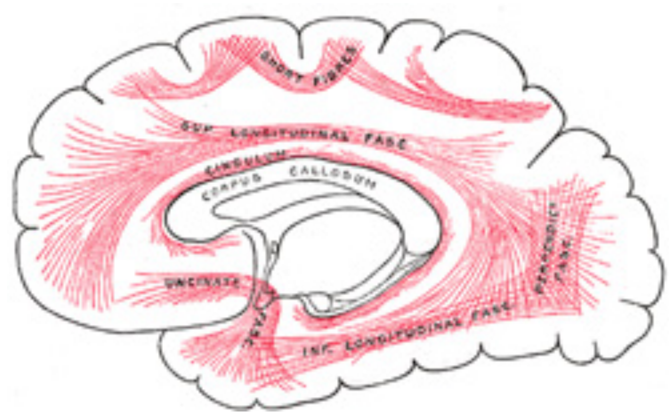


FIG. 751– Diagram showing principal systems of association fibers in the cerebrum. (See enlarged image)

3. The **association fibers** (Fig. 751) unite different parts of the same hemisphere, and are of two kinds: (1) those connecting adjacent gyri, **short association fibers;** (2) those passing between more distant parts, **long association fibers.** *142*

The *short association fibers* lie immediately beneath the gray substance of the cortex of the hemispheres, and connect together adjacent gyri. *143*

The *long association fibers* include the following: (*a*) the uncinate fasciculus; (*b*) the cingulum; (*c*) the superior longitudinal fasciculus; (*d*) the inferior longitudinal fasciculus; (*e*) the perpendicular fasciculus; (*f*) the occipitofrontal fasciculus; and (*g*) the fornix. *144*

(*a*) The *uncinate fasciculus* passes across the bottom of the lateral fissure, and unites the gyri of the frontal lobe with the anterior end of the temporal lobe. *145*

(*b*) The *cingulum* is a band of white matter contained within the cingulate gyrus. Beginning in front at the anterior perforated substance, it passes forward and upward parallel with the rostrum, winds around the genu, runs backward above the corpus callosum, turns around the splenium, and ends in the hippocampal gyrus. *146* (*c*) The *superior longitudinal fasciculus* passes backward from the frontal lobe above the lentiform nucleus and insula; some of its fibers end in the occipital lobe, and others curve downward and forward into the temporal lobe. 147

FIG. 752– Dissection of cortex and brain-stem showing association fibers and island of Reil after removal of its superficial gray substance. (See enlarged image)

(*d*) The *inferior longitudinal fasciculus* connects the temporal and occipital lobes, running along the lateral walls of the inferior and posterior cornua of the lateral ventricle. 148

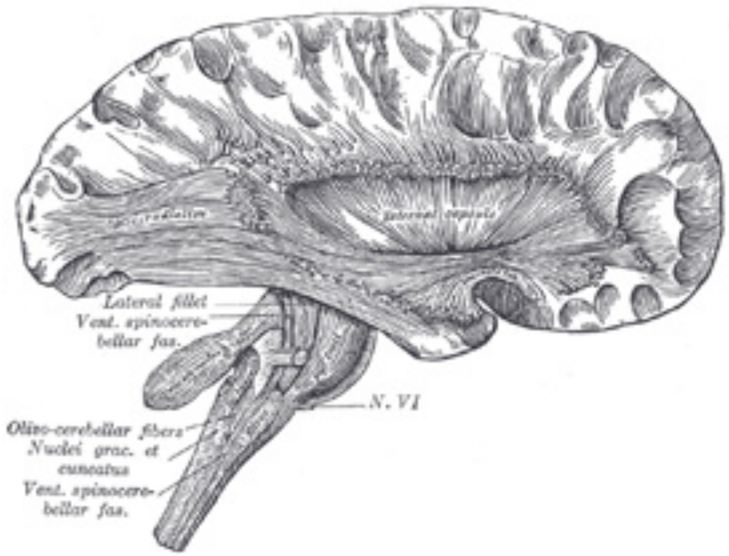


FIG. 753– Deep dissection of cortex and brain-stem. (See enlarged image)

149 (*e*) The *perpendicular fasciculus* runs vertically through the front part of the occipital lobe, and connects the inferior parietal lobule with the fusiform gyrus.

150 (*f*) The *occipitofrontal fasciculus* passes backward from the frontal lobe, along the lateral border of the caudate nucleus, and on the mesial aspect of the corona radiata; its fibers radiate in a fan-like manner and pass into the occipital and temporal lobes lateral to the posterior and inferior cornua. Déjerine regards the fibers of the tapetum as being derived from this fasciculus, and not from the corpus callosum.

151 (*g*) The *fornix* connects the hippocampal gyrus with the corpus mammillare and, by means of the thalamomammillary fasciculus, with the thalamus (see page 839). Through the fibers of the hippocampal commissure it probably also unites the opposite hippocampal gyri.

152 The **gray substance of the hemisphere** is divided into: (1) that of the cerebral cortex, and (2) that of the caudate nucleus, the lentiform nucleus, the claustrum, and the nucleus amygdalæ.

153 **Structure of the Cerebral Cortex (Fig. 754).**—The cerebral cortex differs in thickness and structure in different parts of the hemisphere. It is thinner in the occipital region than in the anterior and posterior central gyri, and it is also much thinner at the bottom of the sulci than on the top of the gyri. Again, the minute structure of the anterior central differs from that of the posterior central gyrus, and areas possessing a specialized type of cortex can be mapped out in the occipital lobe.

On examining a section of the cortex with a lens, it is seen to consist of alternating white and gray layers thus disposed from the surface inward: (1) a thin layer of white substance; (2) a layer of gray substance; (3) a second white layer (*outer band of Baillarger* or *band of Gennari*); (4) a second gray layer; (5) a third white layer (*inner band of Baillarger*); (6) a third gray layer, which rests on the medullary substance of the gyrus. 154

The cortex is made up of nerve cells of varying size and shape, and of nerve fibers which are either medullated or naked axis-cylinders, imbedded in a matrix of neuroglia. 155

Nerve Cells.—According to Cajal, the nerve cells are arranged in four layers, named from the surface inward as follows: (1) the molecular layer, (2) the layer of small pyramidal cells, (3) the layer of large pyramidal cells, (4) the layer of polymorphous cells. 156

The Molecular Layer.—In this layer the cells are polygonal, triangular, or fusiform in shape. Each polygonal cell gives off some four or five dendrites, while its axon may arise directly from the cell or from one of its dendrites. Each triangular cell gives off two or three dendrites, from one of which the axon arises. The fusiform cells are placed with their long axes parallel to the surface and are mostly bipolar, each pole being prolonged into a dendrite, which runs horizontally for some distance and furnishes ascending branches. Their axons, two or three in number, arise from the dendrites, and, like them, take a horizontal course, giving off numerous ascending collaterals. The distribution of the axons and dendrites of all three sets of cells is limited to the molecular layer. 157

The Layer of Small and the Layer of Large Pyramidal Cells.—The cells in these two layers may be studied together, since, with the exception of the difference in size and the more superficial position of the smaller cells, they resemble each other. The average length of the small cells is from 10 to 15μ; that of the large cells from 20 to 30μ. The body of each cell is pyramidal in shape, its base being directed to the deeper parts and its apex toward the surface. It contains granular pigment, and stains deeply with ordinary reagents. The nucleus is of large size, and round or oval in shape. The base of the cell gives off the axis cylinder, and this runs into the central white substance, giving off collaterals in its course, and is distributed as a projection, commissural, or association fiber. The apical and basal parts of the cell give off dendrites; the apical dendrite is directed toward the surface, and ends in the molecular layer by dividing into numerous branches, all of which may be seen, when prepared by the silver or methylene-blue method, to be studded with projecting bristle-like processes. The largest pyramidal cells are found in the upper part of the anterior central gyrus and in the paracentral lobule; they are often arranged in groups or nests of from three to five, and are named the *giant cells of Betz*. In the former situation they may exceed 50μ in length and 40μ in breadth, while in the paracentral lobule they may attain a length of 65μ. 158

Layer of Polymorphous Cells.—The cells in this layer, as their name implies, are very irregular in contour; they may be fusiform, oval, triangular, or star-shaped. Their dendrites are directed outward, but do not reach so far as the molecular layer; their axons pass into the subjacent white matter. 159

There are two other kinds of cells in the cerebral cortex. They are: (*a*) the *cells of Golgi,*the axons of which divide immediately after their origins into a large number of branches, which are directed toward the surface of the cortex; (*b*) the *cells of Martinotti,* which are chiefly found in the polymorphous layer; their dendrites are short, and may have an ascending or descending course, while their axons pass out into the molecular layer and form an extensive horizontal arborization. 160

Nerve Fibers.—These fill up a large part of the intervals between the cells, and may be medullated or non-medullated—the latter comprising 161 the axons of the smallest pyramidal cells and the cells of Golgi. In their direction the fibers may be either tangential or radial. The *tangential fibers* run parallel to the surface of the hemisphere, intersecting the radial fibers at a right angle. They constitute several strata, of which the following are the more important: (1) a stratum of white fibers covering the superficial aspect of the molecular layer (*plexus of Exner*); (2) the band of Bechterew, in the outer part of the layer of small pyramidal cells; (3) the band of Gennari or external band of Baillarger, running through the layer of large pyramidal cells; (4) the internal band of Baillarger, between the layer of large pyramidal cells and the polymorphous layer; (5) the deep tangential fibers, in the lower part of the polymorphous layer. The tangential fibers consist of (*a*) the collaterals of the pyramidal and polymorphous cells and of the cells of Martinotti; (*b*) the branching axons of Golgi's cells; (*c*) the collaterals and terminal arborizations of the projection, commissural, or association fibers. *The radial fibers*.—Some of these, viz., the axons of the pyramidal and polymorphous cells, descend into the central white matter, while others,the terminations of the projection, commissural, or association fibers, ascend to end in the cortex. The axons of the cells of Martinotti are also ascending fibers.

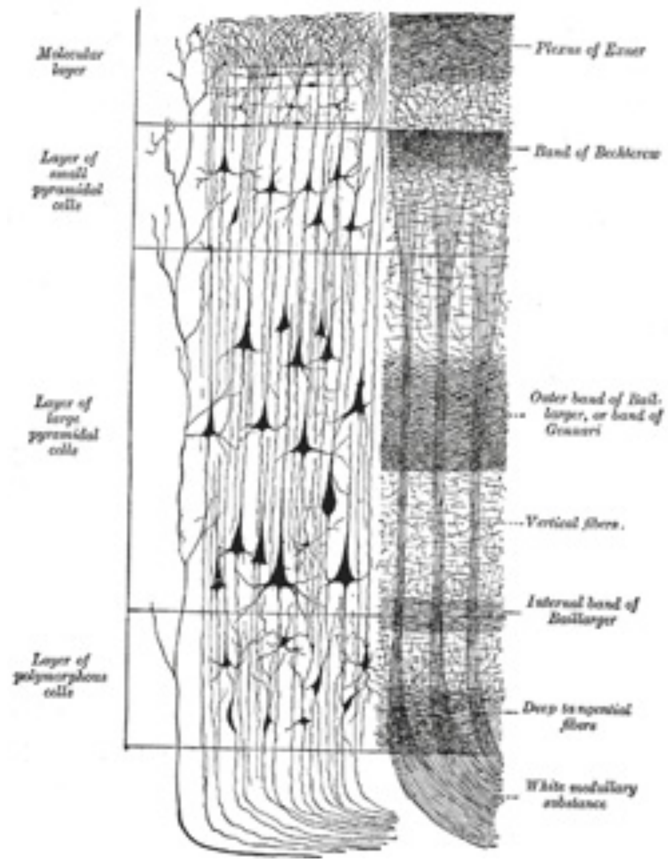


FIG. 754– Cerebral cortex. (Poirier.) To the left, the groups of cells; to the right, the systems of fibers. Quite to the left of the figure a sensory nerve fiber is shown. (See enlarged image)

Special Types of Cerebral Cortex.—It has been already pointed out that the minute structure of the cortex differs in different regions of the 162
hemisphere; and A. W. Campbell 126 has endeavored to prove, as the result of an exhaustive examination of a series of human and anthropoid brains, "that there exists a direct correlation between physiological function and histological structure." The principal regions where the

“typical” structure is departed from will now be referred to.

1. In the calcarine fissure and the gyri bounding it, the internal band of Baillarger is absent, while the band of Gennari is of considerable thickness, and forms a characteristic feature of this region of the cortex. If a section be examined microscopically, an additional layer of cells is seen to be interpolated between the molecular layer and the layer of small pyramidal cells. This extra layer consists of two or three strata of fusiform cells, the long axes of which are at right angles to the surface; each cell gives off two dendrites, external and internal, from the latter of which the axon arises and passes into the white central substance. In the layer of small pyramidal cells, fusiform cells, identical with the above, are seen, as well as ovoid or star-like cells with ascending axons (*cells of Martinotti*). This is the *visual area* of the cortex, and it has been shown by J. S. Bolton 127 that in old-standing cases of optic atrophy the thickness of Gennari’s band is reduced by nearly 50 per cent. 163

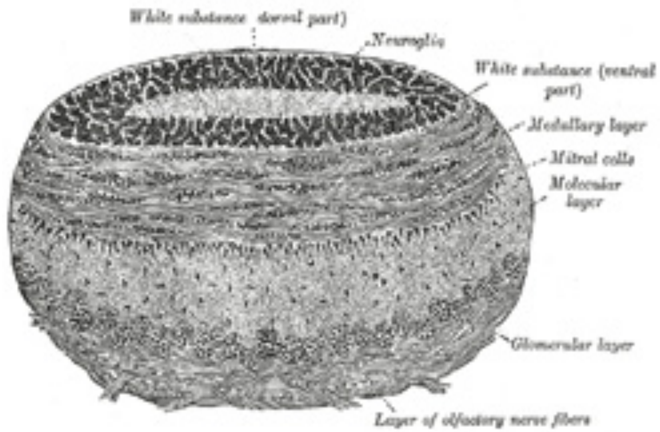


FIG. 755– Coronal section of olfactory bulb. (Schwalbe.) (See enlarged image)

A. W. Campbell says: “Histologically, two distinct types of cortex can be made out in the occipital lobe. The first of these coats the walls and bounding convolutions of the calcarine fissure, and is distinguished by the well-known line of Gennari or Vicq d’Azyr; the second area forms an investing zone a centimetre or more broad around the first, and is characterized by a remarkable wealth of fibers, as well as by curious pyriform cells of large size richly stocked with chromophilic elements—cells which seem to have escaped the observation of Ramón y Cajal, Bolton, and others who have worked at this region. As to the functions of these two regions there is abundant evidence, anatomical, embryological, and pathological, to show that the first or calcarine area is that to which visual sensations primarily pass, and we are gradually obtaining proof to the effect that the second investing area is constituted for the interpretation and further elaboration of these sensations. These areas therefore deserve the names *visuo-sensory* and *visuo-psychic*.” 164

2. The anterior central gyrus is characterized by the presence of the giant cells of Betz and by “a wealth of nerve fibers immeasurably superior 165

to that of any other part” (Campbell), and in these respects differs from the posterior central gyrus. These two gyri, together with the paracentral lobule, were long regarded as constituting the “motor areas” of the hemisphere; but Sherrington and Grunbaum have shown 128 that in the chimpanzee the motor area never extends on to the free face of the posterior central gyrus, but occupies the entire length of the anterior central gyrus, and in most cases the greater part or the whole of its width. It extends into the depth of the central sulcus, occupying the anterior wall, and in some places the floor, and in some extending even into the deeper part of the posterior wall of the sulcus.

3. In the hippocampus the molecular layer is very thick and contains a large number of Golgi cells. It has been divided into three strata: (*a*) *s. convolutum* or *s. granulosum,*containing many tangential fibers; (*b*) *s. lacunosum,* presenting numerous vascular spaces; (*c*) *s. radiatum,* exhibiting a rich plexus of fibrils. The two layers of pyramidal cells are condensed into one, and the cells are mostly of large size. The axons of the cells in the polymorphous layer may run in an ascending, a descending, or a horizontal direction. Between the polymorphous layer and the ventricular ependyma is the white substance of the alveus. *166*

4. In the fascia dentata hippocampi or dentate gyrus the molecular layer contains some pyramidal cells, while the layer of pyramidal cells is almost entirely represented by small ovoid cells. *167*

5. *The Olfactory Bulb.*—In many of the lower animals this contains a cavity which communicates through the olfactory tract with the lateral ventricle. In man the original cavity is filled up by neuroglia and its wall becomes thickened, but much more so on its ventral than on its dorsal aspect. Its dorsal part contains a small amount of gray and white substance, but it is scanty and ill-defined. A section through the ventral part (Fig. 755)shows it to consist of the following layers from without inward: *168*

FIG. 756– Areas of localization on lateral surface of hemisphere. Motor area in red. Area of general sensations in blue. Auditory area in green. Visula area in yellow. The psychic portions are in lighter tints. (See enlarged image)

1. A layer of olfactory nerve fibers, which are the non-medullated axons prolonged from the olfactory cells of the nasal cavity, and reach the 169
bulb by passing through the cribriform plate of the ethmoid bone. At first they cover the bulb, and then penetrate it to end by forming synapses with the dendrites of the mitral cells, presently to be described.

2. *Glomerular Layer*.—This contains numerous spheroidal reticulated enlargements, termed **glomeruli,** produced by the branching and 170
arborization of the processes of the olfactory nerve fibres with the descending dendrites of the mitral cells.

3. *Molecular Layer*.—This is formed of a matrix of neuroglia, imbedded in which are the*mitral cells*. These cells are pyramidal in shape, and 171
the basal part of each gives off a thick dendrite which descends into the glomerular layer, where it arborizes as indicated above, and others which interlace with similar dendrites of neighboring mitral cells. The axons pass through the next layer into the white matter of the bulb, and after becoming bent on themselves at a right angle, are continued into the olfactory tract.

4. *Nerve Fiber Layer*.—This lies next the central core of neuroglia, and its fibers consist of the axons or afferent processes of the mitral cells 172
passing to the brain; some efferent fibers are, however, also present, and end in the molecular layer, but nothing is known as to their exact origin.

Weight of the Encephalon.—The average weight of the brain, in the adult male, is about 1380 gms.; that of the female, about 1250 gms. In the 173
male, the maximum weight out of 278 cases was 1840 gms. and the minimum weight 964 gms. The maximum weight of the adult female brain, out of 191 cases, was 1585 gms. and the minimum weight 879 gms. The brain increases rapidly during the first four years of life, and reaches its maximum weight by about the twentieth year. As age advances, the brain decreases slowly in weight; in old age the decrease takes place more rapidly, to the extent of about 28 gms.

The human brain is heavier than that of any of the lower animals, except the elephant and whale. The brain of the former weighs from 3.5 to 174
5.4 kilogm., and that of a whale, in a specimen 19 metres long, weighed rather more than 6.7 kilogm.

Cerebral Localization.—Physiological and pathological research have now gone far to prove that a considerable part of the surface of the 175
brain may be mapped out into a series of more or less definite areas, each of which is intimately connected with some well-defined function.

The chief areas are indicated in Figs. 756 and 757. 176

Motor Areas.—The motor area occupies the anterior central and frontal gyri and the paracentral lobule. The centers for the lower limb are 177
located on the uppermost part of the anterior central gyrus and its continuation on to the paracentral lobule; those for the trunk are on the upper portion, and those for the upper limb on the middle portion of the anterior central gyrus. The facial centers are situated on the lower part of the anterior central gyrus, those for the tongue, larynx, muscles of mastication, and pharynx on the frontal operculum, while those for the head and neck occupy the posterior end of the middle frontal gyrus.

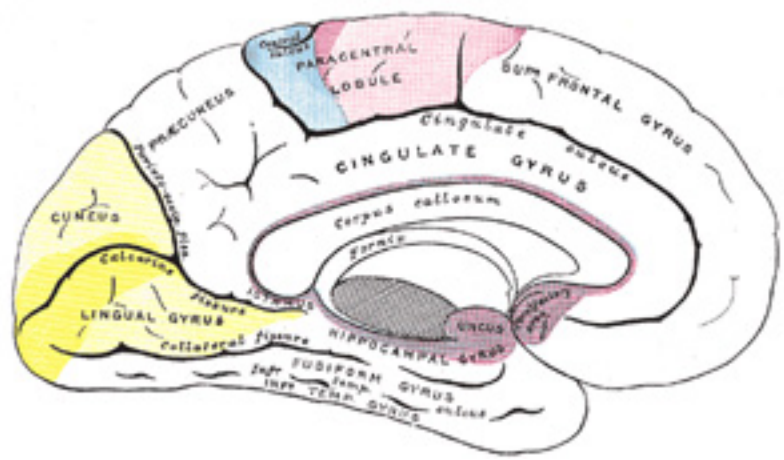


FIG. 757– Areas of localization on medial surface of hemisphere. Motor area in red. Area of general sensations in blue. Visual area in yellow. Olfactory area in purple. The psychic portions are in lighter tints. (See enlarged image)

Sensory Areas.—Tactile and temperature senses are located on the posterior central gyrus, while the sense of form and solidity is on the superior parietal lobule and precuneus. With regard to the special senses, the area for the sense of taste is probably related to the uncus and hippocampal gyrus. The auditory area occupies the middle third of the superior temporal gyrus and the adjacent gyri in the lateral fissure; the visual area, the calcarine fissure and cuneus; the olfactory area, the rhinencephalon. As special centers of much importance may be noted: the emissive center for speech on the left inferior frontal and anterior central gyri (Broca); the auditory receptive center on the transverse and superior temporal gyri, and the visual receptive center on the lingual gyrus and cuneus. *178*

Note 125. Elliot Smith has named the lateral occipital sulcus the *sulcus lunatus;* he regards it as the representative, in the human brain, of the "Affenspalte" of the brain of the ape. [back]

Note 126. Histological Studies on the Localization of Cerebral Function, Cambridge University Press. [back]

Note 127. Philosophical Transactions of Royal Society, Series B, cxciii, 165. [back]

Note 128. Transactions of the Pathological Society of London, vol. liii. [back]

4d. Composition and Central Connections of the Spinal Nerves

The **typical spinal nerve** consists of at least four types of fibers, the **somatic sensory, sympathetic afferent** or **sensory, somatic motor** and **sympathetic efferent** or**preganglionic.** The somatic sensory fibers, afferent fibers, arise from cells in the spinal ganglia and are found in all the spinal nerves, except occasionally the first cervical, and conduct impulses of pain, touch and temperature from the surface of the body through the posterior roots to the spinal cord and impulses of muscle sense, tendon sense and joint sense from the deeper structures. The sympathetic afferent fibers, conduct sensory impulses from the viscera through the rami communicantes and posterior roots to the spinal cord. They are probably limited to the white rami connected with the spinal nerves in two groups, viz., the first thoracic to the second lumbar and the second sacral to the fourth sacral nerves. The somatic motor fibers, efferent fibers, arise from cells in the anterior column of the spinal cord and pass out through the anterior roots to the voluntary muscles. The sympathetic efferent fibers, probably arise from cells in the lateral column or the base of the anterior column and emerge through the anterior roots and white rami communicantes. These are preganglionic fibers which end in various sympathetic ganglia from which postganglionic fibers conduct the motor impulses to the smooth muscles of the viscera and vessels and secretory impulses to the glands. These fibers are also limited to two regions, the first thoracic to the second lumbar and the second sacral to the fourth sacral nerves. 1

The afferent fibers which pass into the spinal cord establish various types of connections, some within the cord itself for spinal reflexes, others for reflexes connected with higher centers in the brain, while still others conduct impulses of conscious sensation by a series of neurons to the cerebral cortex. 2

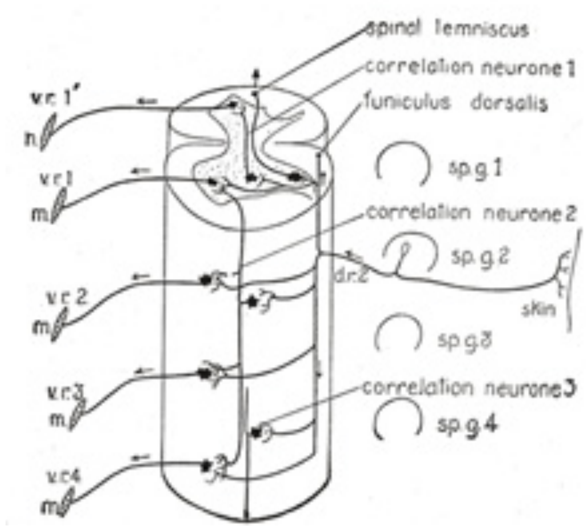


FIG. 758– Diagram of the spinal cord reflex apparatus. Some of the connections of a single afferent neuron from the skin (*d.r.*2) are indicated: *d.r.*2, dorsal root from second spinal ganglion; *m,* muscles; *sp.g.*1 to *sp.g.*4, spinal ganglia; *v.r.*1' to *v.r.*4, ventral roots. (After Herrick.)
(See enlarged image)

The Intrinsic Spinal Reflex Paths.—The collaterals and terminals of the ascending and descending branches of the posterior root fibers which leave the fasciculus cuneatus to enter the gray matter of the spinal cord end in various ways. Many end in the dorsal column, some near its apex, others in the substance of Rolando, others in the intermediate region between the dorsal and ventral columns, others traverse the whole thickness of the gray matter to reach the ventral column, others end in the dorsal nucleus, and others pass through the gray commissure to the dorsal column of the opposite side. All of these collaterals and terminals end in connection with cells or dendrites of cells in the gray columns. The axons of these cells have various destinations, some pass out into the lateral and ventral funiculi and turn upward to reach the brain. Those concerned with the intrinsic spinal reflexes come into relation either directly or indirectly with motor cells in the anterior column. It is very unlikely that either the terminals or collaterals of the dorsal root fibers effect simple direct connections with the motor cells of the ventral column, there is at least one if not several intercalated neurons in the path. These intercalated or correlation neurons may have short axons that do not pass out of the gray matter or the axons may pass out into the proper fasciculi and extend for varying distances up and down or in both directions giving off collaterals and finally terminating in the gray matter of the same or the opposite side. The shortest fibers of the proper fasciculi lie close to the gray matter, the longest ones are nearer the periphery of the proper fasciculi and are more or less intermingled with the long ascending and descending fasciculi which occupy the more marginal regions of the spinal cord. 3

Each sensory neuron, with its ascending and descending branches, giving off as it does many collaterals into the gray matter, each one of which may form a synapse with one or several correlation neurons, is thus brought into relation with many correlation neurons and each one of these in turn, with its ascending and descending branches and their numerous collaterals, is brought into relation, either directly or through the intercalation of additional correlation neurons, with great numbers of motor cells in the anterior column. The great complexity of these so-called simple reflex mechanisms, in the least complex portion of the nervous system the spinal cord, renders them extremely difficult of exact analysis. 4

The association or correlation neurons are concerned not only with the reflex mechanisms of the spinal cord but play an equally important role in the transmission of impulses from the higher centers in the brain to the motor neurons of the spinal cord. 5

The complex mechanisms just described are probably concerned not so much in the contraction of individual muscles as in the complicated action of groups of muscles concerned in the enormous number of movements, which the limbs and trunk exhibit in the course of our daily life. 6

Sensory Pathways from the Spinal Cord to the Brain.—The posterior root fibers conducting the impulses of **conscious muscle sense,** tendon sense and joint sense, those impulses which have to do with the coördination and adjustment of muscular movements, ascend in the fasciculus gracilis and fasciculus cuneatus to the nucleus gracilis and nucleus cuneatus in the medulla oblongata (Fig. 759). 7

In the nucleus gracilis and nucleus cuneatus synaptic relations are found with neurons whose cell bodies are located in these nuclei and whose axons pass by way of the internal arcuate fibers, cross in the raphé to the opposite side in the region between the olives and turn abruptly upward to form the medial lemniscus or medial fillet. The medial fillet passes upward in the ventral part of the formatio reticularis through the medulla 8 oblongata, pons and mid-brain to the principal sensory nucleus of the ventro-lateral region of the thalamus. Here the terminals form synapses with neurons of the third order whose axons pass through the internal capsule and corona radiata to the somatic sensory area of the cortex in the post-central gyrus.

Fibers conducting the impulses of **unconscious muscle sense** pass to the cerebellum partly by way of the fasciculus gracilis and fasciculus 9
cuneatus to the nucleus gracilis and nucleus cuneatus, thence neurons of the second order convey the impulses either via the dorsal external arcuate fibers directly into the inferior peduncle of the cerebellum or via the ventral external arcuate fibers which are continued from the internal arcuate fibers through the ventral part of the raphé and after crossing the midline emerge on the surface of the medulla in the ventral sulcus between the pyramids or in the groove between the pyramid and the olive. They pass over the lateral surface of the medulla and olive to reach the inferior peduncle through which they pass to the cerebellum.

Other fibers conducting impulses of unconscious muscle sense pass upward in the dorsal spinocerebellar fasciculus, which arises from cells in 10
the nucleus dorsalis. The posterior root fibers conducting these impulses pass into the fasciculus cuneatus and the collaterals from them to the nucleus dorsalis are said to come almost exclusively from the middle area of the fasciculus cuneatus. They form by their multiple division baskets about the individual cells of the nucleus dorsalis, each fiber coming in relation with the bodies and dendrites of several cells. The axons of the second order pass into the dorsal spinocerebellar fasciculus of the same side and ascend along the lateral surface of the spinal cord and medulla oblongata until they arrive at the level of the olive, they then curve backward beneath the external arcuate fibers into the inferior peduncle and pass into the cerebellum. Here they give off collaterals to the dentate nucleus and finally terminate in the cortex of the dorsal and superior portion of the vermis, partly on the same side, but to a great extent by way of a large commissure to the opposite side. The fibers lose their myelin sheaths as they enter the gray substance and terminate by end ramifications among the nerve cells and their processes. Some of the fibers are said to end in the nucleus dentatus and the roof nuclei of the cerebellum (the nucleus globosus, nucleus emboliformis and nucleus fastigius) and others pass through them to terminate in the inferior vermis. A few fibers of the dorsal spinocerebellar fasciculus are said not to enter the inferior peduncle but to pass with the ventral spinocerebellar fasciculus. The cerebellar reflex are is supposed to be completed by the fibers of the superior peduncle which pass from the cerebellum to the red nucleus of the mid-brain where some of their terminals and collaterals form synapses with neurons whose axons descend to the spinal cord in the rubrospinal fasciculus. The terminal and collaterals of this fasciculus end either directly or indirectly about the motor cells in the anterior column.

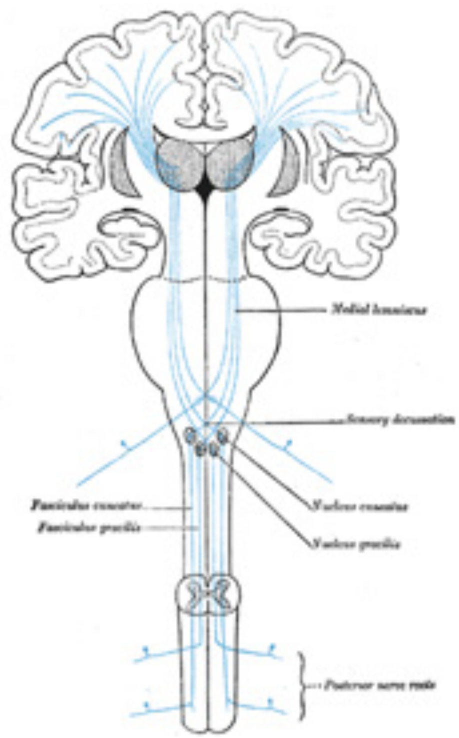


FIG. 759– The sensory tract. (Modified from Poirier.) (See enlarged image)

The ventral spinocerebellar fasciculus, since most of its fibers pass to the cerebellum, is also supposed to be concerned in the conduction of 11
unconscious muscle sense. The location of its cells of origin is uncertain. They are probably in or near the dorsal nucleus of the same and the opposite side; various other locations are given, the dorsal column, the intermediate zone of the gray matter and the central portion of the anterior column. The neurons of the first order whose central fibers enter the fasciculus cuneatus from the dorsal roots send collaterals and terminals to form synapses with these cells. The fibers which come from the opposite gray columns cross some in the white and some in the gray commissure and pass with fibers from the same side through the lateral funiculus to the marginal region ventral to the dorsal spinocerebellar fasciculus. The fasciculus begins about the level of the third lumbar nerve and continues upward on the lateral surface of the spinal cord and medulla oblongata until it passes under cover of the external arcuate fibers. It passes just dorsal to the olive and above this joins the lateral edge of the lateral lemniscus along which it runs, ventral to the roots of the trigeminal nerve, almost to the level of the superior colliculus, it then crosses over the

superior peduncle, turns abruptly backward along its medial border, enters the cerebellum with it and ends in the vermis of the same and the opposite side. Some of its fibers are said to join the dorsal spinocerebellar fasciculus in the medulla oblongata and enter the cerebellum through the inferior peduncle. A number of fibers are said to continue upward in the dorsolateral part of the tegmentum as far as the superior colliculus and a few pass to the thalamus. They probably form part of the sensory or higher reflex path.

The posterior root fibers conducting impulses of **pain** and **temperature** probably terminate in the posterior column or the intermediate region *12*
of the gray matter soon after they enter the spinal cord. The neurons of the second order are supposed to pass through the anterior commissure to the superficial antero-lateral fasciculus (tract of Gowers) and pass upward in that portion of it known as the lateral spinothalamic fasciculus. This fasciculus lies along the medial side of the ventral spinocerebellar fasciculus. It is stated by some authors that the pain fibers pass upward in the antero-lateral ground bundles. In some of the lower mammals this pathway carries the pain fibers upward by a series of neurons some of which cross to the opposite side, so that in part there is a double path. In man, however, the lateral spinothalamic fasciculus is probably the most important pathway. On reaching the medulla these fibers continue upward through the formatio reticularis in the neighborhood of the median fillet to the thalamus, probably its ventro-lateral region. Whether higher neurons convey the pain impulses to the cortex through the internal capsule is uncertain. The pathway is probably more complex and Head is of the opinion that our sensations of pain are essentially thalamic. The pain and temperature pathways in the lateral spinothalamic fasciculus are not so closely intermingled but that one can be destroyed without injury to the other.

Ransom suggests that the non-medullated fibers of the posterior roots, which turn into Lissauer's tract and ascend or descend for short distances *13*
not exceeding one or two segments and finally end in the substantia gelatinosa, are in part at least pain fibers and that the fasciculus of Lissauer and the substantia gelatinosa represent part of the mechanism for reflexes associated with pain conduction and reception while the fibers to the higher centers pass up in the spinothalamic tract.

The fibers of **tactile discrimination,** according to Head and Thompson, pass up in the fasciculus cuneatus and fasciculus gracilis of the same *14*
side and follow the path of the muscle-sense fibers. The axons of the second order arising in the nucleus cuneatus and gracilis cross with the internal arcuate fibers and ascend to the thalamus with the medial lemniscus, thence by neurons of higher order the impulses are carried to the somatic sensory area of the cortex through the internal capsule. The other **touch fibers,** shortly after entering the spinal cord, terminate in the dorsal column or intermediate gray matter. Neurons of the second order send their axons through the anterior commissure to pass upward in the antero-lateral funiculus probably in the **ventral spinothalamic fasciculus.** In the medulla they join or pass upward in the neighborhood of the medial lemniscus to the thalamus and thence by neurons of higher order to the somatic sensory area of the cortex.

The remaining ascending fasciculi form a part of the complex known as the **superficial antero-lateral fasciculus** (*tract of Gowers*). *15*
The **spinotectal fasciculus,** as its name indicates, is supposed to have its origin in the gray matter of the cord and terminations in the superior and inferior (?) colliculi of the mid-brain serving for reflexes between the cord and the visceral and auditory centers of the mid-brain.

The **spino-olivary fasciculus** (*olivospinal; bulbospinal, Helweg's bundle*) is likewise of unknown constitution and function; there is *16*
uncertainty even in regard to the direction of its fibers.

Sympathetic afferent fibers (*visceral afferent; viscero-sensory; splanchnic afferent*) enter the spinal cord by the posterior roots of the thoracic *17*
and first two or three lumbar nerves and the second to the fourth sacral nerves. The fibers pass to these nerves from the peripheral sympathetic system through the white rami communicantes. Some of the cell bodies of these afferent fibers are located in the spinal ganglia and others are in the sympathetic ganglia. Some of the afferent sympathetic fibers end about the cell bodies of somatic sensory neurons and visceral impulses are thus transmitted to these neurons which conduct them as well as their own special impulses to the spinal cord. Other sympathetic afferent

neurons whose cell bodies are located in the spinal ganglia send collaterals to neighboring cells of somatic sensory neurons and thus have a double path of transmission to the spinal cord. Such an arrangement provides a mechanism for some of the referred pains.

These sympathetic afferent fibers presumably divide on entering the spinal cord into ascending and descending branches. Their distribution and termination within the spinal cord are unknown. Some of them probably eventually come into relation with the sympathetic efferent fibers whose cell bodies are located in the lateral column. Our knowledge concerning both the termination and origin of these fibers is very unsatisfactory. *18*

The **sympathetic efferent fibers** (*splanchnic motor; viscero-motor; preganglionic fibers*) are supposed to arise from cells in the intermediate zone between the dorsal and ventral gray columns and in the intermedio-lateral column at the margin of the lateral column. These preganglionic sympathetic fibers are not distributed throughout the entire series of spinal nerves but are confined to two groups, the thoraco-lumbar from the first thoracic to the second or third lumbar nerves and the sacral group from the second to the fourth sacral nerves. They pass out with the anterior root fibers and through the rami communicantes to end in sympathetic ganglia. The impulses are distributed from cells in these ganglia through postganglionic fibers to the smooth muscles and glands. The thoraco-lumbar outflow and the sacral outflow form two distinct functional groups which are considered more fully under the sympathetic system.

4e. Composition and Central Connections of the Spinal Nerves

The cranial nerves are more varied in their composition than the spinal nerves. Some, for example, contain somatic motor fibers only, others contain the various types of fibers found in the spinal nerves, namely, somatic motor, sympathetic efferent, somatic sensory and sympathetic sensory. In addition there are included the nerves of the special senses, namely, the nerves of smell, sight, hearing, equilibration and taste. *1*

The **Hypoglossal Nerve** (*XII cranial*) consists of somatic motor fibers only and supplies the muscles of the tongue. Its axons arise from cells in the hypoglossal nucleus and pass forward between the white reticular formation and the gray reticular formation to emerge from the antero-lateral sulcus of the medulla. The hypoglossal nuclei of the two sides are connected by many commissural fibers and also by dendrites of motor cells which extend across the midline to the opposite nucleus. The hypoglossal nucleus receives either directly or indirectly numerous collaterals and terminals from the opposite pyramidal tract (cortico-bulbar or cerebrobulbar fibers) which convey voluntary motor impulses from the cerebral cortex. Many reflex collaterals enter the nucleus from the secondary sensory paths of the trigeminal and vagus and probably also from the nervus intermedius and the glossopharyngeal. Collaterals from the posterior longitudinal bundle and the ventral longitudinal bundle are said to pass to the nucleus. *2*

The **Accessory Nerve** (*XI cranial*) contains somatic motor fibers. The **spinal part** arises from lateral cell groups in the anterior column near its dorso-lateral margin in the upper five or six segments of the cord, its roots pass through the lateral funiculus to the lateral surface of the cord. It supplies the Trapezius and Sternocleidomastoideus. The **cranial part** arises from the nucleus ambiguus, the continuation in the medulla oblongata of the lateral cell groups of the anterior column of the spinal cord from which the spinal part has origin. The upper part of the nucleus ambiguus gives motor fibers to the vagus and glossopharyngeal nerves. The cranial part sends it fibers through the vagus to the laryngeal nerves to supply the muscles of the larynx. The root fibers of the cranial part of the accessory nerve pass anterior to the spinal tract of the trigeminal while those of the vagus pass through or dorsal to the trigeminal root, and emerge in the line of the postero-lateral sulcus. The nucleus of origin of the spinal part undoubtedly receives either directly or indirectly terminals and collaterals controlling voluntary movements from the pyramidal tracts. It is probable that terminals and collaterals reach the nucleus either directly or indirectly from the rubrospinal and the vestibulospinal *3* tracts. It is also connected indirectly with the spinal somatic sensory nerves by association fibers of the proper fasciculi. The cranial part receives indirectly or directly terminals and collaterals from the opposite pyramidal tract and form the terminal sensory nuclei of the cranial nerves. A few fibers of the cranial part are said to arise in the dorsal nucleus of the vagus and are thus sympathetic efferent. They are said to join the vagus nerve.

4 The **Vagus Nerve** (*X cranial*) contains somatic sensory, sympathetic afferent, somatic motor, sympathetic efferent and (taste fibers?). The afferent fibers (somatic sensory, sympathetic, and taste) have their cells of origin in the jugular ganglion and in the nodosal ganglion (ganglion of the trunk) and on entering the medulla divide into ascending and descending branches as do the sensory fibers of the posterior roots of the spinal nerves after they enter the spinal cord.

5 (1) The **somatic sensory fibers** are few in number, convey impulses from a limited area of the skin on the back of the ear and posterior part of the external auditory meatus, and probably join the spinal tract of the trigeminal nerve to terminate in its nucleus. Connections are probably established through the central path of the trigeminal with the thalamus and somatic sensory area of the cortex for the conscious recognition of impulses. The descending fibers in the spinal tract of the trigeminal terminating in the nucleus of the tract probably establish relations through connecting neurons with motor nuclei in the anterior column of the spinal cord and with motor nuclei of the medulla.

6 (2) The **sympathetic afferent fibers** are usually described as terminating in the dorsal nucleus of the vagus and glossopharyngeal. Some authors, however, believe they join the tractus solitarius and terminate in its nucleus. These afferent fibers convey impulses from the heart, the pancreas, and probably from the stomach, esophagus and respiratory tract. Their terminals in the dorsal nucleus come into relation with neurons whose axons probably descend into the spinal cord, conveying impulses to the motor nuclei supplying fibers to the muscles of respiration, *i. e.,* the phrenic nerve and the nerves to the intercostal and levatores costarum muscles. Other axons probably convey vasomotor impulses to certain sympathetic efferent neurons throughout the spinal cord. The dorsal nucleus (nucleus of the ala cinerea) and the posterior continuation of it into the commissural nucleus of the ala cinerea constitute probably the so-called respiratory and vaso-motor center of the medulla. The shorter reflex neurons of the dorsal nucleus probably effect connections either directly or indirectly with motor cells of the vagus itself and other cranial nerves.

7 (3) **Taste fibers** conducting impulses from the epiglottis and larynx are supposed to pass in the vagus and to join the tractus solitarius, finally terminating in the nucleus of the tractus solitarius. It is not certain that this nucleus represents the primary terminal center for taste and some authors maintain that the taste fibers terminate in the dorsal nucleus. The secondary ascending pathways from the primary gustatory nucleus to the cortex as well as the location of the cortical center for taste are unknown. A gustatory center has been described near the anterior end of the temporal lobe. The nucleus of the tractus solitarius is connected with motor centers of the pons, medulla and spinal cord for the reactions of mastication and swallowing.

8 (4) **Somatic motor fibers** to the cross striated muscles of the pharynx and larynx arise in the nucleus ambiguus. This nucleus undoubtedly receives either directly or indirectly collaterals or terminals from the opposite pyramidal tract controlling the voluntary movements of the pharynx and larynx. The reflex pathways conveying impulses from the terminal sensory nuclei are unknown, but probably form part of the intricate maze of fibers constituting the reticular formation.

9 (5) **Sympathetic efferent fibers** arise from cells in the dorsal nucleus (nucleus of the ala cinerea). These are preganglionic fibers of the sympathetic system and all terminate in sympathetic ganglia from which postganglionic fibers are distributed to various organs, *i. e.,* motor fibers to the esophagus, stomach, small intestine, gallbladder, and to the lungs; inhibitory fibers to the heart; secretory fibers to the stomach and pancreas. The dorsal nucleus not only receives terminals of sympathetic afferent fibers for reflexes but undoubtedly receives terminals and collaterals from many other sources, but the exact pathways are at present unknown.

The **Glossopharyngeal Nerve** (*IX cranial*) is similar to the vagus nerve as regards its central connections and is usually described with it. It 10
contains somatic sensory, sympathetic afferent, taste, somatic motor and sympathetic efferent fibers. The afferent sensory fibers arise from cells
in the superior ganglion and in the petrosal ganglion. The same uncertainty exists concerning the nuclei of termination and nuclei of origin of the
various components as for the vagus.

(1) The **somatic sensory fibers** are few in number. Some are distributed with the auricular branch of the vagus to the external ear; others 11
probably pass to the pharynx and fauces. They are supposed to join the spinal tract of the trigeminal and terminate in its nucleus. The
connections are similar to those of the somatic sensory fibers of the vagus.

(2) **Sympathetic afferent fibers** from the pharynx and middle ear are supposed to terminate in the dorsal nucleus. Connections are probably 12
established with motor nuclei concerned in chewing and swallowing; very little is known, however, about the connections with other parts of the
brain.

(3) **Taste fibers** from the tongue probably terminate in the nucleus of the tractus solitarius. These fibers together with similar fibers from the 13
facial (nervus intermedius) and the vagus are supposed to form the tractus solitarius and terminate in its nucleus. The central connections have
been considered under the vagus.

(4) **Somatic motor fibers** to the Sylopharyngeus muscle arise in the upper end of the nucleus ambiguus. The existence of these fibers in the 14
roots of the glossopharyngeal is uncertain, as there are other paths by which such fibers might reach the glossopharyngeal from the vagus. The
sources of impulses passing to the nucleus ambiguus are considered under the vagus.

(5) **Sympathetic efferent fibers** (*motor and secretory fibers*) arise from the nucleus dorsalis. Some authors believe that the secretory fibers to 15
the parotid gland arise from a distinct nucleus, the inferior salivatory nucleus, situated near the dorsal nucleus. The preganglionic fibers from this
nucleus terminate in the otic ganglion; the postganglionic fibers from the otic ganglion pass to the parotid gland.

The **Acoustic Nerve** (*VIII cranial*) consists of two distinct nerves the **cochlear nerve,** the nerve of hearing, and the **vestibular nerve,** the nerve 16
of equilibration.

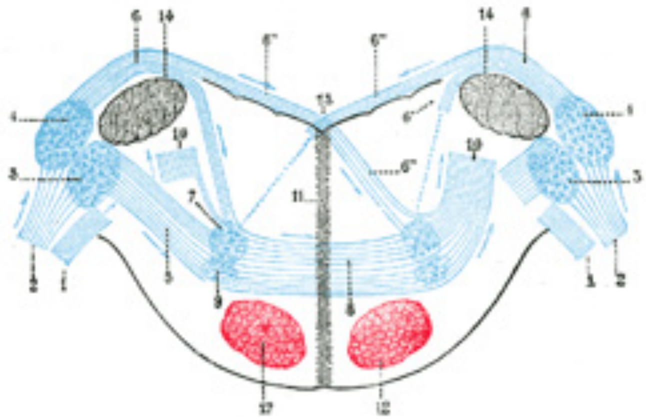


FIG. 760– Terminal nuclei of the cochlear nerve, with their upper connections. (Schematic.) The vestibular nerve with its terminal nuclei and their efferent fibers have been suppressed. On the other hand, in order not to obscure the trapezoid body, the efferent fibers of the terminal nuclei on the right side have been resected in a considerable portion of their extent. The trapezoid body, therefore, shows only one-half of its fibers, viz., those which come from the left. 1. Vestibular nerve, divided at its entrance into the medulla oblongata. 2. Cochlear nerve. 3. Accessory nucleus of acoustic nerve. 4. Tuberculum acusticum. 5. Efferent fibers of accessory nucleus. 6. Efferent fibers of tuberculum acusticum, forming the striae medullares, with 6’, their direct bundle going to the superior olivary nucleus of the same side; 6’’, their decussating bundles going to the superior olivary nucleus of the opposite side. 7. Superior olivary nucleus. 8. Trapezoid body. 9. Trapezoid nucleus. 10. Central acoustic tract (lateral lemniscus). 11. Raphé. 12. Cerebrospinal fasciculus. 13. Fourth ventricle. 14. Inferior peduncle. (Testut.) (See enlarged image)

The **Cochlear Nerve** arises from bipolar cells in the spiral ganglion of the cochlea; the peripheral fibers end in the organ of Corti, the central 17
fibers bifurcate as they enter the**cochlear nucleus;** the short ascending branches end in the ventral portion of the nucleus, the longer descending branches terminate in the dorsal portion of the nucleus. From the dorsal portion of the cochlear nucleus axons arise which pass across the dorsal aspect of the inferior peduncle and the floor of the fourth ventricle, the **striæ medullares,** to the median sulcus. Here they dip into the substance of the pons, cross the median plane, and join the lateral lemniscus. Some of the fibers terminate in the superior olivary nucleus. The fibers of the striæ medullares are not always visible on the floor of the rhomboid fossa. From the ventral portion of the cochlear nucleus axons pass into the trapezoid body, here some of them end in the superior olivary nucleus of the same side, others cross the midline and end in the superior olivary nucleus of the opposite side or pass by these nuclei, giving off collaterals to them, and join the lateral lemniscus. Other fibers either terminate in or give off collaterals to the nucleus of the trapezoid body of the same or the opposite side. Other fibers from the ventral portion of the cochlear nucleus pass dorsal to the inferior peduncle and then dip into the substance of the pons to join the trapezoid body or the superior olivary nucleus of the same side. From the superior olivary nucleus of the same and opposite sides axons join the lateral lemniscus. Collaterals and probably terminals also pass from the lateral lemniscus to other nuclei in its path and receive in turn axons from these nuclei. They are the accessory

nucleus, the medial preolivary nucleus, the lateral preolivary or semilunar nucleus and the nucleus of the lateral lemniscus.

The **trapezoid body** consists of horizontal fibers in the ventral part of the formatio reticularis of the lower part of the pons behind its deep transverse fibers and the pyramid bundles. The axons come from the dorsal and ventral portions of the cochlear nucleus. After crossing the raphé, where they decussate with those from the opposite side, they turn upward to form the lateral lemniscus. Fibers from the striæ medullares contribute to the trapezoid body, in addition it sends terminals or collaterals to and receives axons from the superior olivary nucleus, the nucleus of the trapezoid body, the lateral preolivary or semilunar nucleus and the mesial preolivary nucleus. *18*

The **cochlear nucleus,** the terminal nucleus for the nerve of hearing, is usually described as consisting of a larger dorsal nucleus on the dorsal and lateral aspect of the inferior peduncle forming a prominent projection, the **acoustic tubercle,** and a ventral or accessory cochlear nucleus more ventral to the inferior peduncle. The two nuclei are continuous and are merely portions of one large nucleus. The axons from cells of the spiral ganglion of the cochlear nerve on reaching the nucleus divide into ascending and descending branches which enter the ventral and dorsal nuclei respectively. Axons from the large fusiform cells of the dorsal nucleus pass partly by way of the striæ medullares to the trapezoid body and lateral lemniscus and the nuclei associated with the former, and partly transversely beneath the inferior peduncle and spinal tract of the trigeminal to the trapezoid body. Axons from the ventral cochlear nucleus pass partly by the striæ medullares but for the most part horizontally to the trapezoid body. *19*

The **superior olivary nucleus** is a small mass of gray matter situated on the dorsal surface of the lateral part of the trapezoid body. Some of its axons pass backward to the abducent nucleus, this bundle is known as the **peduncle of the superior olivary nucleus.** Other fibers from the nucleus join the posterior longitudinal bundle and terminate in the nuclei of the trochlear and oculomotor nerves. The majority of its axons, after giving off collaterals to the nucleus itself join the lateral lemniscus of the same side, other axons pass in the trapezoid body toward the ventral portion of the cochlear nucleus. *20*

The **nucleus of the trapezoid body** lies between the root fibers of the abducent nerve and the superior olivary nucleus. Its cells lie among the fibers of the trapezoid body. In it terminate fibers and collaterals of the trapezoid body which come from the cochlear nucleus of the opposite and probably the same side and from the opposite trapezoid nucleus. They terminate in the nucleus of the trapezoid body in diffuse arborizations and peculiar end plaques or acoustic calyces of yellowish color which fuse with the cell bodies. Its cells are round and of medium size; their axons pass into the trapezoid body, cross the median line and probably join the lateral fillet. *21*

The **lateral preolivary** or **semilunar nucleus** lies ventral to the superior olivary nucleus. In it end terminals and collaterals of the trapezoid body and probably fibers of the opposite cochlear nucleus. Its axons mingle with the trapezoid body and join the lateral fillet. *22*

The **mesial preolivary nucleus** is in contact with the ventral side of the nucleus of the trapezoid body. It receives many collaterals from the trapezoid body. Its cells are smaller than those of the trapezoid nucleus, their axons join the lateral fillet. *23*

The **lateral lemniscus** (*lateral fillet*), the continuation upward of the central path of hearing, consists of fibers which come from the cochlear nuclei of the same and the opposite side by way of the trapezoid body and from the preolivary nuclei. It lies in the ventral or ventro-lateral part of the reticular formation of the pons, at first ventral then lateral to the median fillet. Above the pons these ascending fibers come to the surface at the side of the reticular formation in the trigonum lemnisci and are covered by a layer of ependyma. This part of the lateral lemniscus is known as the **fillet of Reil.** On reaching the level of the inferior colliculus the dorsal fibers which overlie the superior peduncle decussate in the velum medullare anterius with similar fibers of the opposite side. Numerous small masses of cells are scattered along the path of the lateral lemniscus above the superior olivary nucleus and constitute **lower and upper nuclei of the lateral lemniscus.** They are supplied with many collaterals and possibly terminals from the fibers of the lemniscus. The axons of the lower nucleus of the lateral lemniscus, which arise from the larger stellate *24* or spindle-shaped cells, with long, smooth, much branched dendrites, are said by some authors to join the lateral lemniscus, but according to Cajal they pass medially toward the raphé; their termination is unknown. The cells of the upper nucleus of the lateral lemniscus are more scattered. The same uncertainty exists in regard to their termination.

The fibers of the lateral lemniscus end by terminals or collaterals in the inferior colliculus and the medial geniculate body. A few of the fibers are said to pass by the inferior colliculus to terminate in the middle portion of the stratum griseum of the superior colliculus, and are probably concerned with reflex movements of the eyes depending on acoustic stimuli. *25*

The **inferior colliculi** (*lower or posterior quadrigeminal bodies*) are important auditory reflex centers. Each consists of a compact nucleus of gray matter covered by a superficial white layer and separated from the central gray matter about the aqueduct by a thin, deep, white layer. Many of the axons which appear in the superficial white layer ascend through the inferior brachium to the medial geniculate body. Others mainly from large cells in the dorso-mesial part of the nucleus pass through the deep white layer into the tegmentum of the same and the opposite side and descend. Their termination is unknown, but they probably constitute an auditory reflex path to the lower motor centers, perhaps descending into the spinal cord with the tectospinal fasciculus. Other axons are said to descend in the lateral lemniscus to the various nuclei in the auditory path (Held) and probably to motor nuclei of the medulla and spinal cord. *26*

The **medial geniculate body** receives terminals and collaterals from the lateral lemniscus (the central auditory path) and also large numbers of axons from the inferior colliculus of the same side and a few from the opposite side. It is thus a station in the central auditory path. A large proportion of its axons pass forward beneath the optic tract to join the corona radiata and then sweep backward and lateralward as the auditory radiation to terminate in the cortex of the superior temporal gyrus. V. Monakow holds that Golgi cells type II are interpolated between the terminations of the incoming fibers to the medial geniculate body and the cells located there which give rise to the fibers of the auditory radiation. the medial geniculate bodies are united by the long, slender **commissure of Gudden.** These fibers join the optic tract as it passes over the edge of the medial geniculate and passes through the posterior part of the optic chiasma. It is probably a commissure connected with the auditory system. *27*

The **Vestibular Nerve** (*vestibular root, VIII cranial*) arise from the bipolar cells in the vestibular ganglion (Scarpa's ganglion). The peripheral fibers end in the semicircular canals, the saccule and the utricle, the end-organs concerned with mechanism for the maintenance of bodily equilibrium. The central fibers enter the medulla oblongata and pass between the inferior peduncle and the spinal tract of the trigeminal. They bifurcate into ascending and descending branches as do the dorsal root fibers of all the spinal nerves and all afferent cranial nerves. The descending branches terminate in the dorsal (medial) vestibular nucleus, the principal nucleus of the vestibular nerve. This nucleus is prolonged downward into a descending portion in which end terminals and collaterals of the descending branch. The ascending branches pass to Deiters's nucleus, to Bechterew's nucleus and through the inferior peduncle of the cerebellum to the nucleus tecti of the opposite side. *28*

The **dorsal vestibular nucleus** (*medial or principal nucleus*) is a large mass of small cells in the floor of the fourth ventricle under the area acustica, located partly in the medulla and partly in the pons. The striæ medullares cross the upper part of it. It is separated from the median plane by the nucleus intercalatus. Its axons pass into the posterior longitudinal bundle of the same and the opposite side and ascend to terminate in the nucleus abducens of the same side and in the trochlear nucleus and the oculo-motor nucleus of the opposite side, and to the motor nuclei of the trigeminal on both sides. The descending portion, the nucleus of the descending tract extends downward as far as the upper end of the nucleus gracilis, and the decussation of the medial lemniscus. It is sometimes called the **inferior vestibular nucleus.** Many of its axons cross the midline and probably ascend with the medial lemniscus to the ventro-lateral region of the thalamus. *29*

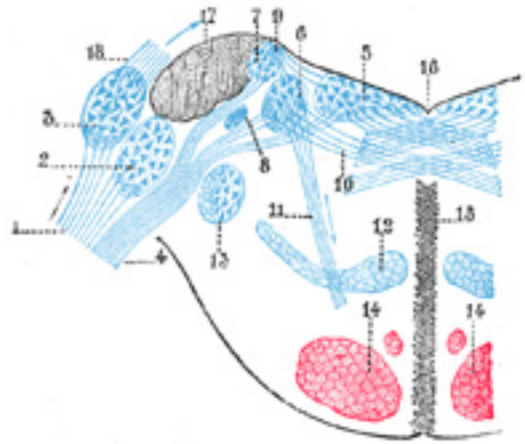


FIG. 761– Terminal nuclei of the vestibular nerve, with their upper connections. (Schematic.) 1. Cochlear nerve, with its two nuclei. 2. Accessory nucleus. 3. Tuberculum acusticum. 4. Vestibular nerve. 5. Internal nucleus. 6. Nucleus of Deiters. 7. Nucleus of Bechterew. 8. Inferior or descending root of acoustic. 9. Ascending cerebellar fibers. 10. Fibers going to raphé. 11. Fibers taking an oblique course. 12. Lemniscus. 13. Inferior sensory root of trigeminal. 14. Cerebrospinal fasciculus. 15. Raphé. 16. Fourth ventricle. 17. Inferior peduncle. Origin of striæ medullares. (Testut.) (See enlarged image)

The **lateral vestibular nucleus** (*Deiters's nucleus*) is the continuation upward and lateralward of the principal nucleus, and in it terminate 30
many of the ascending branches of the vestibular nerve. It consists of very large multipolar cells whose axons form an important part of the posterior longitudinal bundle of the same and the opposite side. The axons bifurcate as they enter the posterior longitudinal bundle, the ascending branches send terminals and collaterals to the motor nuclei of the abducens, trochlear and oculomotor nerves, and are concerned in coördinating the movements of the eyes with alterations in the position of the head; the descending branches pass down in the posterior longitudinal bundle into the anterior funiculus of the spinal cord as the vestibulospinal fasciculus (anterior marginal bundle) and are distributed to motor nuclei of the anterior column by terminals and collaterals. Other fibers are said to pass directly to the vestibulospinal fasciculus without passing into the posterior longitudinal bundle. The fibers which pass into the vestibulospinal fasciculus are intimately concerned with equilibratory reflexes. Other axons from Deiters's nucleus are supposed to cross and ascend in the opposite medial lemniscus to the ventro-lateral nuclei of the thalamus; still other fibers pass into the cerebellum with the inferior peduncle and are distributed to the cortex of the vermis and the roof nuclei of the cerebellum; according to Cajal they merely pass through the nucleus fastigii on their way to the cortex of the vermis and the hemisphere.

The **superior vestibular nucleus** (*Bechterew's nucleus*) is the dorso-lateral part of the vestibular nucleus and receives collaterals and terminals 31
from the ascending branches of the vestibular nerve. Its axons terminate in much the same manner as do those from the lateral nucleus.

The **Facial Nerve** (*VII cranial*) consists of somatic sensory, sympathetic afferent, taste, somatic motor and sympathetic efferent fibers. The 32 afferent or sensory fibers arise from cells in the geniculate ganglion. This portion of the nerve is often described as the nervus intermedius.

(1) The **somatic sensory fibers** are few in number and convey sensory impulses from the middle ear region. Their existence has not been fully 33
confirmed. Their central termination is likewise uncertain, it is possible that they join the spinal tract of the trigeminal as do the somatic sensory fibers of the vagus and glossopharyngeal.

(2) The **sympathetic afferent fibers** are likewise few in number and of unknown termination. 34

(3) **Taste fibers** convey impulses from the anterior two-thirds of the tongue via the chorda tympani. They are supposed to join the tractus 35
solitarius and terminate in its nucleus. The central connections of this nucleus have already been considered.

(4) **Somatic motor fibers,** supplying the muscles derived from the hyoid arch, arise from the large multipolar cells of the nucleus of the facial 36
nerve. This nucleus is serially homologous with the nucleus ambiguus and lateral part of the anterior column of the spinal cord. Voluntary impulses from the cerebral cortex are conveyed by terminals and collaterals of the pyramidal tract of the opposite side, indirectly, that is with the interpolation of a connecting neuron, to the facial nucleus. This nucleus undoubtedly receives many reflex fibers from various sources, *i. e.,* from the superior colliculus via the ventral longitudinal bundle (*tectospinal fasciculus*) for optic reflexes; from the inferior colliculus via the auditory reflex path; and indirectly from the terminal sensory nuclei of the brain-stem. Through the posterior longitudinal bundle it is intimately connected with other motor nuclei of the brain-stem.

(5) **Sympathetic efferent fibers** (*preganglionic fibers*) arise according to some authors from the small cells of the facial nucleus, or according 37
to others from a special nucleus of cells scattered in the reticular formation, dorso-medial to the facial nucleus. This is sometimes called the **superior salivatory nucleus.** These preganglionic fibers are distributed partly via the chorda tympani and lingual nerves to the submaxillary ganglion, thence by postganglionic (vasodilator) fibers to the submaxillary and sublingual glands. Some of the preganglionic fibers pass to the sphenopalatine ganglion via the great superficial petrosal nerve.

The **Abducens Nerve** (*VI cranial*) contains somatic motor fibers only which supply the lateral rectus muscle of the eye. The fibers arise from 38
the nucleus of the abducens nerve and pass ventrally through the formatio reticularis of the pons to emerge in the transverse groove between the caudal edge of the pons and the pyramid. The nucleus is serially homologous with the nuclei of the trochlear and oculomotor above and with the hypoglossal and medial part of the anterior column of the spinal cord below. It is situated close to the floor of the fourth ventricle, just above the level of the striæ medullares. Voluntary impulses from the cerebral cortex are conducted by the pyramidal tract fibers (**corticopontine fibers**). These fibers probably terminate in relation with association neurons which control the coördinated action of all the eye muscles. This association and coördination mechanism is interposed between the terminals and collaterals of the voluntary fibers and the neurons within the nuclei of origin of the motor fibers to the eye muscles. The fibers of the posterior longitudinal bundle are supposed to play an important role in the coördination of the movements of the eyeball. Whether it is concerned only with coördinations between the vestibular apparatus and the eye or with more extensive coördinations is unknown. Many fibers of the posterior longitudinal bundle have their origin in the terminal nuclei of the vestibular nerve and from the posterior longitudinal bundle many collaterals and terminals are given off to the abducent nucleus as well as to the trochlear and oculomotor nuclei. The abducens nucleus probably receives collaterals and terminals from the ventral longitudinal bundle (tectospinal fasciculus); fibers which have their origin in the superior colliculus, the primary visual center, and are concerned with visual reflexes. Others probably come from the reflex auditory center in the inferior colliculus and from other sensory nuclei of the brain-stem.

The **Trigeminal Nerve** (*V cranial*) contains somatic motor and somatic sensory fibers. The motor fibers arise in the motor nucleus of the 39
trigeminal and pass ventro-laterally through the pons to supply the muscles of mastication. The sensory fibers arise from the unipolar cells of the semilunar ganglion; the peripheral branches of the T-shaped fibers are distributed to the face and anterior two-thirds of the head; the central

fibers pass into the pons with the motor root and bifurcate into ascending and descending branches which terminate in the sensory nuclei of the trigeminal.

The **motor nucleus** of the trigeminal is situated in the upper part of the pons beneath the lateral angle of the fourth ventricle. It is serially 40
homologous with the facial nucleus and the nucleus ambiguus (motor nucleus of the vagus and glossopharyngeal) which belong to the motor nuclei of the lateral somatic group. The axons arise from large pigmented multipolar cells. The motor nucleus receives reflex collaterals and terminals, (1) from the terminal nucleus of the trigeminal of the same and a few from the opposite side, via the central sensory tract (trigeminothalamic tract); (2) from the mesencephalic root of the trigeminal; (3) from the posterior longitudinal bundle; (4) and probably from fibers in the formatio reticularis. It also receives collaterals and terminals from the opposite pyramidal tract (corticopontine fibers) for voluntary movements. There is probably a connecting or association neuron interposed between these fibers and the motor neurons.

The **terminal sensory nucleus** consists of an enlarged upper end, the **main sensory nucleus,** and a long more slender descending portion 41
which passes down through the pons and medulla to become continuous with the dorsal part of the posterior column of the gray matter especially the substantia gelatinosa of the spinal cord. This descending portion consists mainly of substantia gelatinosa and is called the **nucleus of the spinal tract of the trigeminal nerve.**

The **main sensory nucleus** lies lateral to the motor nucleus beneath the superior peduncle. It receives the short ascending branches of the 42
sensory root. The descending branches which form the **tractus spinalis,** pass down through the pons and medulla on the lateral side of the **nucleus of the tractus spinalis,** in which they end by collaterals and terminals, into the spinal cord on the level of the second cervical segment. It decreases rapidly in size as it descends. At first it is located between the emergent part of the facial nerve and the vestibular nerve, then between the nucleus of the facial nerve and the inferior peduncle. Lower down in the upper part of the medulla it lies beneath the inferior peduncle and is broken up into bundles by the olivocerebellar fibers and the roots of the ninth and tenth cranial nerves. Finally it comes to the surface of the medulla under the tubercle of Rolando and continues in this position lateral to the fasciculus cuneatus as far as the upper part of the cervical region where it disappears.

The cells of the sensory nucleus are of large and medium size and send their axons into the formatio reticularis where they form a distinct 43
bundle, the **central path of the trigeminal** (*trigeminothalamic tract*), which passes upward through the formatio reticularis and tegmentum to the ventro-lateral part of the thalamus. Most of the fibers cross to the trigeminothalamic tract of the opposite side. This tract lies dorsal to the medial fillet; approaches close to it in the tegmentum and terminates in a distinct part of the thalamus. From the thalamus impulses are conveyed to the somatic sensory area of the cortex by axons of cells in the thalamus through the internal capsule and corona radiata. Many collaterals are given off in the medulla and pass from the trigeminothalamic tract to the motor nuclei, especially to the nucleus ambiguus, the facial nucleus and the motor nucleus of the trigeminal.

The somatic sensory fibers of the vagus, the glossopharyngeal and the facial nerves probably end in the nucleus of the descending tract of the 44
trigeminal and their cortical impulses are probably carried up in the central sensory path of the trigeminal.

The **mesencephalic root** (*descending root of the trigeminal*) arises from unipolar cells arranged in scattered groups in a column at the lateral 45
edge of the central gray matter surrounding the upper end of the fourth ventricle and the cerebral aqueduct. They have usually been considered as motor fibers that join the motor root, but Johnston claims that they join the sensory root of the trigeminal, that they develop in the alar, not in the basal lamina, and that the pear-shaped unipolar cells are sensory in type.

The **Trochlear Nerve** (*IV cranial*) contains somatic motor fibers only. It supplies the superior oblique muscle of the eye. Its nucleus of 46
origin, **trochlear nucleus,** is a small, oval mass situated in the ventral part of the central gray matter of the cerebral aqueduct at the level of the

upper part of the inferior colliculus. The axons from the nucleus pass downward in the tegmentum toward the pons, but turn abruptly dorsalward before reaching it, and pass into the superior medullary velum, in which they cross horizontally, to decussate with the nerve of the opposite side, and emerges from the surface of the velum, immediately behind the inferior colliculus. The cells of the trochlear nucleus are large, irregular and yellowish in color. The nuclei of the two sides are separated by the raphé through which dendrites extend from one nucleus to the other. They receive many collaterals and terminals from the posterior longitudinal bundle which lies on the ventral side of the nucleus.

There are no branches from the fibers of the pyramidal tracts to these nuclei; the volitional pathway must be an indirect one, as is the case with 47
other motor nuclei.

The **Oculomotor Nerve** (*III cranial*) contains somatic motor fibers to the Obliquus inferior, Rectus inferior, Rectus superior, Levator palpebræ 48
superioris and Rectus medialis muscles and sympathetic efferent fibers (preganglionic fibers) to the ciliary ganglion. The postganglionic fibers connected with these supply the ciliary muscle and the sphincter of the iris. The axons arise from the nucleus of the oculomotor nerve and pass in bundles through the posterior longitudinal bundle, the tegmentum, the red nucleus and the medial margin of the substantia nigra in a series of curves and finally emerge from the oculomotor sulcus on the medial side of the cerebral peduncle.

The **oculomotor nucleus** lies in the gray substance of the floor of the cerebral aqueduct subjacent to the superior colliculus and extends in front 49
of the aqueduct a short distance into the floor of the third ventricle. The inferior end is continuous with the trochlear nucleus. It is from 6 to 10 mm. in length. It is intimately related to the posterior longitudinal bundle which lies against its ventro-lateral aspect and many of its cells lie among the fibers of the posterior longitudinal bundle. The nucleus of the oculomotor nerve contains several distinct groups of cells which differ in size and appearance from each other and are supposed to send their axons each to a separate muscle. Much uncertainty still exists as to which group supplies which muscle. There are seven of these groups or nuclei on either side of the midline and one medial nucleus. The cells of the anterior nuclei are smaller and are supposed to give off the sympathetic efferent axons. The majority of fibers arise from the nucleus of the same side some, however, cross from the opposite side and are supposed to supply the Rectus medialis muscle. Since oculomotor and abducens nuclei are intimately connected by the posterior longitudinal bundle this decussation of fibers to the Medial rectus may facilitate the conjugate movements of the eyes in which the Medial and Lateral recti are especially involved.

Many collaterals and terminals are given off to the oculomotor nucleus from the posterior longitudinal bundle and thus connect it with the 50
vestibular nucleus, the trochlear and abducens nuclei and probably with other cranial nuclei. Fibers from the visual reflex center in the superior colliculus pass to the nucleus. It is also connected with the cortex of the occipital lobe of the cerebrum by fibers which pass through the optic radiation. The pathway for voluntary motor impulses is probably similar to that for the abducent nerve.

The **Optic Nerve** or **Nerve of Sight** (*II cranial*) consists chiefly of coarse fibers which arise from the ganglionic layer of the retina. They 51
constitute the third neuron in the series composing the visual path and are supposed to convey only visual impressions. A number of fine fibers also pass in the optic nerve from the retina to the primary centers and are supposed to be concerned in the pupillary reflexes. There are in addition a few fibers which pass from the brain to the retina; they are supposed to control chemical changes in the retina and the movements of the pigment cells and cones. Each optic nerve has, according to Salzer, about 500,000 fibers.

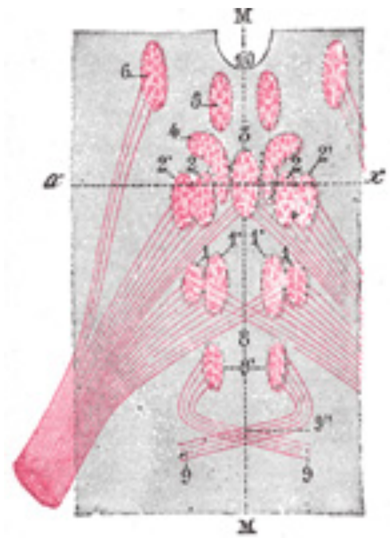


FIG. 762– Figure showing the different groups of cells, which constitute, according to Perlia, the nucleus of origin of the oculomotor nerve. 1. Posterior dorsal nucleus. 1’. Posterior ventral nucleus. 2. Anterior dorsal nucleus. 2’. Anterior ventral nucleus. 3. Central nucleus. 4. Nucleus of Edinger and Westphal. 5. Antero-internal nucleus. 6. Antero-external nucleus. 8. Crossed fibers. 9. Trochlear nerve, with 9’, its nucleus of origin, and 9", its decussation. 10. Third ventricle. *M, M*. Median line. (Testut.) (See enlarged image)

In the optic chiasma the nerves from the medial half of each retina cross to enter the opposite optic tract, while the nerves from the lateral half 52
of each retina pass into the optic tract of the same side. The crossed fibers tend to occupy the medial side of each optic nerve, but in the chiasma and in the optic tract they are more intermingled. The optic tract is attached to the tuber cinereum and lamina terminalis and also to the cerebral peduncle as it crosses obliquely over its under surface. These are not functional connections. A small band of fibers from the medial geniculate body joins the optic tract as the latter passes over it and crosses to the opposite tract and medial geniculate body in the posterior part of the chiasma. This is the commissure of Gudden and is probably connected with the auditory system.

Most of the fibers of the optic tract terminate in the lateral geniculate body, some pass through the superior brachium to the superior colliculus, 53
and others either pass over or through the lateral geniculate body to the pulvinar of the thalamus. These end-stations are often called the **primary visual centers.**

The **lateral geniculate body** consists of medium-sized pigmented nerve cells arranged in several layers by the penetrating fibers of the optic 54
tract. Their axons pass upward beneath the longer fibers of the optic tract, the tænia semicircularis, the caudate nucleus and the posterior horn of the lateral ventricle where they join the optic radiation of Gratiolet. They pass backward and medially to terminate in the visuo-sensory cortex in the immediate neighborhood of the calcarine fissure of the occipital lobe. This center is connected with the one in the opposite side by

commissural fibers which course in the optic radiation and the splenium of the corpus callosum. Association fibers connect it with other regions of the cortex of the same side.

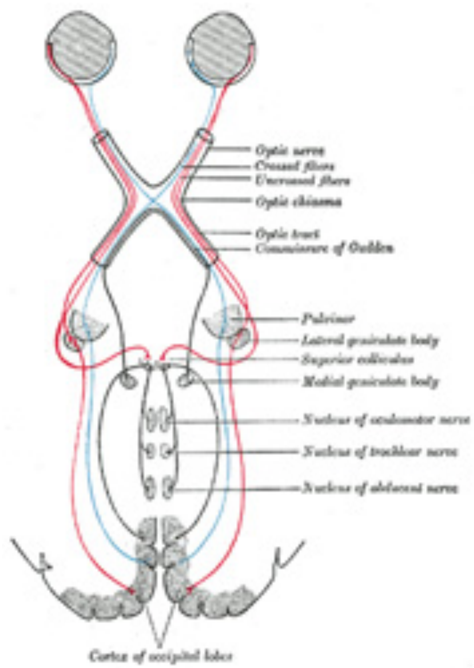


FIG. 763– Scheme showing central connections of the optic nerves and optic tracts. (See enlarged image)

The region of the pulvinar in which optic tract fibers terminate resembles in structure the lateral geniculate body. Its axons also have a similar course though in a somewhat more dorsal plane. 55

The **superior colliculus** receives fibers from the optic tract through the superior brachium. Some enter by the superficial white layer (**stratum zonale**), others appear to dip down into the gray cap (**stratum cinereum**) while others probably decussate across the midline to the opposite colliculus. Other fibers from the superior brachium pass into the **stratum opticum**(upper gray-white layer). Some of these turn upward into the gray cap while others terminate among the cells of this layer. Since the superior colliculi appear to be the central organs concerned in the control of eye-muscle movements and eye-muscle reflexes we should expect to find them receiving fibers from other sensory paths. Many fibers pass to the superior colliculus from the medial fillet as the latter passes through the tegmentum bringing the superior colliculus into relation with the 56 sensory fibers of the spinal cord. Fibers from the central sensory path of the trigeminal probably pass with these. Part of the ventral spinocerebellar tract (Gowers) is said to pass up through the reticular formation of the pons and mid-brain toward the superior colliculus and the thalamus. The superior colliculus is intimately connected with the central auditory path (the **lateral lemniscus**), as part of its fibers pass the inferior colliculus and terminate in the superior colliculus. They are probably concerned with reflex movements of the eyes depending on auditory stimuli. The superior colliculus is said to receive fibers from the stria medullaris thalamis of the opposite side which pass through the commissura habenulæ and turn back to the roof of the mid-brain, especially to the superior colliculus. By this path both the primary and cortical olfactory centers are brought into relation with the eye-muscle reflex apparatus.

The fibers which pass to the nuclei of the eye muscles arise from large cells in the stratum opticum and stratum lemnisci and pass around the *57*
ventral aspect of the central gray matter where most of them cross the midline in the fountain decussation of Meynert, and then turn downward to form the ventral longitudinal bundle. This bundle runs down partly through the red nucleus, in the formatio reticularis, ventral to the posterior longitudinal bundle of the mid-brain, pons and medulla oblongata into the ventral funiculus of the spinal cord where it is known as the **tectospinal fasciculus.** Some of the fibers are said to pass down with the rubrospinal tract in the lateral funiculus. Some fibers do not decussate but pass down in the ventral longitudinal bundle of the same side on which they arise unless possibly they come from the opposite colliculus over the aqueduct. From the ventral longitudinal bundle collaterals are given off to the nuclei of the eye muscles, the oculomotor, the trochlear and the abducens. Many collaterals pass to the red nucleus, and are probably concerned with the reflexes of the rubrospinal tract. The fibers of the tectospinal tract end by collaterals and terminals either directly or indirectly among the motor cells in the anterior column of the spinal cord.

The superior colliculus receives fibers from the visual sensory area of the occipital cortex; they pass in the optic radiation. Probably no fibers *58*
pass from the superior colliculus to the visual sensory cortex.

The **Olfactory Nerves** (*I cranial*) or **nerves of smell** arise from spindle-shaped bipolar cells in the surface epithelium of the olfactory region of *59*
the nasal cavity. The non-medullated axons pass upward in groups through numerous foramina in the cribriform plate to the olfactory bulb; here several fibers, each ending in a tuft of terminal filaments, come into relation with the brush-like end of a single dendrite from a mitral cell. This interlacing gives rise to the olfactory glomeruli of the bulb. The termination of several or many olfactory fibers in a single glomerulus where they form synapses with the dendrites of one or two mitral cells provides for the summation of stimuli in the mitral cells and accounts in part at least for the detection by the olfactory organs of very dilute solutions. Lateral arborizations of the dendrites of the mitral cells and the connection of neighboring glomeruli by the axons of small cells of the glomeruli and the return of impulses of the mitral cells by collaterals either directly or through the interpolation of granule cells to the dendrites of the mitral cells reinforce the discharge of the mitral cells along their axons. The axons turn abruptly backward in the deep fiber layer of the bulb to form the olfactory tract. The olfactory tract is continued into the olfactory trigone, just in front of the anterior perforated substance. The axons of the mitral cells on reaching the olfactory trigone separate into three bundles, the **lateral olfactory stria,** the **medial olfactory stria** and the less marked **intermedial olfactory stria.**

The **lateral olfactory striæ** curve lateralward, a few of the fibers end in the olfactory trigone and the antero-lateral portion of the anterior *60*
perforated substance. Most of the fibers, however, pass into the uncus, the anterior end of the hippocampal gyrus, and there end in the complicated cortex of the hippocampal gyri. The lateral striæ more or less disappear as they cross the antero-lateral region of the anterior perforated substance.

The greater mass of the fibers of the olfactory tract pass into the lateral stria. Numerous collaterals are given into the plexiform layer of the *61*
subfrontal cortex, over which the striæ pass on their way to the uncus, where they intermingle with the apical dendrons of the medium-sized and

small pyramidal cells of the pyramidal layer of this subfrontal or frontal olfactory cortex. The axons give rise to projection fibers which take an antero-posterior direction to the subthalamic region sending collaterals and terminal branches to the stria medullaris and others toward the thalamus. Some of the fibers extend farther back and are believed to reach the pons and medulla oblongata.

Most of the fibers of the lateral olfactory stria pass to the hippocampal region of the cortex, especially to the gyrus hippocampi, which may be regarded as the main ending place of the secondary olfactory path derived from axons of the mitral cells. 62

The fibers of the **medial olfactory striæ** terminate for the most part in the parolfactory area (*Broca's area*), a few end in the subcallosal gyrus and a few in the anterior perforated substance and the adjoining part of the septum pellucidum. Some of the fibers pass into the anterior commissure (**pars olfactoria**) to the olfactory tract of the opposite side where they end partly within the granular layer and partly in the neighborhood of the glomeruli of the olfactory bulb, thus connecting the bulbs of the two sides. 63

The **intermediate olfactory striæ** are as a rule scarcely visible, the fibers terminate in the anterior perforated substance, a few are said to continue to the uncus. 64

The trigonum olfactorium, anterior perforated substance and the adjoining part of the septum pellucidum are important primary olfactory centers, especially for olfactory reflexes; in these centers terminate many axons from the mitral cells of the olfactory bulb. In addition the gray substance of the olfactory tract and the gyrus subcallosus receive terminals of the mitral cells. 65

The pathways from these centers to lower centers in the brain-stem and spinal cord are only partially known. The most direct path, the **tractus olfactomesencephalicus** (*basal olfactory bundle of Wallenburg*), is supposed to arise from cells in the gray substance of the olfactory tract, the olfactory trigone, the anterior perforated substance and the adjoining part of the septum pellucidum. The fibers are said to pass direct to the tuber cinereum, to the corpus mammillare, to the brainstem and the spinal cord. The fibers which enter the mammillary body probably come into relation with cells whose axons give rise to the**fasciculus mammillo-tegmentalis** (*mammillo-tegmental bundle of Gudden*) which is supposed to end in the gray substance of the tegmentum and of the aqueduct; some of its fibers are said to join the posterior longitudinal bundle and others to extend as far as the reticular formation of the pons. 66

Some of the fibers of the medial olfactory stria came into relation with cells in the parolfactory area of Broca and in the anterior perforated substance, whose axons course in the medullary stria of the thalamus. As the axons pass through the lower part of the septum pellucidum they are joined by other fibers whose cells receive impulses from the mitral cells. These fibers of the medullary stria end for the most part in the habenular nucleus of the same side, some, however, cross in the habenular commissure (dorsal part of the posterior commissure) to the habenular nucleus of the opposite side. A few fibers of the medullary stria are said to pass by the habenular nucleus to the roof of the mid-brain, especially the superior colliculus, while a few others come into relation with the posterior longitudinal bundle and association tracts of the mesencephalon. 67

The ganglion of the habenulæ located in the trigonum habenulæ just in front of the superior colliculus contains a mesial nucleus with small cells and a lateral nucleus with larger cells. The axons of these cells are grouped together in a bundle, the **fasciculus retroflexus of Meynert,** which passes ventrally medial to the red nucleus and terminates in a small medial ganglion in the substantia perforata posterior, immediately in front of the pons, called the **interpeduncular ganglion.** 68

The **interpeduncular ganglion** has rather large nerve cells whose axons curve backward and downward as the **tegmental bundle of Gudden,** to end partly in the dorsal tegmental nucleus and surrounding gray substance where they come into relation with association neurons and the dorsal longitudinal bundle of Schütz. 69

The majority of the axons that arise from the mitral cells of the olfactory bulb and course in the olfactory tract course in the lateral olfactory 70 stria to the uncus and hippocampal gyrus, and terminate in the cortex. Other fibers probably pass to the uncus and hippocampal gyrus from the primary olfactory centers in the trigonum and anterior perforated substance. The gyrus hippocampus is continued through the isthmus into the gyrus cinguli which passes over the corpus callosum to the area parolfactoria. The cortical portions of these gyri are connected together by a thick association bundle, the **cingulum,** that lies buried in the depth of the gyrus cinguli extending forward to the parolfactory area and backward into the hippocampal region. The axons from the gyrus cinguli pass into the cingulum, many of them bifurcate, the anterior branches together with the axons which run in that direction are traceable as far forward as the anterior part of the septum pellucidum and the anterior end of the corpus striatum, where some of them are incorporated with projection fibers passing toward the internal capsule. The branches and axons which pass backward terminate partly in the hippocampus, the dentate gyrus and hippocampal gyrus. Shorter association fibers connect various sections of the gyrus fornicatus (cingulate gyrus, isthmus, and hippocampal gyrus) and these with other regions of the cortex. These gyri constitute the cortical center for smell.

The **dentate gyrus** which may be considered as a modified part of the hippocampus is partially separated from the gyrus hippocampus by the hippocampal fissure and from the fimbria by the fimbrio-dentate sulcus; it is intimately connected with the hippocampal gyrus and the hippocampus. When followed backward the dentate gyrus separates from the fimbria at the splenium, loses its incisions and knobs, and as the fasciola cinerea passes over the splenium onto the dorsal surface of the corpus callosum and spreads out into a thin layer of gray substance known as the **indusium,** which can be traced forward around the genu of the corpus callosum into the gyrus subcallosus. The white matter of the indusium known as the **medial longitudinal striæ** (*nerves of Lancisi*) and the **lateral longitudinal striæ,** are related to the indusium somewhat as the cingulum is to the gyrus cinguli. Axons from the indusium pass into the longitudinal striæ, some running forward and others backward while some after entering the medial longitudinal stria, pierce the corpus callosum to join the fornix. Some of the fibers which pass forward extend around the front of the corpus callosum and the anterior commissure, then curve downward, according to Cajal, to enter the corpus striatum where they join the olfactory projection-path. Other fibers are said to arise in the parolfactory area, the **gyrus subcallosus** and the **anterior perforated substance** (*diagonal band of Broca*) and course backward in the longitudinal striæ to the dentate gyrus and the hippocampal region. The indusium is usually considered as a rudimentary part of the rhinencephalon. *71*

The **olfactory projection fibers** which arise from the pyramid cells of the uncus and hippocampus and from the polymorphic cells of the dentate gyrus form a dense stratum on the ventricular surface, especially on the hippocampus, called the **alveus.** These fibers pass over into the fimbria and are continued into the **fornix.** About one-fourth of all the fibers of the fimbria are large projection fibers, the other three-fourths consist of fine commissural fibers which pass from the hippocampus of one side through the fimbria and **hippocampal commissure** (*ventral psalterium or lyre*), to the fimbria and hippocampus of the opposite side where they penetrate the pyramidal layer and terminate in the stratum radiatum. The fibers which course in the fornix pass forward and downward into the corpora mammillare where numerous collaterals are given off and a few terminate. Most of the fibers in the fornix, however, pass through the corpora, cross the middle line and turn downward in the reticular formation in which they are said to be traceable as far as the pons and possibly farther. As the fornix passes beneath the corpus callosum it receives fibers from the longitudinal striæ of the indusium and from the cingulum; these are the perforating fibers of the fornix which pass through the corpus callosum and course in the fornix toward the mammillary body. As the fornix passes the anterior end of the thalamus a few fibers are given off to the stria medullaris of the thalamus and turn back in the stria to the habenular ganglion of the same and the opposite side, having probably the same relation that the reflex fibers have which arise from the primary centers and course in the stria medullaries of the thalamus. Aside from the fibers of the fornix which pass through the mammillary body to decussate and descend (as the mammillo-mesencephalic fasciculus), many fibers are said to pass into the **bundle of Vicq d’Azyr,** and one bundle of fibers is said to pass from the fornix *72* to the tuber cinereum.

The mammillary bodies receive collaterals and terminals then from the cortical centers via the fornix and probably other collaterals and terminals are received directly from the primary centers through the tractus olfactomesencephalicus. According to Cajal fibers also reach the mammillary body through the peduncle of the corpus mammillare from the arcuate fibers of the tegmentum and from the main fillet. The fornix probably brings the cortical centers into relation with the reflex path that runs from the primary centers to the mammillary body and the tuber cinereum. *73*

The **bundle of Vicq d'Azyr** (*mammillo-thalamic fasciculus*) arises from cells in both the medial and lateral nuclei of the mammillary body and by fibers that are directly continued from the fornix. There axons divide within the gray matter; the coarser branches pass into the anterior nucleus of the thalamus as the bundle of Vicq d'Azyr, the finer branches pass downward as the mammillo-tegmental bundle of Gudden. The bundle of Vicq d'Azyr spreads out fan-like as it terminates in the anterior or dorsal nucleus of the thalamus. A few of the fibers pass through the dorsal nucleus to the angular nucleus of the thalamus. The axons from these nuclei are supposed to form part of the thalamocortical system. *74*

The mammillo-tegmental bundle has already been considered under the olfactory reflex paths. *75*

The **amygdaloid nucleus** and the **tænia semicircularis** (*stria terminalis*) probably belong to the central olfactory apparatus. The tænia semicircularis extends from the region of the anterior perforated substance to the nucleus amygdalæ. Its anterior connections are not clearly understood. Fibers are said to arise from cells in the anterior perforated substance; some of the fibers pass in front of the anterior commissure, others join the fornix for a short distance as they pass behind the anterior commissure. The two strands ultimately join to form the tænia and pass backward in the groove between the caudate nucleus and the thalamus to the amygdaloid nucleus. Other fibers are said to pass in the opposite direction from the amygdaloid nucleus to the thalamus. *76*

1F. Pathways from the Brain to the Spinal Cord

The descending fasciculi which convey impulses from the higher centers to the spinal cord and located in the lateral and ventral funiculi. *1*

The **Motor Tract** (Fig. 764), conveying voluntary impulses, arises from the pyramid cells situated in the motor area of the cortex, the anterior central and the posterior portions of the frontal gyri and the paracentral lobule. The fibers are at first somewhat widely diffused, but as they descend through the corona radiata they gradually approach each other, and pass between the lentiform nucleus and thalamus, in the genu and anterior two-thirds of the occipital part of the internal capsule; those in the genu are named the **geniculate fibers,**while the remainder constitute the **cerebrospinal fibers;** proceeding downward they enter the middle three-fifths of the base of the cerebral peduncle. The geniculate fibers cross the middle line, and end by arborizing around the cells of the motor nuclei of the cranial nerves. The cerebrospinal fibers are continued downward into the pyramids of the medulla oblongata, and the transit of the fibers from the medulla oblongata is effected by two paths. The fibers nearest to the anterior median fissure cross the middle line, forming the**decussation of the pyramids,** and descend in the opposite side of the medulla spinalis, as the **lateral cerebrospinal fasciculus** (*crossed pyramidal tract*). Throughout the length of the medulla spinalis fibers from this column pass into the gray substance, to terminate either directly or indirectly around the motor cells of the anterior column. The more laterally placed portion of the tract does not decussate in the medulla oblongata, but descends as the**anterior cerebrospinal fasciculus** (*direct pyramidal tract*); these fibers, however, end in the anterior gray column of the opposite side of the medulla spinalis by passing across in the anterior white commissure. There is considerable variation in the extent to which decussation takes place in the medulla oblongata; about two-thirds or three-fourths of the fibers usually decussate in the medulla oblongata and the remainder in the medulla spinalis. *2*

The axons of the motor cells in the anterior column pass out as the fibers of the anterior roots of the spinal nerves, along which the impulses are 3
conducted to the muscles of the trunk and limbs.

From this it will be seen that all the fibers of the motor tract pass to the nuclei of the motor nerves on the opposite side of the brain or medulla 4
spinalis, a fact which explains why a lesion involving the motor area of one side causes paralysis of the muscles of the opposite side of the body. Further, it will be seen that there is a break in the continuity of the motor chain; in the case of the cranial nerves this break occurs in the nuclei of these nerves; and in the case of the spinal nerves, in the anterior gray column of the medulla spinalis. For clinical purposes it is convenient to emphasize this break and divide the motor tract into two portions: (1) a series of **upper motor neurons** which comprises the motor cells in the cortex and their descending fibers down to the nuclei of the motor nerves; (2) a series of **lower motor neurons** which includes the cells of the nuclei of the motor cerebral nerves or the cells of the anterior columns of the medulla spinalis and their axiscylinder processes to the periphery.

The **rubrospinal fasciculus** arises from the large cells of the red nucleus. The fibers cross the raphé of the mid-brain in the decussation of Forel 5
and descend in the formatio reticularis of the pons and medulla dorsal to the medial lemniscus and as they pass into the spinal cord come to lie in a position ventral to the crossed pyramidal tracts in the lateral funiculus. The rubrospinal fibers end either directly or indirectly by terminals and collaterals about the motor cells in the anterior column on the side opposite from their origin in the red nucleus. A few are said to pass down on the same side. Since the red nucleus is intimately related to the cerebellum by terminals and collaterals of the superior peduncle which arises in the dentate nucleus of the cerebellum, the rubrospinal fasciculus is supposed to be concerned with cerebellar reflexes, complex motor coördinations necessary in locomotion and equilibrium. The afferent paths concerned in these reflexes have already been partly considered, namely, the dorsal and ventral spinocerebellar fasciculi, and probably some of the fibers of the posterior funiculi which reach the cerebellum by the inferior peduncle.

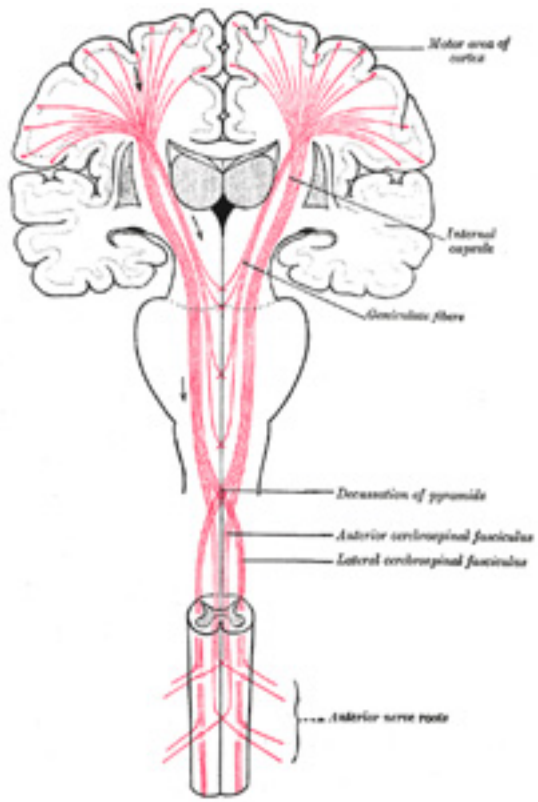


FIG. 764– The motor tract. (Modified from Poirier.) (See enlarged image)

The **tectospinal fasciculus** arises from the superior colliculus of the roof (tectum) of the mid-brain. The axons come from large cells in the stratum opticum and stratum lemnisci and sweep ventrally around the central gray matter of the aqueduct, cross the raphé in the fountain decussation of Meynert and turn downward in the tegmentum in the ventral longitudinal bundle. Some of the fibers do not cross in the raphé but pass down on the same side; it is uncertain whether they come from the superior colliculus of the same side or arch over the aqueduct from the colliculus of the opposite side. The tectospinal fasciculus which comprises the major part of the ventral longitudinal bundle passes down through the tegmentum and reticular formation of the pons and medulla oblongata ventral to the medial longitudinal bundle. In the medulla the two bundles are more or less intermingled and the tectospinal portion is continued into the antero-lateral funiculus of the spinal cord ventral to the 6 rubrospinal fasciculus with which some of its fibers are intermingled. Some of the fibers of the tectospinal fasciculus pass through the red nucleus giving off collaterals to it, others are given off to the motor nuclei of the cranial nerves and in the spinal cord they terminate either directly or indirectly by terminals and collaterals among the nuclei of the anterior column. Since the superior colliculus is an important optic reflex center, this tract is probably concerned in optic reflexes; and possibly also with auditory reflexes since some of the fibers of the central auditory path, the lateral lemniscus, terminate in the superior colliculus.

The **vestibulospinal fasciculus** (*part of the anterior marginal fasciculus* or *Loewenthal's tract*) situated chiefly in the marginal part of the anterior funiculus is mainly derived from the cells of the terminal nuclei of the vestibular nerve, probably Deiters's and Bechterew's, and some of its fibers are supposed to come from the nucleus fastigius (roof nucleus of the cerebellum). The latter nucleus is intimately connected with Dieters's and Bechterew's nuclei. The vestibulospinal fasciculus is concerned with equilibratory reflexes. Its terminals and collaterals end about the motor cells in the anterior column. It extends to the sacral region of the cord. Its fibers are intermingled with the ascending spinothalamic fasciculus, with the anterior proper fasciculus and laterally with the tectospinal fasciculus. Its fibers are supposed to be both crossed and uncrossed. In the brain-stem it is associated with the dorsal longitudinal bundle. *7*

The **pontospinal fasciculus** (*Bechterew*) arises from the cells in the reticular formation of the pons from the same and the opposite side and is associated in the brain-stem with the ventral longitudinal bundle. In the cord it is intermingled with the fibers of the vestibulospinal fasciculus in the anterior funiculus. Not much is known about this tract. *8*

There are probably other descending fasciculi such as the thalamospinal but not much is known about them.

4g. The Meninges of the Brain and Medulla Spinalis

The brain and medulla spinalis are enclosed within three membranes. These are named from without inward: the **dura mater,** the **arachnoid,** and the **pia mater.** *1*

The Dura Mater

The **dura mater** is a thick and dense inelastic membrane. The portion which encloses the brain differs in several essential particulars from that which surrounds the medulla spinalis, and therefore it is necessary to describe them separately; but at the same time it must be distinctly understood that the two form one complete membrane, and are continuous with each other at the foramen magnum. *2*

The **Cranial Dura Mater** (*dura mater encephali; dura of the brain*) lines the interior of the skull, and serves the twofold purpose of an internal periosteum to the bones, and a membrane for the protection of the brain. It is composed of two layers, an inner or meningeal and an outer or endosteal, closely connected together, except in certain situations, where, as already described (page 654), they separate to form sinuses for the passage of venous blood. Its outer surface is rough and fibrillated, and adheres closely to the inner surfaces of the bones, the adhesions being most marked opposite the sutures and at the base of the skull its inner surface is smooth and lined by a layer of endothelium. It sends inward four processes which divide the cavity of the skull into a series of freely communicating compartments, for the lodgement and protection of the different parts of the brain; and it is prolonged to the outer surface of the skull, through the various foramina which exist at the base, and thus becomes continuous with the pericranium; its fibrous layer forms sheaths for the nerves which pass through these apertures. Around the margin *3* of the foramen magnum it is closely adherent to the bone, and is continuous with the spinal dura mater.

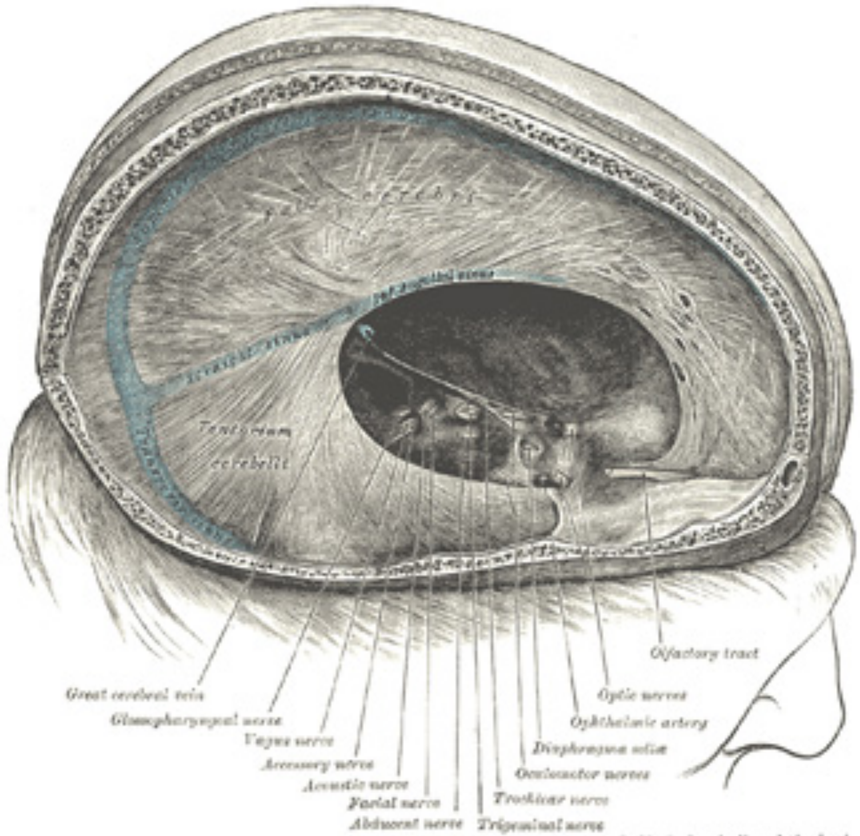


FIG. 765– Dura mater and its processes exposed by removing part of the right half of the skull and the brain. (See enlarged image)

Processes.—The processes of the cranial dura mater, which projects into the cavity of the skull, are formed by reduplications of the inner or 4
meningeal layer of the membrane, and are four in number: the **falx cerebri,** the **tentorium cerebelli,** the **falx cerebelli,** and the**diaphragma**

sellæ.

The **falx cerebri** (Fig. 765), so named from its sickle-like form, is a strong, arched process which descends vertically in the longitudinal fissure 5
between the cerebral hemispheres. It is narrow in front, where it is attached to the crista galli of the ethmoid; and broad behind, where it is connected with the upper surface of the tentorium cerebelli. Its upper margin is convex, and attached to the inner surface of the skull in the middle line, as far back as the internal occipital protuberance; it contains the superior sagittal sinus. Its lower margin is free and concave, and contains the inferior sagittal sinus.

The **tentorium cerebelli** (Fig. 766) is an arched lamina, elevated in the middle, and inclining downward toward the circumference. It covers the 6
superior surface of the cerebellum, and supports the occipital lobes of the brain. Its anterior border is free and concave, and bounds a large oval opening, the **incisura tentorii,** for the transmission of the cerebral peduncles. It is attached, behind, by its convex border, to the transverse ridges upon the inner surface of the occipital bone, and there encloses the transverse sinuses; in front, to the superior angle of the petrous part of the temporal bone on either side, enclosing the superior petrosal sinuses. At the apex of the petrous part of the temporal bone the free and attached borders meet, and, crossing one another, are continued forward to be fixed to the anterior and posterior clinoid processes respectively. To the middle line of its upper surface the posterior border of the falx cerebri is attached, the straight sinus being placed at their line of junction.

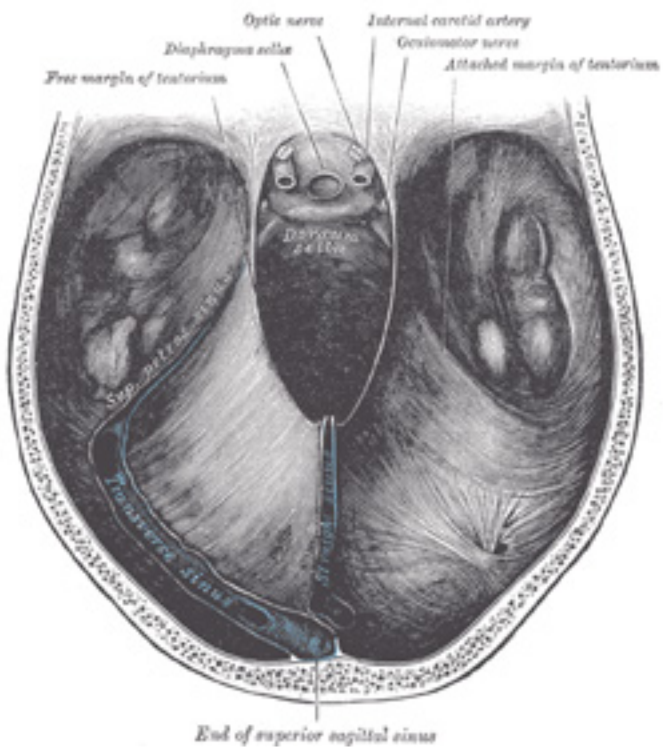


FIG. 766– Tentorium cerebelli seen from above. (See enlarged image)

The **falx cerebelli** is a small triangular process of dura mater, received into the posterior cerebellar notch. Its base is attached, above, to the 7
under and back part of the tentorium; its posterior margin, to the lower division of the vertical crest on the inner surface of the occipital bone. As it descends, it sometimes divides into two smaller folds, which are lost on the sides of the foramen magnum.

The **diaphragma sellæ** is a small circular horizontal fold, which roofs in the sella turcica and almost completely covers the hypophysis; a small 8
central opening transmits the infundibulum.

Structure.—The cranial dura mater consists of white fibrous tissue and elastic fibers arranged in flattened laminæ which are imperfectly 9
separated by lacunar spaces and bloodvessels into two layers, **endosteal** and **meningeal.** The **endosteal layer** is the internal periosteum for the

cranial bones, and contains the bloodvessels for their supply. At the margin of the foramen magnum it is continuous with the periosteum lining the vertebral canal. The **meningeal** or **supporting layer** is lined on its inner surface by a layer of nucleated flattened mesothelium, similar to that found on serous membranes.

The **arteries** of the dura mater are very numerous. Those in the anterior fossa are the anterior meningeal branches of the anterior and posterior ethmoidal and internal carotid, and a branch from the middle meningeal. Those in the middle fossa are the middle and accessory meningeal of the internal maxillary; a branch from the ascending pharyngeal, which enters the skull through the foramen lacerum; branches from the internal carotid, and a recurrent branch from the lacrimal. Those in the posterior fossa are meningeal branches from the occipital, one entering the skull through the jugular foramen, and another through the mastoid foramen; the posterior meningeal **from** the vertebral; occasional meningeal branches from the ascending pharyngeal, entering the skull through the jugular foramen and hypoglossal canal; and a branch from the middle meningeal. *10*

The **veins** returning the blood from the cranial dura mater anastomose with the diploic veins and end in the various sinuses. Many of the meningeal veins do not open directly into the sinuses, but indirectly through a series of ampullæ, termed **venous lacunæ.** These are found on either side of the superior sagittal sinus, especially near its middle portion, and are often invaginated by arachnoid granulations; they also exist near the transverse and straight sinuses. They communicate with the underlying cerebral veins, and also with the diploic and emissary veins. *11*

The **nerves** of the cranial dura mater are filaments from the semilunar ganglion, from the ophthalmic, maxillary, mandibular, vagus, and hypoglossal nerves, and from the sympathetic. *12*

The **Spinal Dura Mater** (*dura mater spinalis; spinal dura*) (Fig. 767) forms a loose sheath around the medulla spinalis, and represents only the inner or meningeal layer of the cranial dura mater; the outer or endosteal layer ceases at the foramen magnum, its place being taken by the periosteum lining the vertebral canal. The spinal dura mater is separated from the arachnoid by a potential cavity, the **subdural cavity;** the two membranes are, in fact, in contact with each other, except where they are separated by a minute quantity of fluid, which serves to moisten the apposed surfaces. It is separated from the wall of the vertebral canal by a space, the **epidural space,** which contains a quantity of loose areolar tissue and a plexus of veins; the situation of these veins between the dura mater and the periosteum of the vertebræ corresponds therefore to that of the cranial sinuses between the meningeal and endosteal layers of the cranial dura mater. The spinal dura mater is attached to the circumference of the foramen magnum, and to the second and third cervical vertebræ; it is also connected to the posterior longitudinal ligament, especially near the lower end of the vertebral canal, by fibrous slips. The subdural cavity ends at the lower border of the second sacral vertebra; below this level the dura mater closely invests the filum terminale and descends to the back of the coccyx, where it blends with the periosteum. The sheath of dura mater is much larger than is necessary for the accommodation of its contents, and its size is greater in the cervical and lumbar regions than in the thoracic. On each side may be seen the double openings which transmit the two roots of the corresponding spinal nerve, the dura mater being continued in the form of tubular prolongations on them as they pass through the intervertebral foramina. These prolongations are short in the upper part of the vertebral column, but gradually become longer below, forming a number of tubes of fibrous membrane, which enclose the lower spinal nerves and are contained in the vertebral canal. *13*

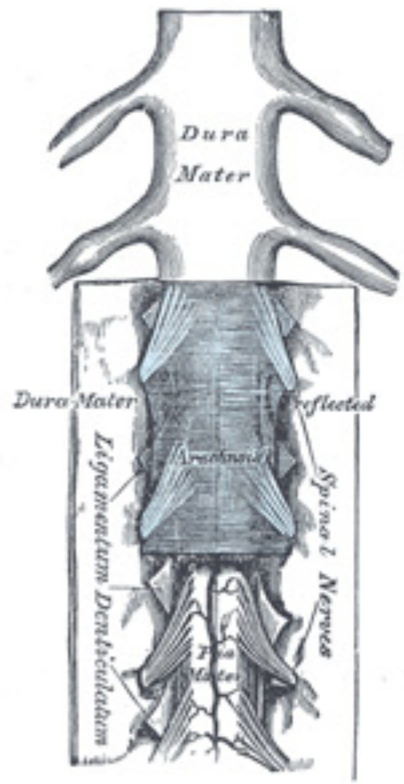


FIG. 767– The medulla spinalis and its membranes. (See enlarged image)

Structure.—The spinal dura mater resembles in structure the meningeal or supporting layer of the cranial dura mater, consisting of white fibrous and elastic tissue arranged in bands or lamellæ which, for the most part, are parallel with one another and have a longitudinal arrangement. Its internal surface is smooth and covered by a layer of mesothelium. It is sparingly supplied with bloodvessels, and a few nerves have been traced into it. *14*

The Arachnoid—The **arachnoid** is a delicate membrane enveloping the brain and medulla spinalis and lying between the pia mater internally *15* and the dura mater externally; it is separated from the pia mater by the subarachnoid cavity, which is filled with cerebrospinal fluid.

The **Cranial Part** (*arachnoidea encephali*) of the arachnoid invests the brain loosely, and does not dip into the sulci between the gyri, nor into 16
the fissures, with the exception of the longitudinal. On the upper surface of the brain the arachnoid is thin and transparent; at the base it is thicker, and slightly opaque toward the central part, where it extends across between the two temporal lobes in front of the pons, so as to leave a considerable interval between it and the brain.

The **Spinal Part** (*arachnoidea spinalis*) of the arachnoid is a thin, delicate, tubular membrane loosely investing the medulla spinalis. *Above,* it 17
is continuous with the cranial arachnoid; *below,* it widens out and invests the cauda equina and the nerves proceeding from it. It is separated from the dura mater by the **subdural space,** but here and there this space is traversed by isolated connective-tissue trabeculæ, which are most numerous on the posterior surface of the medulla spinalis.

The arachnoid surrounds the cranial and spinal nerves, and encloses them in loose sheaths as far as their points of exit from the skull and 18
vertebral canal.

Structure.—The arachnoid consists of bundles of white fibrous and elastic tissue intimately blended together. Its outer surface is covered with a 19
layer of low cuboidal mesothelium. The inner surface and the trabeculæ are likewise covered by a somewhat low type of cuboidal mesothelium which in places are flattened to a pavement type. Vessels of considerable size, but few in number, and, according to Bochdalek, a rich plexus of nerves derived from the motor root of the trigeminal, the facial, and the accessory nerves, are found in the arachnoid.

The **Subarachnoid Cavity** (*cavum subarachnoideale; subarachnoid space*) is the interval between the arachnoid and pia mater. It is occupied 20
by a spongy tissue consisting of trabeculæ of delicate connective tissue, and intercommunicating channels in which the subarachnoid fluid is contained. This cavity is small on the surface of the hemispheres of the brain; on the summit of each gyrus the pia mater and the arachnoid are in close contact; but in the sulci between the gyri, triangular spaces are left, in which the subarachnoid trabecular tissue is found, for the pia mater dips into the sulci, whereas the arachnoid bridges across them from gyrus to gyrus. At certain parts of the base of the brain, the arachnoid is separated from the pia mater by wide intervals, which communicate freely with each other and are named **subarachnoid cisternæ;** in these the subarachnoid tissue is less abundant.

Subarachnoid Cisternæ (*cisternæ subarachnoidales*) (Fig. 768).—The **cisterna cerebellomedullaris** (*cisterna magna*) is triangular on sagittal 21
section, and results from the arachnoid bridging over the interval between the medulla oblongata and the under surfaces of the hemispheres of the cerebellum; it is continuous with the subarachnoid cavity of the medulla spinalis at the level of the foramen magnum. The **cisterna pontis** is a considerable space on the ventral aspect of the pons. It contains the basilar artery, and is continuous behind with the subarachnoid cavity of the medulla spinalis, and with the cisterna cerebellomedullaris; and in front of the pons with the cisterna interpeduncularis. The**cisterna interpeduncularis** (*cisterna basalis*) is a wide cavity where the arachnoid extends across between the two temporal lobes. It encloses the cerebral peduncles and the structures contained in the interpeduncular fossa, and contains the arterial circle of Willis. In front, the cisterna interpeduncularis extends forward across the optic chiasma, forming the **cisterna chiasmatis,** and on to the upper surface of the corpus callosum, for the arachnoid stretches across from one cerebral hemisphere to the other immediately beneath the free border of the falx cerebri, and thus leaves a space in which the anterior cerebral arteries are contained. The **cisterna fossæ cerebri lateralis** is formed in front of either temporal lobe by the arachnoid bridging across the lateral fissure. This cavity contains the middle cerebral artery. The **cisterna venæ magnæ**

cerebri occupies the interval between the splenium of the corpus callosum and the superior surface of the cerebellum; it extends between the layers of the tela chorioidea of the third ventricle and contains the great cerebral vein.

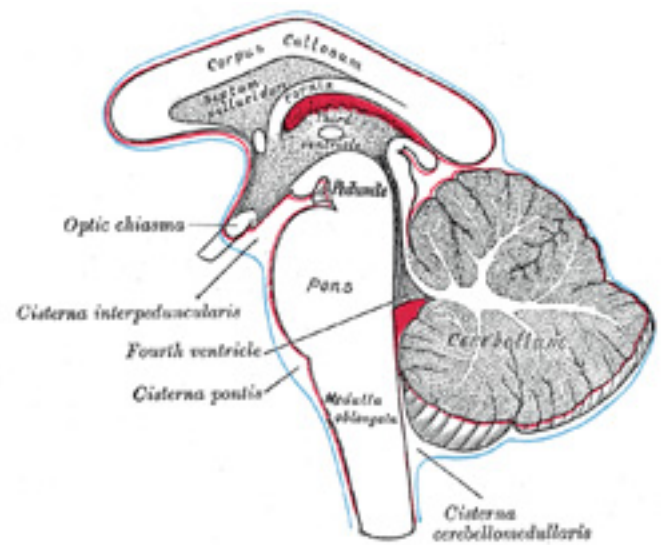


FIG. 768– Diagram showing the positions of the three principal subarachnoid cisternæ. (See enlarged image)

The subarachnoid cavity communicates with the general ventricular cavity of the brain by three openings; one, the **foramen of Majendie,** is in 22
the middle line at the inferior part of the roof of the fourth ventricle; the other two are at the extremities of the lateral recesses of that ventricle, behind the upper roots of the glossopharyngeal nerves and are known as the**foramina of Luschka.** It is still somewhat uncertain whether these foramina are actual openings or merely modified areas of the inferior velum which permit the passage of the cerebrospinal fluid from the ventricle into the subarachnoid spaces as through a permeable membrane.

The spinal part of the subarachnoid cavity is a very wide interval, and is the largest at the lower part of the vertebral canal, where the arachnoid 23
encloses the nerves which form the cauda equina. Above, it is continuous with the cranial subarachnoid cavity; below, it ends at the level of the lower border of the second sacral vertebra. It is partially divided by a longitudinal septum, the **subarachnoid septum,** which connects the arachnoid with the pia mater opposite the posterior median sulcus of the medulla spinalis, and forms a partition, incomplete and cribriform above, but more perfect in the thoracic region. The spinal subarachnoid cavity is further subdivided by the **ligamentum denticulatum,** which will be described with the pia mater.

The cerebrospinal fluid is a clear limpid fluid, having a saltish taste, and a slightly alkaline reaction. According to Lassaigne, it consists of 98.5 24 parts of water, the remaining 1.5 per cent. being solid matters, animal and saline. It varies in quantity, being most abundant in old persons, and is quickly secreted.

The **Arachnoid Villi** (*granulationes arachnoideales; glandulæ Pacchioni; Pacchionian bodies*) (Fig. 769) are small, fleshy-looking elevations, 25
usually collected into clusters of variable size, which are present upon the outer surface of the dura mater, in the vicinity of the superior sagittal sinus, and in some other situations. Upon laying open the sagittal sinus and the venous lacunæ on either side of it villi will be found protruding into its interior. They are not seen in infancy, and very rarely until the third year. They are usually found after the seventh year; and from this period they increase in number and size as age advances. They are not glandular in structure, but are enlarged normal villi of the arachnoid. As they grow they push the thinned dura mater before them, and cause absorption of the bone from pressure, and so produce the pits or depressions on the inner wall of the calvarium.

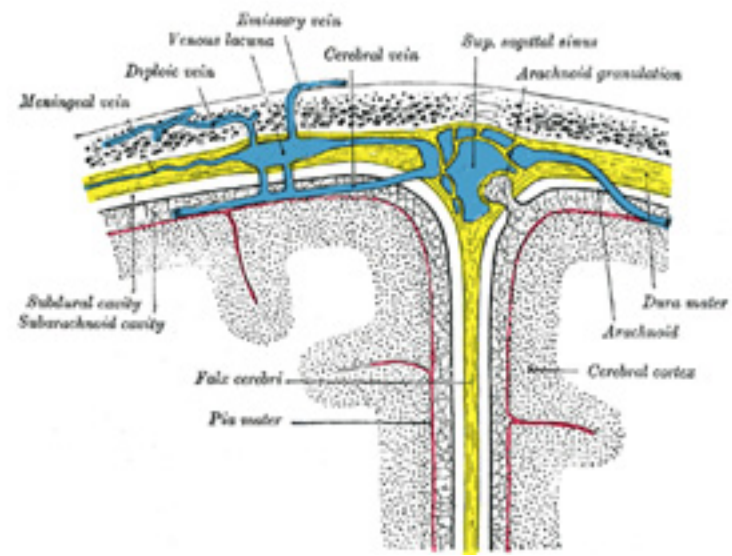


FIG. 769– Diagrammatic representation of a section across the top of the skull, showing the membranes of the brain, etc. (Modified from Testut.) (See enlarged image)

Structure.—An arachnoidal villus represents an invasion of the dura by the arachnoid membrane, the latter penetrates the dura in such a manner 26
that the arachnoid mesothelial cells come to lie directly beneath the vascular endothelium of the great dural sinuses. It consists of the following parts: (1) In the interior is a core of subarachnoid tissue, continuous with the meshwork of the general subarachnoid tissue through a narrow

pedicle, by which the villus is attached to the arachnoid. (2) Around this tissue is a layer of arachnoid membrane, limiting and enclosing the subarachnoid tissue. (3) Outside this is the thinned wall of the lacuna, which is separated from the arachnoid by a potential space which corresponds to and is continuous with the subdural cavity. (4) And finally, if the villus projects into the sagittal sinus, it will be covered by the greatly thinned wall of the sinus which may consist merely of endothelium. It will be seen, therefore, that fluid injected into the subarachnoid cavity will find its way into these villi, and it has been found experimentally that it passes from the villi into the venous sinuses into which they project.

The Pia Mater—The **pia mater** is a vascular membrane, consisting of a minute plexus of bloodvessels, held together by an extremely fine areolar tissue and covered by a reflexion of the mesothelial cells from the arachnoid trabeculæ. It is an incomplete membrane, absent probably at the foramen of Majendie and the two foramina of Luschka and perforated in a peculiar manner by all the bloodvessels as they enter or leave the nervous system. In the perivascular spaces, the pia apparently enters as a mesothelial lining of the outer surface of the space; a variable distance from the exterior these cells become unrecognizable and are apparently lacking, replaced by neuroglia elements. The inner walls of these perivascular spaces seem likewise covered for a certain distance by the mesothelial cells, reflected with the vessels from the arachnoid covering of these vascular channels as they traverse the subarachnoid spaces. *27*

The **Cranial Pia Mater** (*pia mater encephali; pia of the brain*) invests the entire surface of the brain, dips between the cerebral gyri and cerebellar laminæ, and is invaginated to form the tela chorioidea of the third ventricle, and the choroid plexuses of the lateral and third ventricles (pages 840 and 841); as it passes over the roof of the fourth ventricle, it forms the tela chorioidea and the choroid plexuses of this ventricle. On the cerebellum the membrane is more delicate; the vessels from its deep surface are shorter, and its relations to the cortex are not so intimate. *28*

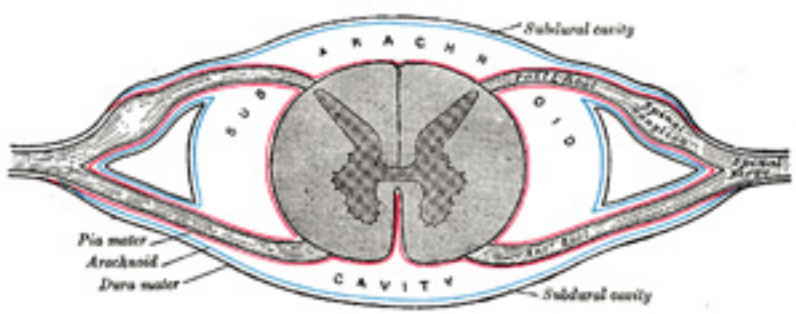


FIG. 770– Diagrammatic transverse section of the medulla spinalis and its membranes. (See enlarged image)

The **Spinal Pia Mater** (*pia mater spinalis; pia of the cord*) (Figs. 767, 770) is thicker, firmer, and less vascular than the cranial pia mater: this is due to the fact that it consists of two layers, the outer or additional one being composed of bundles of connective-tissue fibers, arranged for the most part longitudinally. Between the layers are cleft-like spaces which communicate with the subarachnoid cavity, and a number of *29* bloodvessels which are enclosed in perivascular lymphatic sheaths. The spinal pia mater covers the entire surface of the medulla spinalis, and is very intimately adherent to it; in front it sends a process backward into the anterior fissure. A longitudinal fibrous band, called the **linea splendens,** extends along the middle line of the anterior surface; and a somewhat similar band, the **ligamentum denticulatum,** is situated on either side. Below the conus medullaris, the pia mater is continued as a long, slender filament (**filum terminale**), which descends through the center of the mass of nerves forming the cauda equina. It blends with the dura mater at the level of the lower border of the second sacral vertebra, and extends downward as far as the base of the coccyx, where it fuses with the periosteum. It assists in maintaining the medulla spinalis in its position during the movements of the trunk, and is, from this circumstance, called the **central ligament** of the medulla spinalis.

The pia mater forms sheaths for the cranial and spinal nerves; these sheaths are closely connected with the nerves, and blend with their common 30
membranous investments.

The **ligamentum denticulatum** (*dentate ligament*) (Fig. 767) is a narrow fibrous band situated on either side of the medulla spinalis throughout its entire length, and separating the anterior from the posterior nerve roots. Its medial border is continuous with the pia mater at the side of the medulla spinalis. Its lateral border presents a series of triangular tooth-like processes, the points of which are fixed at intervals to the dura mater. These processes are twenty-one in number, on either side, the first being attached to the dura mater, opposite the margin of the foramen magnum, between the vertebral artery and the hypoglossal nerve; and the last near the lower end of the medulla spinalis.

4h. The Cerebrospinal Fluid

The cerebrospinal fluid, [129] for the most part elaborated by the choroid plexuses, is poured into the cerebral ventricles which are lined by smooth 1
ependyma. That portion of the fluid formed in the lateral ventricles escapes by the foramen of Monro into the third ventricle and thence by the aqueduct into the fourth ventricle. Likewise an ascending current of fluid apparently occurs in the central canal of the spinal cord; this, representing a possible product of the ependyma, may be added to the intraventricular supply. From the fourth ventricle the fluid is poured into the subarachnoid spaces through the medial foramen of Majendie and the two lateral foramina of Luschka. There is no evidence that functional communications between the cerebral ventricles and the subarachnoid spaces exist in any region except from the fourth ventricle.

In addition to the elaboration of the cerebrospinal fluid by the choroid plexuses, there seems fairly well established a second source of the fluid 2
from the nervous system itself. The bloodvessels that enter and leave the brain are surrounded by perivascular channels. It seems most likely that the outer wall of these channels is lined by a continuation inward of the pial mesothelium while the inner wall is probably derived from the mesothelial covering of the vessels, which are thus protected throughout the subarachnoid spaces. These mesothelial cells continue inward only a short distance, neuroglia cells probably replacing on the outer surface the mesothelial elements. Through these perivascular channels there is probably a small amount of fluid flowing from nerve-cell to subarachnoid space. The chemical differences between the subarachnoid fluid (product of choroid plexuses and perivascular system) and the ventricular fluid (product of choroid plexuses alone) indicate that the products of nerve-metabolism are poured into the subarachnoid space.

The absorption of the cerebrospinal fluid is a dual process, being chiefly a rapid drainage through the arachnoid villi into the great dural sinuses, 3
and, in small part, a slow escape into the true lymphatic vessels, by way of an abundant but indirect perineural course.

In general the arachnoid channels are equipped as fluid retainers with unquestionable powers of diffusion or absorption in regard to certain 4 elements in the normal cerebrospinal fluid, deriving in this way a cellular nutrition.

The subdural space (between arachnoid and dura) is usually considered to be a part of the cerebrospinal channels. It is a very small space, the 5
two limiting surfaces being separated by merely a capillary layer of fluid. Whether this fluid is exactly similar to the cerebrospinal fluid is very difficult to ascertain. Likewise our knowledge of the connections between the subdural and subarachnoid spaces is hardly definite. In some ways the subdural space may be likened to a serous cavity. The inner surface of the dura is covered by flattened polygonal mesothelial cells but the outer surface of the arachnoid is covered by somewhat cuboidal mesothelium. The fluid of the subdural space has probably a local origin from the cells lining it.

Note 129. Weed. L. H., Anat. Record, 1917, 12. [back]

5. The Cranial Nerves

(Nervi Cerebrales; Cerebral Nerves) 1

There are twelve pairs of cranial nerves; they are attached to the brain and are transmitted through foramina in the base of the cranium. The different pairs are named from before backward as follows:

1st. Olfactory.	7th. Facial.
2d. Optic.	8th. Acoustic.
3d. Oculomotor.	9th. Glossopharyngeal.
4th. Trochlear.	10th. Vagus.
5th. Trigeminal.	11th. Accessory.
6th. Abducent.	12th. Hypoglossal.

The area of attachment of a cranial nerve to the surface of the brain is termed its**superficial** or **apparent origin.** The fibers of the nerve can be traced into the substance of the brain to a special *nucleus* of gray substance. The motor or efferent cranial nerves arise within the brain from groups of nerve cells which constitute their **nuclei of origin.** The sensory or afferent cranial nerves arise from groups of nerve cells outside the brain; these nerve cells may be grouped to form ganglia on the trunks of the nerves or may be situated in peripheral sensory organs such as the nose and eye. The central processes of these cells run into the brain, and there end by arborizing around nerve cells, which are grouped to form**nuclei of termination.** The nuclei of origin of the motor nerves and the nuclei of termination of the sensory nerves are brought into relationship with the cerebral cortex, the former through the geniculate fibers of the internal capsule, the latter through the lemniscus. The geniculate fibers arise from the cells of the motor area of the cortex, and, after crossing the middle line, end by arborizing around the cells of the nuclei of origin of the motor cranial nerves. On the other hand, fibers arise from the cells of the nuclei of termination of the sensory nerves, and after crossing to the opposite side, join the lemniscus, and thus connect these nuclei, directly or indirectly, with the cerebral cortex.

5a. The Olfactory Nerves

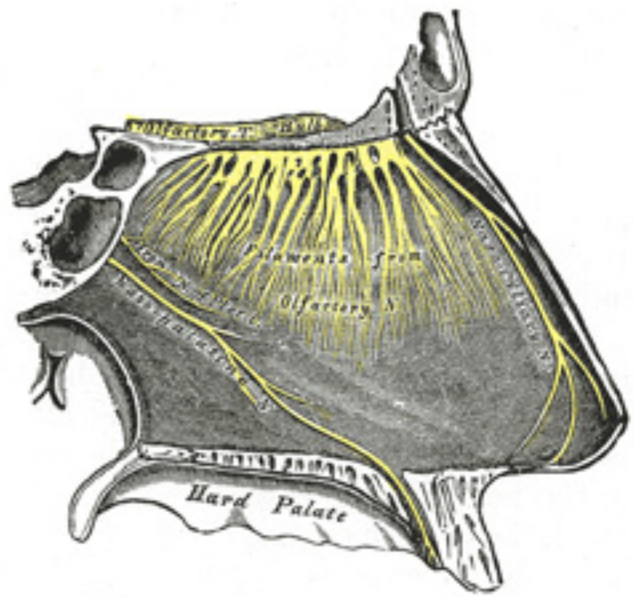


FIG. 771– Nerves of septum of nose. Right side. (See enlarged image)

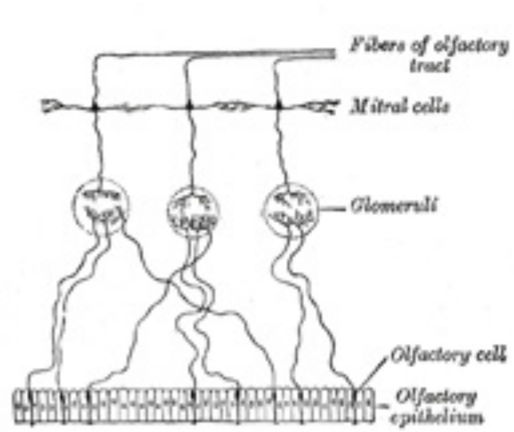


FIG. 772– Plan of olfactory neurons. (See enlarged image)

(NN. Olfactorii; First Nerve) 1

The **olfactory nerves** (Fig. 771) or **nerves of smell** are distributed to the mucous membrane of the olfactory region of the nasal cavity: this region comprises the superior nasal concha, and the corresponding part of the nasal septum. The nerves originate from the central or deep processes of the olfactory cells of the nasal mucous membrane. They form a plexiform net-work in the mucous membrane, and are then collected into about twenty branches, which pierce the cribriform plate of the ethmoid bone in two groups, a **lateral** and a **medial group,** and end in the glomeruli of the olfactory bulb (Fig. 772). Each branch receives tubular sheaths from the dura mater and pia mater, the former being lost in the periosteum of the nose, the latter in the neurolemma of the nerve.

The olfactory nerves are non-medullated, and consist of axis-cylinders surrounded by nucleated sheaths, in which, however, there are fewer 2
nuclei than are found in the sheaths of ordinary non-medullated nerve fibers.

The olfactory center in the cortex is generally associated with the rhinencephalon (page 826). 3

The olfactary nerves are developed from the cells of the ectoderm which lines the olfactory pits; these cells undergo proliferation and give rise to what are termed the **olfactory cells** of the nose. The axons of the olfactory cells grow into the overlying olfactory bulb and form the olfactory nerves.

5b. The Optic Nerve

(N. Opticus; Second Nerve) 1

The **optic nerve** (Fig. 773), or **nerve of sight,** consists mainly of fibers derived from the ganglionic cells of the retina. These axons terminate in arborizations around the cells in the lateral geniculate body, pulvinar, and superior colliculus which constitute the lower or primary visual centers. From the cells of the lateral geniculate body and the pulvinar fibers pass to the cortical visual center, situated in the cuneus and in the neighborhood of the calcarine fissure. A few fibers of the optic nerve, of small caliber, pass from the primary centers to the retina and are supposed to govern chemical changes in the retina and also the movements of some of its elements (pigment cells and cones). There are also a few fine fibers, afferent fibers, extending from the retina to the brain, that are supposed to be concerned in pupillary reflexes.

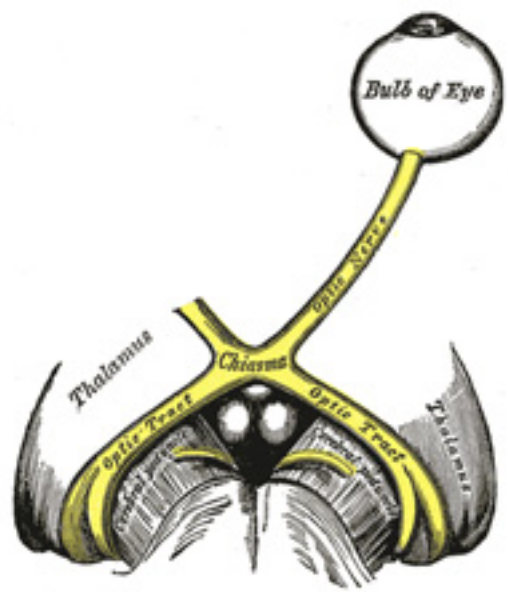


FIG. 773– The left optic nerve and the optic tracts. (See enlarged image)

The optic nerve is peculiar in that its fibers and ganglion cells are probably third in the series of neurons from the receptors to the brain. 2
Consequently the optic nerve corresponds rather to a tract of fibers within the brain than to the other cranial nerves. Its fibers pass backward and

medialward through the orbit and optic foramen to the optic commissure where they partially decussate. The mixed fibers from the two nerves are continued in the optic tracts, the **primary visual centers of the brain.**

The orbital portion of the optic nerve is from 20 mm. to 30 mm. in length and has a slightly sinuous course to allow for movements of the eyeball. It is invested by an outer sheath of dura mater and an inner sheath from the arachnoid which are attached to the sclera around the area where the nerve fibers pierce the choroid and sclera of the bulb. A little behind the bulb of the eye the central artery of the retina with its accompanying vein perforates the optic nerve, and runs within it to the retina. As the nerve enters the optic foramen its dural sheath becomes continuous with that lining the orbit and the optic foramen. In the optic foramen the ophthalmic artery lies below and to its outer side. The intercranial portion of the optic nerve is about 10 mm. in length. *3*

The **Optic Chiasma** (*chiasma opticum*), somewhat quadrilateral in form, rests upon the tuberculum sellæ and on the anterior part of the diaphragma sellæ. It is in relation, *above,*with the lamina terminalis; *behind,* with the tuber cinereum; on *either side,* with the anterior perforated substance. Within the chiasma, the optic nerves undergo a partial decussation. The fibers forming the medial part of each tract and posterior part of the chiasma have no connection with the optic nerves. They simply cross in the chiasma, and connect the medial geniculate bodies of the two sides; they form the **commissure of Gudden.** The remaining and principal part of the chiasma consists of two sets of fibers, crossed and uncrossed. The**crossed fibers** which are the more numerous, occupy the central part of the chiasma, and pass from the optic nerve of one side to the optic tract of the other, decussating in the chiasma with similar fibers of the opposite optic nerve. The **uncrossed fibers** occupy the lateral part of the chiasma, and pass from the nerve of one side into the tract of the same side. 130 *4*

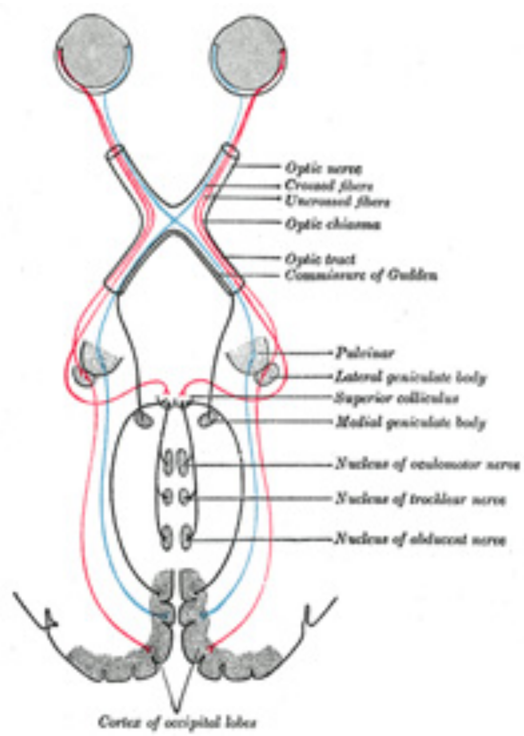


FIG. 774– Scheme showing central connections of the optic nerves and optic tracts. (See enlarged image)

The crossed fibers of the optic nerve tend to occupy the medial side of the nerve and the uncrossed fibers the lateral side. In the optic tract, however, the fibers are much more intermingled. 5

The **Optic Tract** (Fig. 774), passes backward and outward from the optic chiasma over the tuber cinereum and anterior perforated space to the cerebral peduncle and winds obliquely across its under surface. Its fibers terminate in the lateral geniculate body, the pulvinar and the superior colliculus. It is adherent to the tuber cinereum and the cerebral peduncle as it passes over them. In the region of the lateral geniculate body it splits into two bands. The medial and smaller one is a part of the commissure of Gudden and ends in the medial geniculate body. 6

From its mode of development, and from its structure, the optic nerve must be regarded as a prolongation of the brain substance, rather than as an ordinary cerebrospinal nerve. As it passes from the brain it receives sheaths from the three cerebral membranes, a perineural sheath from the pia mater, an intermediate sheath from the arachnoid, and an outer sheath from the dura mater, which is also connected with the periosteum as it 7 passes through the optic foramen. These sheaths are separated from each other by cavities which communicate with the subdural and subarachnoid cavities respectively. The innermost or perineural sheath sends a process around the arteria centralis retinæ into the interior of the nerve, and enters intimately into its structure.

Note 130. A specimen of congenital absence of the optic chiasma is to be found in the Museum of the Westminister Hospital. See also Henle, *Nervenlehre,* p. 393, ed. 2. [back]

5c. The Oculomotor Nerve

(N. Oculomotorius; Third Nerve) 1

The **oculomotor nerve** (Figs. 775, 776, 777) supplies somatic motor fibers to all the ocular muscles, except the Obliquus superior and Rectus lateralis; it also supplies through its connections with the ciliary ganglion, sympathetic motor fibers to the Sphincter pupillæ and the Ciliaris muscles.

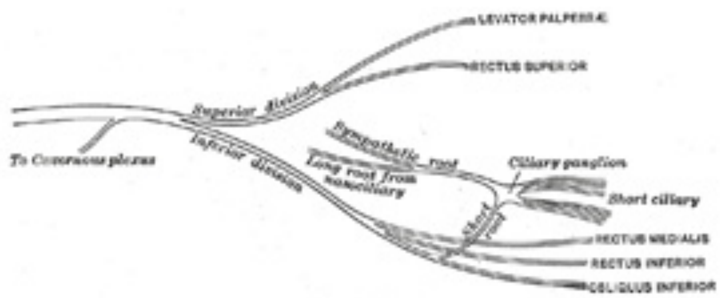


FIG. 775– Plan of oculomotor nerve. (See enlarged image)

The fibers of the oculomotor nerve arise from a nucleus which lies in the gray substance of the floor of the cerebral aqueduct and extends in front of the aqueduct for a short distance into the floor of the third ventricle. From this nucleus the fibers pass forward through the tegmentum, the red nucleus, and the medial part of the substantia nigra, forming a series of curves with a lateral convexity, and emerge from the oculomotor sulcus on the medial side of the cerebral peduncle. 2

The nucleus of the oculomotor nerve does not consist of a continuous column of cells, but is broken up into a number of smaller nuclei, which are arranged in two groups, anterior and posterior. Those of the posterior group are six in number, five of which are symmetrical on the two sides 3 of the middle line, while the sixth is centrally placed and is common to the nerves of both sides. The anterior group consists of two nuclei, an antero-medial and an antero-lateral (Fig. 762).

The nucleus of the oculomotor nerve, considered from a physiological standpoint, can be subdivided into several smaller groups of cells, each group controlling a particular muscle. 4

On emerging from the brain, the nerve is invested with a sheath of pia mater, and enclosed in a prolongation from the arachnoid. It passes between the superior cerebellar and posterior cerebral arteries, and then pierces the dura mater in front of and lateral to the posterior clinoid process, passing between the free and attached borders of the tentorium cerebelli. It runs along the lateral wall of the cavernous sinus, above the other orbital nerves, receiving in its course one or two filaments from the cavernous plexus of the sympathetic, and a communicating branch from the ophthalmic division of the trigeminal. It then divides into two branches, which enter the orbit through the superior orbital fissure, between the two heads of the Rectus lateralis. Here the nerve is placed below the trochlear nerve and the frontal and lacrimal branches of the ophthalmic nerve, while the nasociliary nerve is placed between its two rami. 5

The **superior ramus,** the smaller, passes medialward over the optic nerve, and supplies the Rectus superior and Levator palpebræ superioris. The **inferior ramus,** the larger, divides into three branches. One passes beneath the optic nerve to the Rectus medialis; another, to the Rectus inferior; the third and longest runs forward between the Recti inferior and lateralis to the Obliquus inferior. From the last a short thick branch is given off to the lower part of the ciliary ganglion, and forms its **short root.** All these branches enter the muscles on their ocular surfaces, with the exception of the nerve to the Obliquus inferior, which enters the muscle at its posterior border. 6

5d. The Trochlear Nerve (N. Trochlearis; Fourth Nerve)

(N. Trochlearis; Fourth Nerve) 1

The **trochlear nerve** (Fig. 776), the smallest of the cranial nerves, supplies the Obliquus superior oculi.

It *arises* from a nucleus situated in the floor of the cerebral aqueduct, opposite the upper part of the inferior colliculus. From its origin it runs downward through the tegmentum, and then turns backward into the upper part of the anterior medullary velum. Here it decussates with its fellow of the opposite side and emerges from the surface of the velum at the side of the frenulum veli, immediately behind the inferior colliculus. 2

The nerve is directed across the superior cerebellar peduncle, and then winds forward around the cerebral peduncle, immediately above the pons, pierces the dura mater in the free border of the tentorium cerebelli, just behind, and lateral to, the posterior clinoid process, and passes forward in the lateral wall of the cavernous sinus, between the oculomotor nerve and the ophthalmic division of the trigeminal. It crosses the oculomotor nerve, and enters the orbit through the superior orbital fissure. It now becomes the highest of all the nerves, and lies medial to the frontal nerve. In the orbit it passes medialward, above the origin of the Levator palpebræ superioris, and finally enters the orbital surface of the Obliquus superior. 3

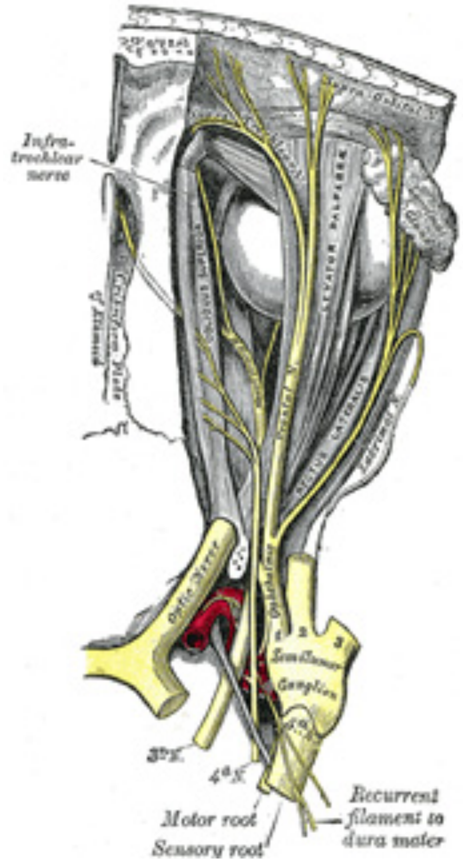


FIG. 776– Nerves of the orbit. Seen from above. (See enlarged image)

In the lateral wall of the cavernous sinus the trochlear nerve forms communications with the ophthalmic division of the trigeminal and with the cavernous plexus of the sympathetic. In the superior orbital fissure it occasionally gives off a branch to the lacrimal nerve. It gives off a recurrent branch which passes backward between the layers of the tentorium cerebelli and divides into two or three filaments which may be traced as far as the wall of the transverse sinus.

5e. The Trigeminal Nerve

(N. Trigeminus; Fifth Or Trifacial Nerve) 1

The **trigeminal nerve** is the largest cranial nerve and is the great sensory nerve of the head and face, and the motor nerve of the muscles of mastication.

It emerges from the side of the pons, near its upper border, by a small *motor* and a large*sensory root*—the former being situated in front of and 2
medial to the latter.

Motor Root.—The fibers of the motor root *arise* from two nuclei, a superior and an inferior. The **superior nucleus** consists of a strand of cells 3
occupying the whole length of the lateral portion of the gray substance of the cerebral aqueduct. The **inferior** or **chief nucleus** is situated in the upper part of the pons, close to its dorsal surface, and along the line of the lateral margin of the rhomboid fossa. The fibers from the superior nucleus constitute the **mesencephalic root:** they descend through the mid-brain, and, entering the pons, join with the fibers from the lower nucleus, and the motor root, thus formed, passes forward through the pons to its point of emergence. It is uncertain whether the mesencephalic root is motor or sensory.

Sensory Root.—The fibers of the sensory root *arise* from the cells of the semilunar ganglion which lies in a cavity of the dura mater near the 4
apex of the petrous part of the temporal bone. They pass backward below the superior petrosal sinus and tentorium cerebelli, and, entering the pons, divide into upper and lower roots. The upper root ends partly in a nucleus which is situated in the pons lateral to the lower motor nucleus, and partly in the locus cæruleus; the lower root descends through the pons and medulla oblongata, and ends in the upper part of the substantia gelatinosa of Rolando. This lower root is sometimes named the **spinal root** of the nerve. Medullation of the fibers of the sensory root begins about the fifth month of fetal life, but the whole of its fibers are not medullated until the third month after birth.

The **Semilunar Ganglion** (*ganglion semilunare* [*Gasseri*]; *Gasserian ganglion*) occupies a cavity (*cavum Meckelii*) in the dura mater covering 5
the trigeminal impression near the apex of the petrous part of the temporal bone. It is somewhat crescentic in shape, with its convexity directed forward: medially, it is in relation with the internal carotid artery and the posterior part of the cavernous sinus. The motor root runs in front of and medial to the sensory root, and passes beneath the ganglion; it leaves the skull through the foramen ovale, and, immediately below this foramen, joins the mandibular nerve. The greater superficial petrosal nerve lies also underneath the ganglion.

The ganglion receives, on its medial side, filaments from the carotid plexus of the sympathetic. It give off minute branches to the tentorium 6
cerebelli, and to the dura mater in the middle fossa of the cranium. From its convex border, which is directed forward and lateralward, three large nerves proceed, viz., the **ophthalmic, maxillary,** and **mandibular.**The ophthalmic and maxillary consist exclusively of sensory fibers; the mandibular is joined outside the cranium by the motor root.

Associated with the three divisions of the trigeminal nerve are four small ganglia. The**ciliary ganglion** is connected with the ophthalmic nerve; 7
the **sphenopalatine ganglion**with the maxillary nerve; and the **otic** and **submaxillary ganglia** with the mandibular nerve. All four receive

sensory filaments from the trigeminal, and motor and sympathetic filaments from various sources; these filaments are called the **roots of the ganglia.**

The **Ophthalmic Nerve** (*n. ophthalmicus*) (Figs. 776, 777), or **first division** of the trigeminal, is a sensory nerve. It supplies branches to the 8
cornea, ciliary body, and iris; to the lacrimal gland and conjunctiva; to the part of the mucous membrane of the nasal cavity; and to the skin of the eyelids, eyebrow, forehead, and nose. It is the smallest of the three divisions of the trigeminal, and *arises* from the upper part of the semilunar ganglion as a short, flattened band, about 2.5 cm. long, which passes forward along the lateral wall of the cavernous sinus, below the oculomotor and trochlear nerves; just before entering the orbit, through the superior orbital fissure, it divides into three branches, **lacrimal, frontal,** and**nasociliary.**

The ophthalmic nerve is joined by filaments from the cavernous plexus of the sympathetic, and communicates with the oculomotor, trochlear, 9
and abducent nerves; it gives off a recurrent filament which passes between the layers of the tentorium.

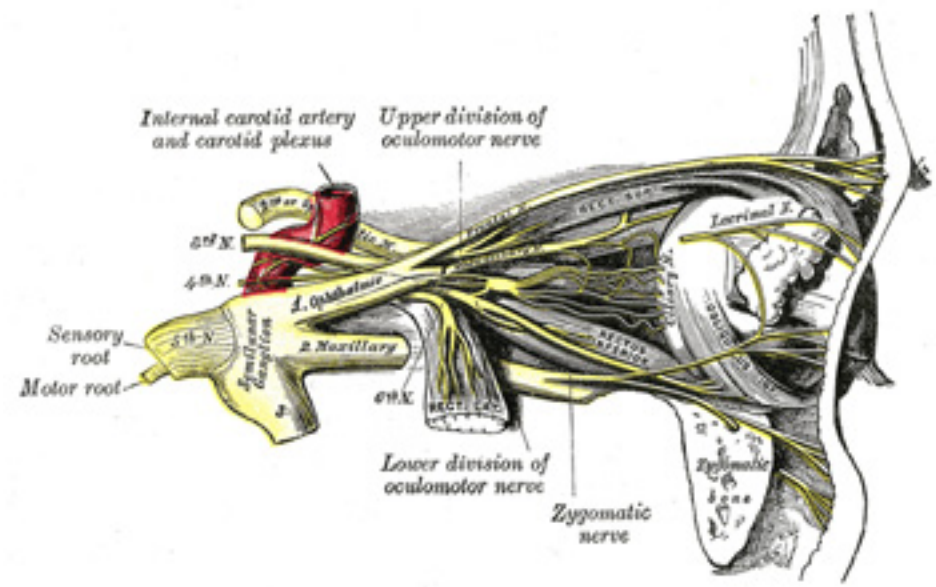


FIG. 777– Nerves of the orbit, and the ciliary ganglion. Side view. (See enlarged image)

The **Lacrimal Nerve** (*n. lacrimalis*) is the smallest of the three branches of the ophthalmic. It sometimes receives a filament from the trochlear 10
nerve, but this is possibly derived from the branch which goes from the ophthalmic to the trochlear nerve. It passes forward in a separate tube of

dura mater, and enters the orbit through the narrowest part of the superior orbital fissure. In the orbit it runs along the upper border of the Rectus lateralis, with the lacrimal artery, and communicates with the zygomatic branch of the maxillary nerve. It enters the lacrimal gland and gives off several filaments, which supply the gland and the conjunctiva. Finally it pierces the orbital septum, and ends in the skin of the upper eyelid, joining with filaments of the facial nerve. The lacrimal nerve is occasionally absent, and its place is then taken by the zygomaticotemporal branch of the maxillary. Sometimes the latter branch is absent, and a continuation of the lacrimal is substituted for it.

The **Frontal Nerve** (*n. frontalis*) is the largest branch of the ophthalmic, and may be regarded, both from its size and direction, as the 11
continuation of the nerve. It enters the orbit through the superior orbital fissure, and runs forward between the Levator palpebræ superioris and the periosteum. Midway between the apex and base of the orbit it divides into two branches, **supratrochlear** and **supraorbital.**

The **supratrochlear nerve** (*n. supratrochlearis*), the smaller of the two, passes above the pulley of the Obliquus superior, and gives off a 12
descending filament, to join the infratrochlear branch of the nasociliary nerve. It then escapes from the orbit between the pulley of the Obliquus superior and the supraorbital foramen, curves up on to the forehead close to the bone, ascends beneath the Corrugator and Frontalis, and dividing into branches which pierce these muscles, it supplies the skin of the lower part of the forehead close to the middle line and sends filaments to the conjunctiva and skin of the upper eyelid.

The **supraorbital nerve** (*n. supraorbitalis*) passes through the supraorbital foramen, and gives off, in this situation, palpebral filaments to the 13
upper eyelid. It then ascends upon the forehead, and ends in two branches, a medial and a lateral, which supply the integument of the scalp, reaching nearly as far back as the lambdoidal suture; they are at first situated beneath the Frontalis, the medial branch perforating the muscle, the lateral branch the galea aponeurotica. Both branches supply small twigs to the pericranium.

The **Nasociliary Nerve** (*n. nasociliaris; nasal nerve*) is intermediate in size between the frontal and lacrimal, and is more deeply placed. It 14
enters the orbit between the two heads of the Rectus lateralis, and between the superior and inferior rami of the oculomotor nerve. It passes across the optic nerve and runs obliquely beneath the Rectus superior and Obliquus superior, to the medial wall of the orbital cavity. Here it passes through the anterior ethmoidal foramen, and, entering the cavity of the cranium, traverses a shallow groove on the lateral margin of the front part of the cribriform plate of the ethmoid bone, and runs down, through a slit at the side of the crista galli, into the nasal cavity. It supplies **internal nasal branches** to the mucous membrane of the front part of the septum and lateral wall of the nasal cavity. Finally, it emerges, as the **external nasal branch,** between the lower border of the nasal bone and the lateral nasal cartilage, and, passing down beneath the Nasalis muscle, supplies the skin of the ala and apex of the nose.

The nasociliary nerve gives off the following branches, viz.: the **long root of the ciliary ganglion,** the **long ciliary,** and the **ethmoidal nerves.** 15

The **long root of the ciliary ganglion** (*radix longa ganglii ciliaris*) usually *arises* from the nasociliary between the two heads of the Rectus 16
lateralis. It passes forward on the lateral side of the optic nerve, and enters the postero-superior angle of the ciliary ganglion; it is sometimes joined by a filament from the cavernous plexus of the sympathetic, or from the superior ramus of the trochlear nerve.

The **long ciliary nerves** (*nn. ciliares longi*), two or three in number, are given off from the nasociliary, as it crosses the optic nerve. They 17
accompany the short ciliary nerves from the ciliary ganglion, pierce the posterior part of the sclera, and running forward between it and the choroid, are distributed to the iris and cornea. The long ciliary nerves are supposed to contain sympathetic fibers from the superior cervical ganglion to the Dilator pupillæ muscle.

The **infratrochlear nerve** (*n. infratrochlearis*) is given off from the nasociliary just before it enters the anterior ethmoidal foramen. It runs 18
forward along the upper border of the Rectus medialis, and is joined, near the pulley of the Obliquus superior, by a filament from the

supratrochlear nerve. It then passes to the medial angle of the eye, and supplies the skin of the eyelids and side of the nose, the conjunctiva, lacrimal sac, and caruncula lacrimalis.

19 The **ethmoidal branches** (*nn. ethmoidales*) supply the ethmoidal cells; the posterior branch leaves the orbital cavity through the posterior ethmoidal foramen and gives some filaments to the sphenoidal sinus.

20 **The Ciliary Ganglion (*ophthalmic or lenticular ganglion*) (Figs. 775, 777).**—The ciliary ganglion is a small, sympathetic ganglion, of a reddish-gray color, and about the size of a pin's head; it is situated at the back part of the orbit, in some loose fat between the optic nerve and the Rectus lateralis muscle, lying generally on the lateral side of the ophthalmic artery.

21 Its **roots** are three in number, and enter its posterior border. One, the long or sensory root, is derived from the nasociliary nerve, and joins its postero-superior angle. The second, the short or motor root, is a thick nerve (occasionally divided into two parts) derived from the branch of the oculomotor nerve to the Obliquus inferior, and connected with the postero-inferior angle of the ganglion. The motor root is supposed to contain sympathetic efferent fibers (preganglionic fibers) from the nucleus of the third nerve in the mid-brain to the ciliary ganglion where they form synapses with neurons whose fibers (postganglionic) pass to the Ciliary muscle and to Sphincter muscle of the pupil. The third, the sympathetic root, is a slender filament from the cavernous plexus of the sympathetic; it is frequently blended with the long root. According to Tiedemann, the ciliary ganglion receives a twig of communication from the sphenopalatine ganglion.

22 Its **branches** are the **short ciliary nerves.** These are delicate filaments, from six to ten in number, which *arise* from the forepart of the ganglion in two bundles connected with its superior and inferior angles; the lower bundle is the larger. They run forward with the ciliary arteries in a wavy course, one set above and the other below the optic nerve, and are accompanied by the long ciliary nerves from the nasociliary. They pierce the sclera at the back part of the bulb of the eye, pass forward in delicate grooves on the inner surface of the sclera, and are distributed to the Ciliaris muscle, iris, and cornea. Tiedemann has described a small branch as penetrating the optic nerve with the arteria centralis retinæ.

23 The **Maxillary Nerve** (*n. maxillaris; superior maxillary nerve*) (Fig. 778), or **second division** of the trigeminal, is a sensory nerve. It is intermediate, both in position and size, between the ophthalmic and mandibular. It begins at the middle of the semilunar ganglion as a flattened plexiform band, and, passing horizontally forward, it leaves the skull through the foramen rotundum, where it becomes more cylindrical in form, and firmer in texture. It then crosses the pterygopalatine fossa, inclines lateralward on the back of the maxilla, and enters the orbit through the inferior orbital fissure; it traverses the infraorbital groove and canal in the floor of the orbit, and appears upon the face at the infraorbital foramen. 131 At its termination, the nerve lies beneath the Quadratus labii superioris, and divides into a leash of branches which spread out upon the side of the nose, the lower eyelid, and the upper lip, joining with filaments of the facial nerve.

24 **Branches.**—Its branches may be divided into four groups, according as they are given off in the **cranium,** in the **pterygopalatine fossa,** in the **infraorbital canal,** or on the face.

In the Cranium..............	Middle meningeal.
	Zygomatic.
In the Pterygopalatine Fossa...	Sphenopalatine.
	Posterior superior alveolar.

In the Infraorbital Canal………	Anterior superior alveolar. Middle superior alveolar.
On the Face…………………	Inferior palpebral. External nasal. Superior labial.

The **Middle Meningeal Nerve** (*n. meningeus medius; meningeal or dural branch*) is given off from the maxillary nerve directly after its origin 25
from the semilunar ganglion; it accompanies the middle meningeal artery and supplies the dura mater.

The **Zygomatic Nerve** (*n. zygomaticus; temporomalar nerve; orbital nerve*) *arises* in the pterygopalatine fossa, enters the orbit by the inferior 26
orbital fissure, and divides at the back of that cavity into two branches, **zygomaticotemporal** and **zygomaticofacial.**

The **zygomaticotemporal branch** (*ramus zygomaticotemporalis; temporal branch*) runs along the lateral wall of the orbit in a groove in the 27
zygomatic bone, receives a branch of communication from the lacrimal, and, passing through a foramen in the zygomatic bone, enters the temporal fossa. It ascends between the bone, and substance of the Temporalis muscle, pierces the temporal fascia about 2.5 cm. above the zygomatic arch, and is distributed to the skin of the side of the forehead, and communicates with the facial nerve and with the auriculotemporal branch of the mandibular nerve. As it pierces the temporal fascia, it gives off a slender twig, which runs between the two layers of the fascia to the lateral angle of the orbit.

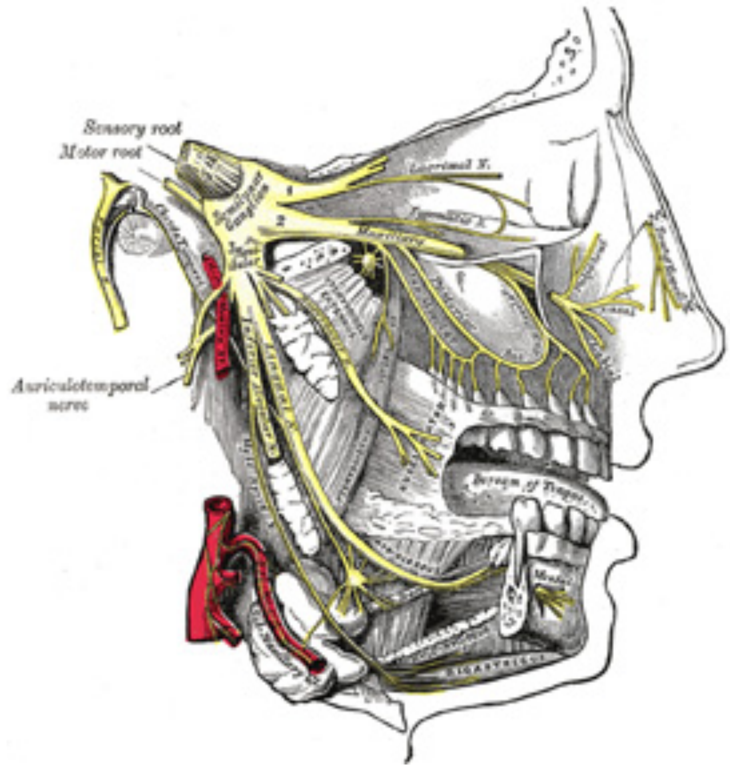


FIG. 778– Distribution of the maxillary and mandibular nerves, and the submaxillary ganglion. (See enlarged image)

The **zygomaticofacial branch** (*ramus zygomaticofacialis; malar branch*) passes along the infero-lateral angle of the orbit, emerges upon the face through a foramen in the zygomatic bone, and, perforating the Orbicularis oculi, supplies the skin on the prominence of the cheek. It joins with the facial nerve and with the inferior palpebral branches of the maxillary. 28

The **Sphenopalatine Branches** (*nn. sphenopalatini*), two in number, descend to the sphenopalatine ganglion. 29

The **Posterior Superior Alveolar Branches** (*rami alveolares superiores posteriores; posterior superior dental branches*) *arise* from the trunk of the nerve just before it enters the infraorbital groove; they are generally two in number, but sometimes arise by a single trunk. They descend on the tuberosity of the maxilla and give off several twigs to the gums and neighboring parts of the mucous membrane of the cheek. They then enter the posterior alveolar canals on the infratemporal surface of the maxilla, and, passing from behind forward in the substance of the bone, 30 communicate with the middle superior alveolar nerve, and give off branches to the lining membrane of the maxillary sinus and three twigs to each molar tooth; these twigs enter the foramina at the apices of the roots of the teeth.

The **Middle Superior Alveolar Branch** (*ramus alveolaris superior medius; middle superior dental branch*), is given off from the nerve in the posterior part of the infraorbital canal, and runs downward and forward in a canal in the lateral wall of the maxillary sinus to supply the two premolar teeth. It forms a superior dental plexus with the anterior and posterior superior alveolar branches. 31

The **Anterior Superior Alveolar Branch** (*ramus alveolaris superior anteriores; anterior superior dental branch*), of considerable size, is given off from the nerve just before its exit from the infraorbital foramen; it descends in a canal in the anterior wall of the maxillary sinus, and divides into branches which supply the incisor and canine teeth. It communicates with the middle superior alveolar branch, and gives off a **nasal branch,** which passes through a minute canal in the lateral wall of the inferior meatus, and supplies the mucous membrane of the anterior part of the inferior meatus and the floor of the nasal cavity, communicating with the nasal branches from the sphenopalatine ganglion. 32

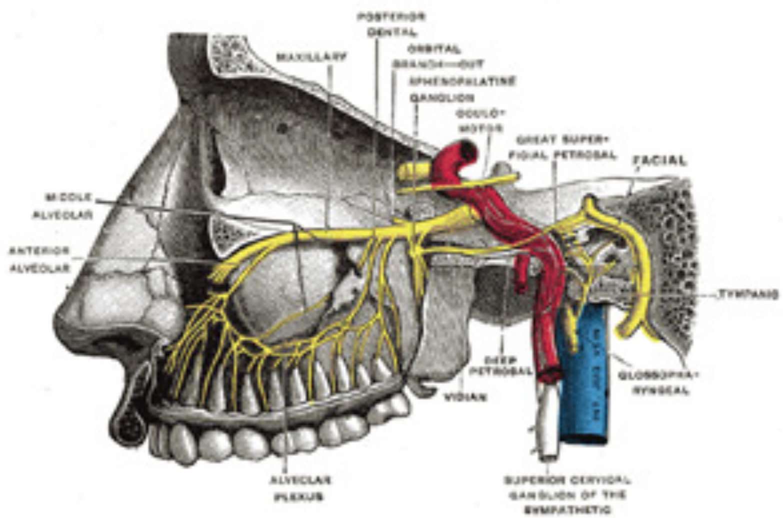


FIG. 779– Alveolar branches of superior maxillary nerve and sphenopalatine ganglion. (Testut.) (See enlarged image)

The **Inferior Palpebral Branches** (*rami palpebrales inferiores; palpebral branches*) ascend behind the Orbicularis oculi. They supply the skin and conjunctiva of the lower eyelid, joining at the lateral angle of the orbit with the facial and zygomaticofacial nerves. 33

The **External Nasal Branches** (*rami nasales externi*) supply the skin of the side of the nose and of the septum mobile nasi, and join with the terminal twigs of the nasociliary nerve. 34

The **Superior Labial Branches** (*rami labiales superiores; labial branches*), the largest and most numerous, descend behind the Quadratus labii superioris, and are distributed to the skin of the upper lip, the mucous membrane of the mouth, and labial glands. They are joined, immediately beneath the orbit, by filaments from the facial nerve, forming with them the **infraorbital plexus.** 35

Sphenopalatine Ganglion (*ganglion of Meckel*) (Fig. 780).—The sphenopalatine ganglion, the largest of the sympathetic ganglia associated with the branches of the trigeminal nerve, is deeply placed in the pterygopalatine fossa, close to the sphenopalatineforamen. It is triangular or heart-shaped, of a reddish-gray color, and is situated just below the maxillary nerve as it crosses the fossa. It receives a sensory, a motor, and a sympathetic root. 36

Its **sensory root** is derived from two sphenopalatine branches of the maxillary nerve; their fibers, for the most part, pass directly into the palatine nerves; a few, however, enter the ganglion, constituting its sensory root. Its **motor root** is probably derived from the nervus intermedius through the greater superficial petrosal nerve and is supposed to consist in part of sympathetic efferent (preganglionic) fibers from the medulla. In the sphenopalatine ganglion they form synapses with neurons whose postganglionic axons, vasodilator and secretory fibers, are distributed with the deep branches of the trigeminal to the mucous membrane of the nose, soft palate, tonsils, uvula, roof of the mouth, upper lip and gums, and to the upper part of the pharynx. Its **sympathetic root** is derived from the carotid plexus through the deep petrosal nerve. These two nerves join to form the nerve of the pterygoid canal before their entrance into the ganglion. 37

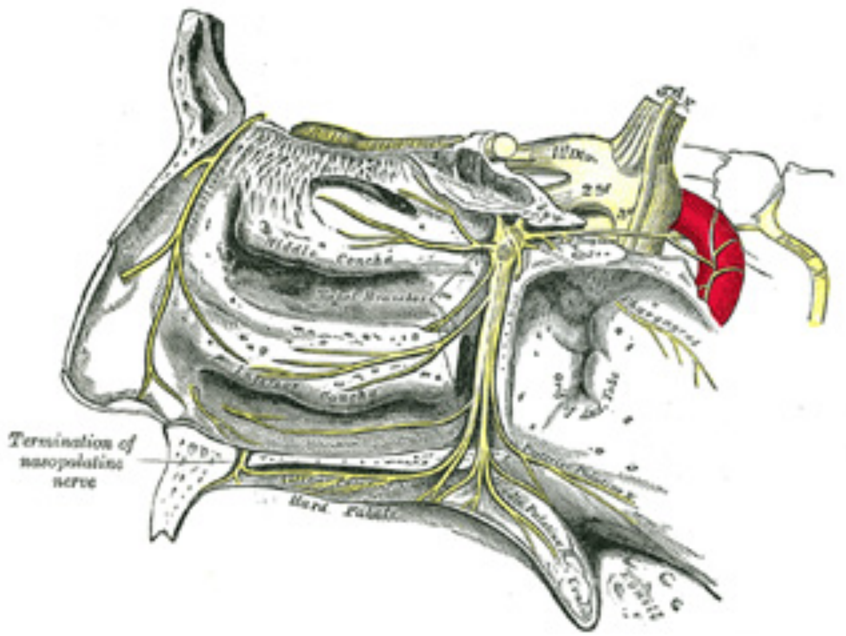


FIG. 780– The sphenopalatine ganglion and its branches. (See enlarged image)

The **greater superficial petrosal nerve** (*n. petrosus superficialis major; large superficial petrosal nerve*) is given off from the genicular 38
ganglion of the facial nerve; it passes through the hiatus of the facial canal, enters the cranial cavity, and runs forward beneath the dura mater in a groove on the anterior surface of the petrous portion of the temporal bone. It then enters the cartilaginous substance which fills the foramen lacerum, and joining with the deep petrosal branch forms the nerve of the pterygoid canal.

The **deep petrosal nerve** (*n. petrosus profundus; large deep petrosal nerve*) is given off from the carotid plexus, and runs through the carotid 39
canal lateral to the internal carotid artery. It then enters the cartilaginous substance which fills the foramen lacerum, and joins with the greater superficial petrosal nerve to form the nerve of the pterygoid canal.

The **nerve of the pterygoid canal** (*n. canalis pterygoidei* [*Vidii*]; *Vidian nerve*), formed by the junction of the two preceding nerves in the 40
cartilaginous substance which fills the foramen lacerum, passes forward, through the pterygoid canal, with the corresponding artery, and is joined by a small ascending **sphenoidal branch** from the otic ganglion. Finally, it enters the pterygopalatine fossa, and joins the posterior angle of the sphenopalatine ganglion.

41 **Branches of Distribution.**—These are divisible into four groups, viz., **orbital, palatine, posterior superior nasal,** and **pharyngeal.**

42 The **orbital branches** (*rami orbitales; ascending branches*) are two or three delicate filaments, which enter the orbit by the inferior orbital fissure, and supply the periosteum. According to Luschka, some filaments pass through foramina in the frontoethmoidal suture to supply the mucous membrane of the posterior ethmoidal and sphenoidal sinuses.

43 The **palatine nerves** (*nn. palatini; descending branches*) are distributed to the roof of the mouth, soft palate, tonsil, and lining membrane of the nasal cavity. Most of their fibers are derived from the sphenopalatine branches of the maxillary nerve. They are three in number:**anterior, middle,** and **posterior.**

44 The **anterior palatine nerve** (*n. palatinus anterior*) descends through the pterygopalatine canal, emerges upon the hard palate through the greater palatine foramen, and passes forward in a groove in the hard palate, nearly as far as the incisor teeth. It supplies the gums, the mucous membrane and glands of the hard palate, and communicates in front with the terminal filaments of the nasopalatine nerve. While in the pterygopalatine canal, it gives off **posterior inferior nasal branches,** which enter the nasal cavity through openings in the palatine bone, and ramify over the inferior nasal concha and middle and inferior meatuses; at its exit from the canal, a palatine branch is distributed to both surfaces of the soft palate.

45 The **middle palatine nerve** (*n. palatinus medius*) emerges through one of the minor palatine canals and distributes branches to the uvula, tonsil, and soft palate. It is occasionally wanting.

46 The **posterior palatine nerve** (*n. palatinus posterior*) descends through the pterygopalatine canal, and emerges by a separate opening behind the greater palatine foramen; it supplies the soft palate, tonsil, and uvula. The middle and posterior palatine join with the tonsillar branches of the glossopharyngeal to form a plexus (**circulus tonsillaris**) around the tonsil.

47 The **posterior superior nasal branches** (*rami nasales posteriores superiores*) are distributed to the septum and lateral wall of the nasal fossa. They enter the posterior part of the nasal cavity by the sphenopalatine foramen and supply the mucous membrane covering the superior and middle nasal conchæ, the lining of the posterior ethmoidal cells, and the posterior part of the septum. One branch, longer and larger than the others, is named the**nasopalatine nerve.** It enters the nasal cavity through the sphenopalatine foramen, passes across the roof of the nasal cavity below the orifice of the sphenoidal sinus to reach the septum, and then runs obliquely downward and forward between the periosteum and mucous membrane of the lower part of the septum. It descends to the roof of the mouth through the incisive canal and communicates with the corresponding nerve of the opposite side and with the anterior palatine nerve. It furnishes a few filaments to the mucous membrane of the nasal septum.

48 The **pharyngeal nerve** (*pterygopalatine nerve*) is a small branch *arising* from the posterior part of the ganglion. It passes through the pharyngeal canal with the pharyngeal branch of the internal maxillary artery, and is distributed to the mucous membrane of the nasal part of the pharynx, behind the auditory tube.

49 The **mandibular nerve** (*n. mandibularis; inferior maxillary nerve*) (Figs. 778, 781) supplies the teeth and gums of the mandible, the skin of the temporal region, the auricula, the lower lip, the lower part of the face, and the muscles of mastication; it also supplies the mucous membrane of the anterior two-thirds of the tongue. It is the largest of the three divisions of the fifth, and is made up of two roots: a large, **sensory root** proceeding from the inferior angle of the semilunar ganglion, and a small **motor root** (the motor part of the trigeminal), which passes beneath the ganglion, and unites with the sensory root, just after its exit through the foramen ovale. Immediately beneath the base of the skull, the nerve gives off from its medial side a recurrent branch (nervus spinosus) and the nerve to the Pterygoideus internus, and then divides into two

trunks, an anterior and a posterior.

The **Nervus Spinosus** (*recurrent or meningeal branch*) enters the skull through the foramen spinosum with the middle meningeal artery. It 50
divides into two branches, anterior and posterior, which accompany the main divisions of the artery and supply the dura mater; the posterior branch also supplies the mucous lining of the mastoid cells; the anterior communicates with the meningeal branch of the maxillary nerve.

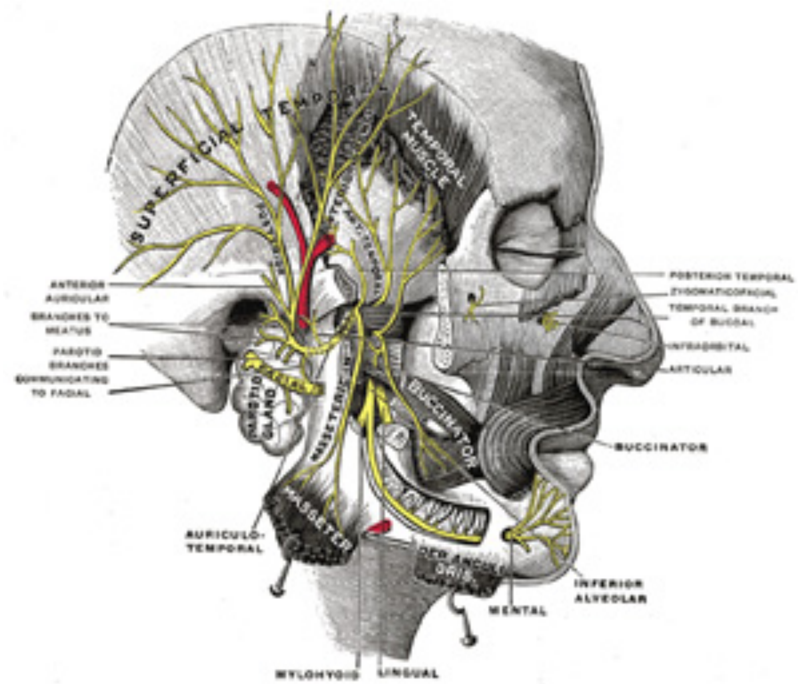


FIG. 781– Mandibular division of the trifacial nerve. (Testut.) (See enlarged image)

The Internal Pterygoid Nerve (*n. pterygoideus internus*).—The nerve to the Pterygoideus internus is a slender branch, which enters the deep 51
surface of the muscle; it gives off one or two filaments to the otic ganglion.

The anterior and smaller division of the mandibular nerve receives nearly the whole of the fibers of the motor root of the nerve, and supplies the 52
muscles of mastication and the skin and mucous membrane of the cheek. Its branches are the **masseteric, deep temporal,**

buccinator, and **external pterygoid.**

The **Masseteric Nerve** (*n. massetericus*) passes lateralward, above the Pterygoideus externus, in front of the temporomandibular articulation, and behind the tendon of the Temporalis; it crosses the mandibular notch with the masseteric artery, to the deep surface of the Masseter, in which it ramifies nearly as far as its anterior border. It gives a filament to the temporomandibular joint. 53

The **Deep Temporal Nerves** (*nn. temporales profundi*) are two in number, anterior and posterior. They pass above the upper border of the Pterygoideus externus and enter the deep surface of the Temporalis. The **posterior branch,** of small size, is placed at the back of the temporal fossa, and sometimes arises in common with the masseteric nerve. The**anterior branch** is frequently given off from the buccinator nerve, and then turns upward over the upper head of the Pterygoideus externus. Frequently a third or intermediate branch is present. 54

The **Buccinator Nerve** (*n. buccinatorus; long buccal nerve*) passes forward between the two heads of the Pterygoideus externus, and downward beneath or through the lower part of the Temporalis; it emerges from under the anterior border of the Masseter, ramifies on the surface of the Buccinator, and unites with the buccal branches of the facial nerve. It supplies a branch to the Pterygoideus externus during its passage through that muscle, and may give off the anterior deep temporal nerve. The buccinator nerve supplies the skin over the Buccinator, and the mucous membrane lining its inner surface. 55

External Pterygoid Nerve (*n. pterygoideus externus*).—The nerve to the Pterygoideus externus frequently *arises* in conjunction with the buccinator nerve, but it may be given off separately from the anterior division of the mandibular nerve. It enters the deep surface of the muscle. 56

The posterior and larger division of the mandibular nerve is for the most part sensory, but receives a few filaments from the motor root. It divides into **auriculotemporal, lingual,**and **inferior alveolar nerves.** 57

The **Auriculotemporal Nerve** (*n. auriculotemporalis*) generally *arises* by two roots, between which the middle meningeal artery ascends. It runs backward beneath the Pterygoideus externus to the medial side of the neck of the mandible. It then turns upward with the superficial temporal artery, between the auricula and condyle of the mandible, under cover of the parotid gland; escaping from beneath the gland, it ascends over the zygomatic arch, and divides into superficial temporal branches. 58

The **branches of communication** of the auriculotemporal nerve are with the facial nerve and with the otic ganglion. The branches to the facial, usually two in number, pass forward from behind the neck of the mandible and join the facial nerve at the posterior border of the Masseter. The filaments to the otic ganglion are derived from the roots of the auriculotemporal nerve close to their origin. 59

Its **branches of distribution** are: 60

Anterior auricular.	Articular.
Branches to the external acoustic meatus.	Parotid.
Superficial temporal.	

The **anterior auricular branches** (*nn. auriculares anteriores*) are usually two in number; they supply the front of the upper part of the auricula, being distributed principally to the skin covering the front of the helix and tragus. 61

The **branches to the external acoustic meatus** (*n. meatus auditorii externi*), two in number, enter the meatus between its bony and cartilaginous portions and supply the skin lining it; the upper one sends a filament to the tympanic membrane. 62

The **articular branches** consist of one or two twigs which enter the posterior part of the temporomandibular joint. 63

The **parotid branches** (*rami parotidei*) supply the parotid gland. 64

The **superficial temporal branches** (*rami temporales superficiales*) accompany the superficial temporal artery to the vertex of the skull; they supply the skin of the temporal region and communicate with the facial and zygomaticotemporal nerves. 65

The **Lingual Nerve** (*n. lingualis*) supplies the mucous membrane of the anterior two-thirds of the tongue. It lies at first beneath the Pterygoideus externus, medial to and in front of the inferior alveolar nerve, and is occasionally joined to this nerve by a branch which may cross the internal maxillary artery. The chorda tympani also joins it at an acute angle in this situation. The nerve then passes between the Pterygoideus internus and the ramus of the mandible, and crosses obliquely to the side of the tongue over the Constrictor pharyngis superior and Styloglossus, and then between the Hyoglossus and deep part of the submaxillary gland; it finally runs across the duct of the submaxillary gland, and along the tongue to its tip, lying immediately beneath the mucous membrane. 66

Its **branches of communication** are with the facial (through the chorda tympani), the inferior alveolar and hypoglossal nerves, and the submaxillary ganglion. The branches to the submaxillary ganglion are two or three in number; those connected with the hypoglossal nerve form a plexus at the anterior margin of the Hyoglossus. 67

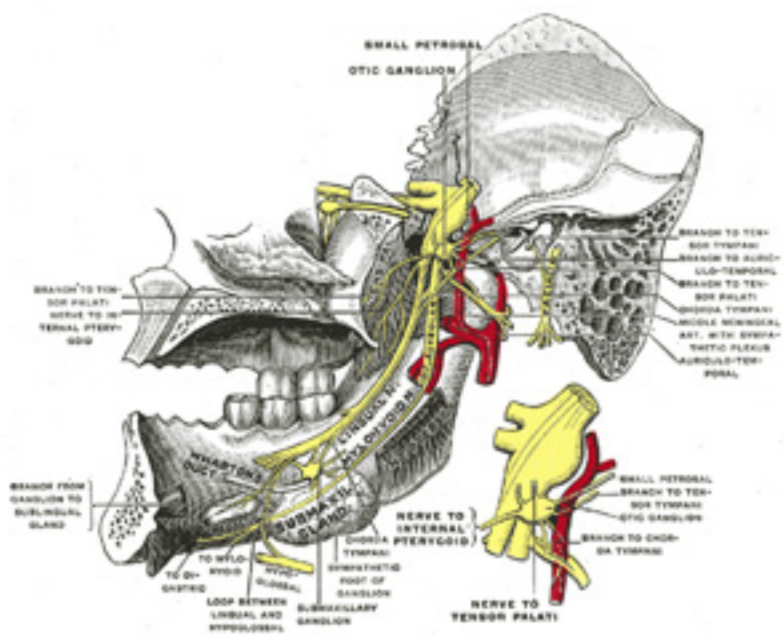


FIG. 782– Mandibular division of trifacial nerve, seen from the middle line. The small figure is an enlarged view of the otic ganglion. (Testut.)

(See enlarged image)

Its **branches of distribution** supply the sublingual gland, the mucous membrane of the mouth, the gums, and the mucous membrane of the anterior two-thirds of the tongue; the terminal filaments communicate, at the tip of the tongue, with the hypoglossal nerve. 68

The **Inferior Alveolar Nerve (*n. alveolaris inferior; inferior dental nerve*)**(Fig. 782) is the largest branch of the mandibular nerve. It descends with the inferior alveolar artery, at first beneath the Pterygoideus externus, and then between the sphenomandibular ligament and the ramus of the mandible to the mandibular foramen. It then passes forward in the mandibular canal, beneath the teeth, as far as the mental foramen, where it divides into two terminal branches, incisive and mental. 69

The branches of the inferior alveolar nerve are the **mylohyoid, dental, incisive,** and**mental.** 70

The **mylohyoid nerve** (*n. mylohyoideus*) is derived from the inferior alveolar just before it enters the mandibular foramen. It descends in a groove on the deep surface of the ramus of the mandible, and reaching the under surface of the Mylohyoideus supplies this muscle and the anterior belly of the Digastricus. 71

The **dental branches** supply the molar and premolar teeth. They correspond in number to the roots of those teeth; each nerve entering the orifice at the point of the root, and supplying the pulp of the tooth; above the alveolar nerve they form an **inferior dental plexus.** 72

The **incisive branch** is continued onward within the bone, and supplies the canine and incisor teeth. 73

The **mental nerve** (*n. mentalis*) emerges at the mental foramen, and divides beneath the Triangularis muscle into three branches; one descends to the skin of the chin, and two ascend to the skin and mucous membrane of the lower lip; these branches communicate freely with the facial nerve. 74

Two small ganglia, the **otic** and the **submaxillary,** are connected with the mandibular nerve. 75

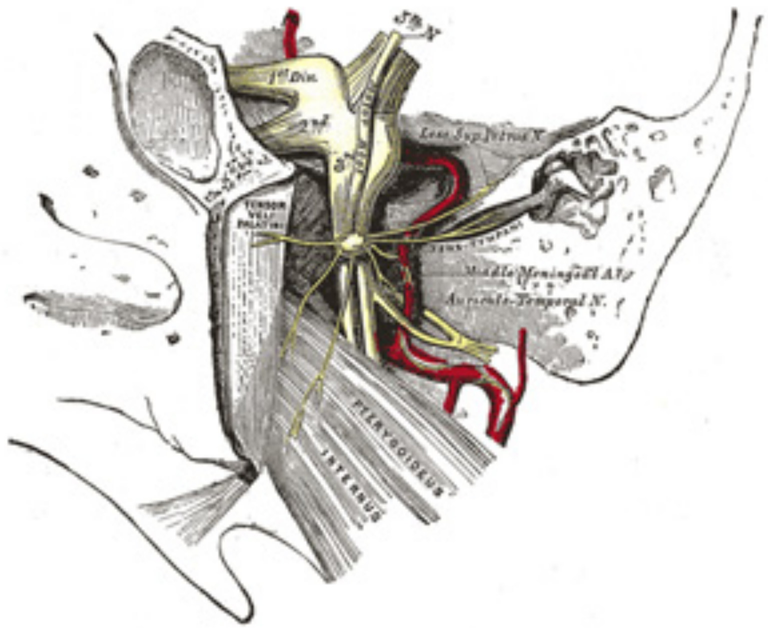


FIG. 783– The otic ganglion and its branches. (See enlarged image)

Otic Ganglion (*ganglion oticum*)(Fig. 783).—The otic ganglion is a small, ovalshaped, flattened ganglion of a reddish-gray color, situated immediately below the foramen ovale; it lies on the medial surface of the mandibular nerve, and surrounds the origin of the nerve to the Pterygoideus internus. It is in relation, *laterally,* with the trunk of the mandibular nerve at the point where the motor and sensory roots join; *medially,* with the cartilaginous part of the auditory tube, and the origin of the Tensor veli palatini; *posteriorly,* with the middle meningeal artery. *76*

Branches of Communication.—It is connected by two or three short filaments with the nerve to the Pterygoideus internus, from which it may obtain a motor, and possibly a sensory root. It communicates with the glossopharyngeal and facial nerves, through the lesser superficial petrosal nerve continued from the tympanic plexus, and through this nerve it probably receives a root from the glossopharyngeal and a motor root from the facial; its sympathetic root consists of a filament from the plexus surrounding the middle meningeal artery. The fibers from the glossopharyngeal which pass to the otic ganglion in the small superficial petrosal are supposed to be sympathetic efferent (preganglionic) fibers *77* from thedorsal nucleus or inferior salivatory nucleus of the medulla. Fibers (postganglionic) from the otic ganglion with which these form synapses are supposed to pass with the auriculotemporal nerve to the parotid gland. A slender filament (sphenoidal) ascends from it to the nerve of the Pterygoid canal, and a small branch connects it with the chorda tympani.

Its **branches of distribution** are: a filament to the Tensor tympani, and one to the Tensor veli palatini. The former passes backward, lateral to the auditory tube; the latter arises from the ganglion, near the origin of the nerve to the Pterygoideus internus, and is directed forward. The fibers of these nerves are, however, mainly derived from the nerve to the Pterygoideus internus. 78

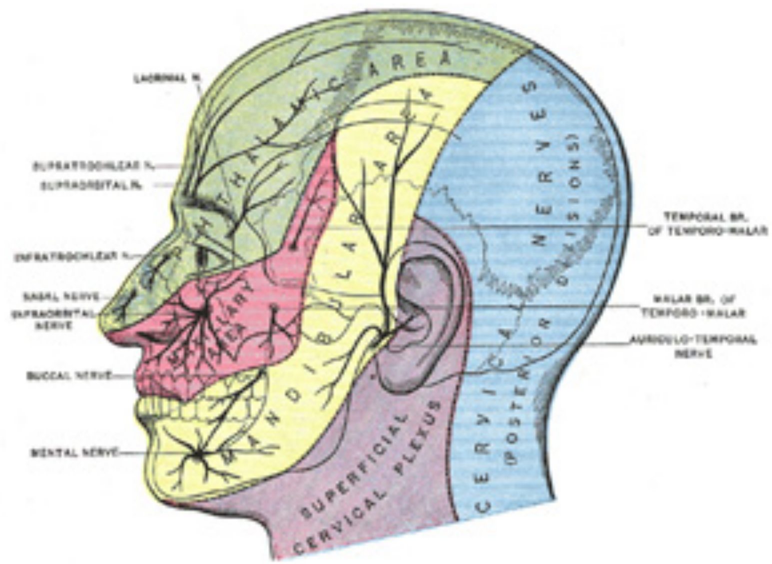


FIG. 784– Sensory areas of the head, showing the general distribution of the three divisions of the fifth nerve. (Modified from Testut.) (See enlarged image)

Submaxillary Ganglion (*ganglion submaxillare*)(Fig. 778).—The submaxillary ganglion is of small size and is fusiform in shape. It is situated above the deep portion of the submaxillary gland, on the hyoglossus, near the posterior border of the Mylohyoideus, and is connected by filaments with the lower border of the lingual nerve. It is suspended from the lingual nerve by two filaments which join the anterior and posterior parts of the ganglion. Through the posterior of these it receives a branch from the chorda tympani nerve which runs in the sheath of the lingual; these are sympathetic efferent (preganglionic) fibers from the facial nucleus or the superior salivatory nucleus of the medulla oblongata that 79 terminate in the submaxillary ganglion. The postganglionic fibers pass to the submaxillary gland, it communicates with the sympathetic by filaments from the sympathetic plexus around the external maxillary artery.

Its **branches of distribution** are five or six in number; they *arise* from the lower part of the ganglion, and supply the mucous membrane of the mouth and the duct of the submaxillary gland, some being lost in the submaxillary gland. The branch of communication from the lingual to the forepart of the ganglion is by some regarded as a branch of distribution, through which filaments pass from the ganglion to the lingual nerve, and by it are conveyed to the sublingual gland and the tongue. 80

Trigeminal Nerve Reflexes.—Pains referred to various branches of the trigeminal nerve are of very frequent occurrence, and should always lead to a careful examination in order to discover a local cause. As a general rule the diffusion of pain over the various branches of the nerve is at first confined to one only of the main divisions, and the search for the causative lesion should always commence with a thorough examination of all those parts which are supplied by that division; although in severe cases pain may radiate over the branches of the other main divisions. The commonest example of this condition is the neuralgia which is so often associated with dental caries—here, although the tooth itself may not appear to be painful, the most distressing referred pains may be experienced, and these are at once relieved by treatment directed to the affected tooth. 81

Many other examples of trigeminal reflexes could be quoted, but it will be sufficient to mention the more common ones. Dealing with the ophthalmic nerve, severe supraorbital pain is commonly associated with acute glaucoma or with disease of the frontal or ethmoidal air cells. Malignant growths or empyema of the maxillary antrum, or unhealthy conditions about the inferior conchæ or the septum of the nose, are often found giving rise to "second division" neuralgia, and should be always looked for in the absence of dental disease in the maxilla. 82

It is on the mandibular nerve, however, that some of the most striking reflexes are seen. It is quite common to meet with patients who complain of pain in the ear, in whom there is no sign of aural disease, and the cause is usually to be found in a carious tooth in the mandible. Moreover, with an ulcer or cancer of the tongue, often the first pain to be experienced is one which radiates to the ear and temporal fossa, over the distribution of the auriculotemporal nerve. 83

Note 131. After it enters the infraorbital canal, the nerve is frequently called the*infraorbital*. [back]

1F. The Abducent Nerve

(N. Abducens; Sixth Nerve) 1

The **abducent nerve** (Fig. 777) supplies the Rectus lateralis oculi.

Its fibers arise from a small nucleus situated in the upper part of the rhomboid fossa, close to the middle line and beneath the colliculus facialis. They pass downward and forward through the pons, and emerge in the furrow between the lower border of the pons and the upper end of the pyramid of the medulla oblongata. 2

From the nucleus of the sixth nerve, fibers are said to pass through the medial longitudinal fasciculus to the oculomotor nerve of the opposite side, along which they are carried to the Rectus medialis. The Rectus lateralis of one eye and the Rectus medialis of the other may therefore be 3 said to receive their nerves from the same nucleus (Fig. 785).

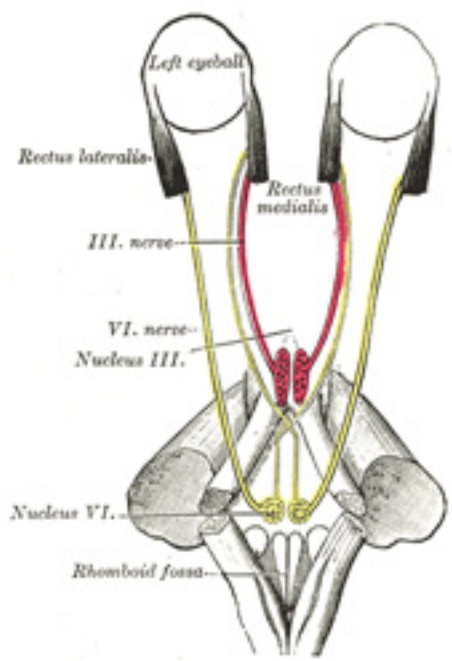


FIG. 785– Figure showing the mode of innervation of the Recti medialis and lateralis of the eye (after Duval and Laborde). (See enlarged image)

The nerve pierces the dura mater on the dorsum sellæ of the sphenoid, runs through a notch in the bone below the posterior clinoid process, and passes forward through the cavernous sinus, on the lateral side of the internal carotid artery. It enters the orbit through the superior orbital fissure, above the ophthalmic vein, from which it is separated by a lamina of dura mater. It then passes between the two heads of the Rectus lateralis, and enters the ocular surface of that muscle. The abducent nerve is joined by several filaments from the carotid and cavernous plexuses, and by one from the ophthalmic nerve. The oculomotor, trochlear, ophthalmic, and abducent nerves bear certain relations to each other in the cavernous sinus, at the superior orbital fissure, and in the cavity of the orbit, as follows: 4

In the **cavernous sinus** (Fig. 786), the oculomotor, trochlear, and ophthalmic nerves are placed in the lateral wall of the sinus, in the order given, 5
from above downward. The abducent nerve lies at the lateral side of the internal carotid artery. As these nerves pass forward to the superior orbital fissure, the oculomotor and ophthalmic divide into branches, and the abducent nerve approaches the others; so that their relative positions

are considerably changed.

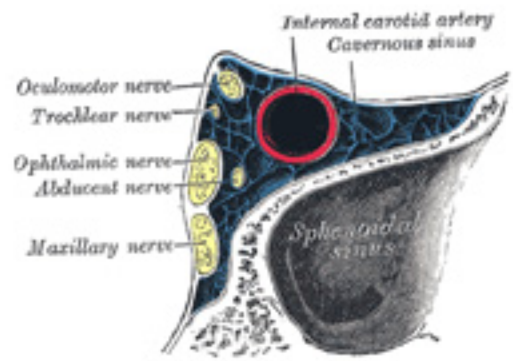


FIG. 786– Oblique section through the right cavernous sinus. (See enlarged image)

In the **superior orbital fissure** (Fig. 787), the trochlear nerve and the frontal and lacrimal divisions of the ophthalmic lie in this order from the medial to the lateral side upon the same plane; they enter the cavity of the orbit above the muscles. The remaining nerves enter the orbit between the two heads of the Rectus lateralis. The superior division of the oculomotor is the highest of these; beneath this lies the nasociliary branch of the ophthalmic; then the inferior division of the oculomotor; and the abducent lowest of all. *6*

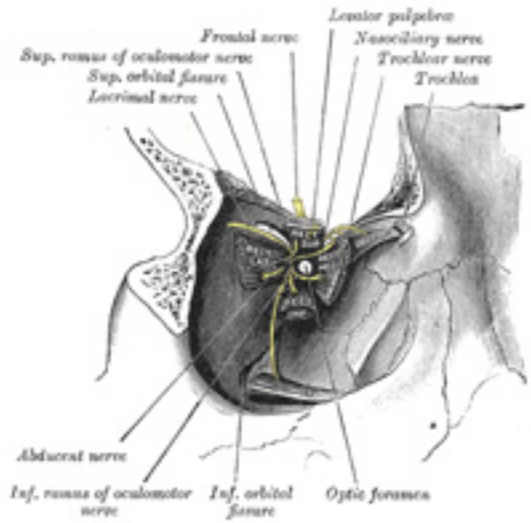


FIG. 787– Dissection showing origins of right ocular muscles, and nerves entering by the superior orbital fissure. (See enlarged image)

In the **orbit,** the trochlear, frontal, and lacrimal nerves lie immediately beneath the periosteum, the trochlear nerve resting on the Obliquus superior, the frontal on the Levator palpebræ superioris, and the lacrimal on the Rectus lateralis. The superior division of the oculomotor nerve lies immediately beneath the Rectus superior, while the nasociliary nerve crosses the optic nerve to reach the medial wall of the orbit. Beneath these is the optic nerve, surrounded in front by the ciliary nerves, and having the ciliary ganglion on its lateral side, between it and the Rectus lateralis. Below the optic nerve are the inferior division of the oculomotor, and the abducent, the latter lying on the medial surface of the Rectus lateralis. *7*

5g. The Facial Nerve

(N. Facialis; Seventh Nerve) *1*

The **facial nerve** (Figs. 788, 790) consists of a motor and a sensory part, the latter being frequently described under the name of the **nervus intermedius** (*pars intermedii of Wrisberg*)(Fig. 788). The two parts emerge at the lower border of the pons in the recess between the olive and the inferior peduncle, the motor part being the more medial, immediately to the lateral side of the sensory part is the acoustic nerve.

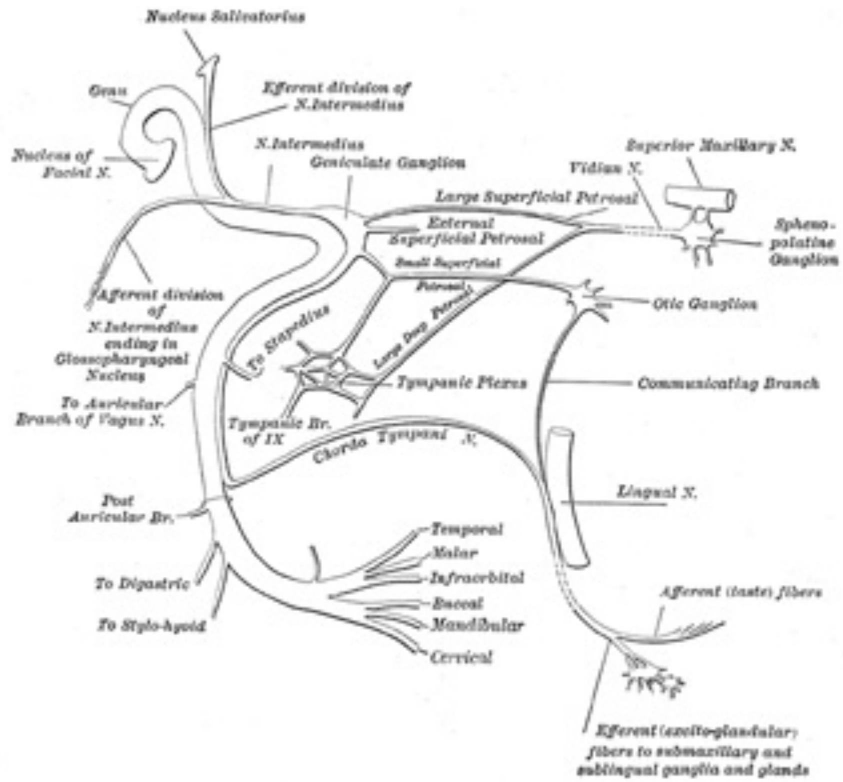


FIG. 788– Plan of the facial and intermediate nerves and their communication with other nerves. (See enlarged image)

The motor part supplies somatic motor fibers to the muscles of the face, scalp, and auricle, the Buccinator and Platysma, the Stapedius, the 2
Stylohyoideus, and posterior belly of the Digastricus; it also contains some sympathetic motor fibers which constitute the vasodilator nerves of the submaxillary and sublingual glands, and are conveyed through the chorda tympani nerve. These are preganglionic fibers of the sympathetic system and terminate in the submaxillary ganglion and small ganglia in the hilus of the submaxillary gland. From these ganglia postganglionic fibers are conveyed to these glands. The sensory part contains the fibers of taste for the anterior two-thirds of the tongue and a few

somatic sensory fibers from the middle ear region. A few splanchnic sensory fibers are also present.

The **motor root** *arises* from a nucleus which lies deeply in the reticular formation of the lower part of the pons. This nucleus is situated above the nucleus ambiguus, behind the superior olivary nucleus, and medial to the spinal tract of the trigeminal nerve. From this origin the fibers pursue a curved course in the substance of the pons. They first pass backward and medialward toward the rhomboid fossa, and, reaching the posterior end of the nucleus of the abducent nerve, run upward close to the middle line beneath the colliculus fasciculus. At the anterior end of the nucleus of the abducent nerve they make a second bend, and run downward and forward through the pons to their point of emergence between the olive and the inferior peduncle. 3

The **sensory root** *arises* from the genicular ganglion, which is situated on the geniculum of the facial nerve in the facial canal, behind the hiatus of the canal. The cells of this ganglion are unipolar, and the single process divides in a T-shaped manner into central and peripheral branches. The central branches leave the trunk of the facial nerve in the internal acoustic meatus, and form the sensory root; the peripheral branches are continued into the chorda tympani and greater superficial petrosal nerves. Entering the brain at the lower border of the pons between the motor root and the acoustic nerve, the fibers of the sensory root pass into the substance of the medulla oblongata and end in the upper part of the terminal nucleus of the glossopharyngeal nerve and in the fasciculus solitarius. 4

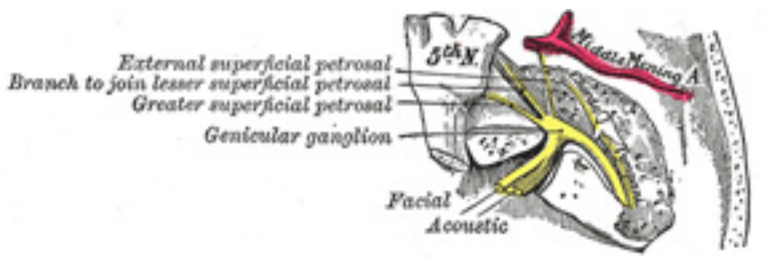


FIG. 789– The course and connections of the facial nerve in the temporal bone. (See enlarged image)

From their superficial attachments to the brain, the two roots of the facial nerve pass lateralward and forward with the acoustic nerve to the internal acoustic meatus. In the meatus the motor root lies in a groove on the upper and anterior surface of the acoustic nerve, the sensory root being placed between them. 5

At the bottom of the meatus, the facial nerve enters the facial canal, which it traverses to its termination at the stylomastoid foramen. It is at first directed lateralward between the cochlea and vestibule toward the medial wall of the tympanic cavity; it then bends suddenly backward and arches downward behind the tympanic cavity to the stylomastoid foramen. The point where it changes its direction is named the **geniculum;** it presents a reddish gangliform swelling, the **genicular ganglion** (*ganglion geniculi; geniculate ganglion; nucleus of the sensory root of the nerve*)(Fig. 789). On emerging from the stylomastoid foramen, the facial nerve runs forward in the substance of the parotid gland, crosses the external carotid artery, and divides behind the ramus of the mandible into branches, from which numerous offsets are distributed over the side of the head, face, and upper part of the neck, supplying the superficial muscles in these regions. The branches and their offsets unite to form 6 the **parotid plexus.**

Branches of Communication.—The branches of communication of the facial nerve may be arranged as follows: 7

In the internal acoustic meatus……………..	With the acoustic nerve.
At the genicular ganglion……………………	With the sphenopalatine ganglion by the greater superficial petrosal nerve. With the otic ganglion by a branch which joins the lesser superficial petrosal nerve. With the sympathetic on the middle meningeal artery.
In the facial canal……………………………	With the auricular branch of the vagus.
At its exit from the stylomastoid foramen……	With the glossopharyngeal. With the vagus. With the great auricular. With the auriculotemporal.
Behind the ear………………………………	With the lesser occipital.
On the face…………………………………	With the trigeminal.
In the neck…………………………………	With the cutaneous cervical.

In the internal acoustic meatus some minute filaments pass from the facial to the acoustic nerve. 8

The **greater superficial petrosal nerve** (*large superficial petrosal nerve*) *arises* from the genicular ganglion, and consists chiefly of sensory branches which are distributed to the mucous membrane of the soft palate; but it probably contains a few motor fibers which form the motor root of the sphenopalatine ganglion. It passes forward through the hiatus of the facial canal, and runs in a sulcus on the anterior surface of the petrous portion of the temporal bone beneath the semilunar ganglion, to the foramen lacerum. It receives a twig from the tympanic plexus, and in the foramen is joined by the deep petrosal, from the sympathetic plexus on the internal carotid artery, to form the nerve of the pterygoid canal which passes forward through the pterygoid canal and ends in the sphenopalatine ganglion. The genicular ganglion is connected with the otic ganglion by a branch which joins the lesser superficial petrosal nerve, and also with the sympathetic filaments accompanying the middle meningeal artery. According to Arnold, a twig passes back from the ganglion to the acoustic nerve. Just before the facial nerve emerges from the stylomastoid foramen, it generally receives a twig from the auricular branch of the vagus. 9

After its exit from the stylomastoid foramen, the facial nerve sends a twig to the glossopharyngeal, and communicates with the auricular branch of the vagus, with the great auricular nerve of the cervical plexus, with the auriculotemporal nerve in the parotid gland, and with the lesser occipital behind the ear; on the face with the terminal branches of the trigeminal, and in the neck with the cutaneous cervical nerve. 10

Branches of Distribution.—The branches of distribution (Fig. 788) of the facial nerve may be thus arranged: 11

With the facial canal…………………………..	Nerve to the Stapedius muscle.

	Chorda tympani.
	Posterior auricular.
At its exit from the stylomastoid foramen………	Digastric.
	Stylohyoid.
	Temporal.
	Zygomatic.
On the face……………………………………	Buccal.
	Mandibular.
	Cervical.

The **Nerve to the Stapedius** (*n. stapedius; tympanic branch*) *arises* opposite the pyramidal eminence (page 1042); it passes through a small canal in this eminence to reach the muscle. 12

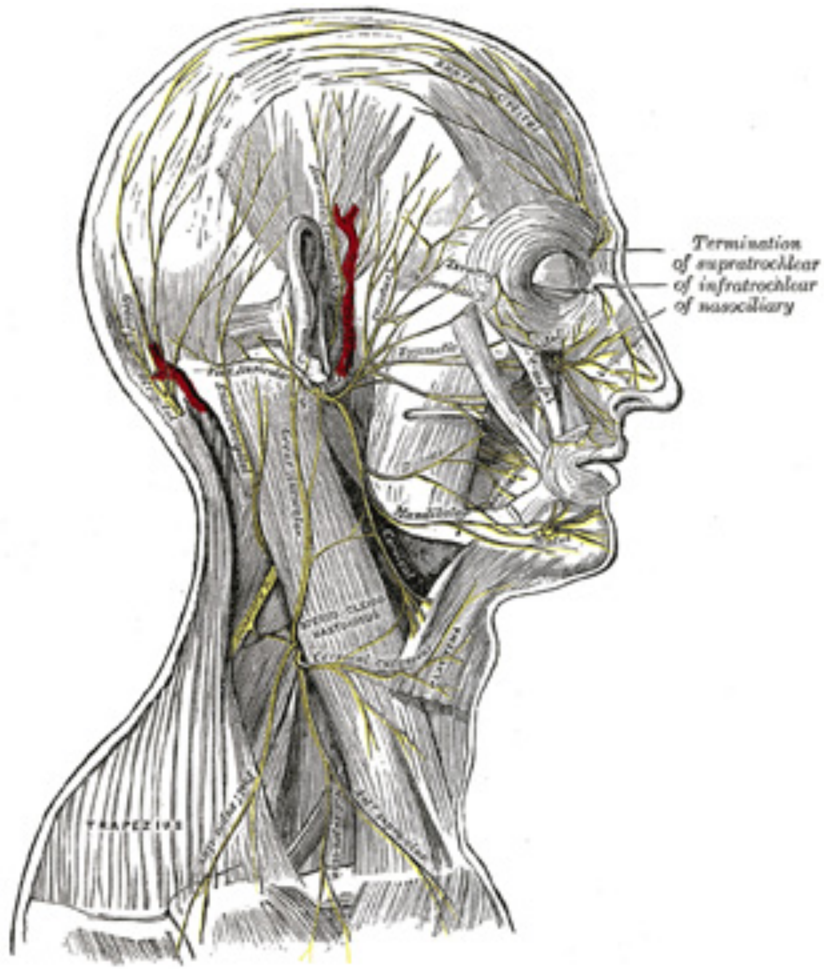


FIG. 790– The nerves of the scalp, face, and side of neck. (See enlarged image)

The **Chorda Tympani Nerve** is given off from the facial as it passes downward behind the tympanic cavity, about 6 mm. from the 13
stylomastoid foramen. It runs upward and forward in a canal, and enters the tympanic cavity, through an aperture (**iter chordæ posterius**) on its

posterior wall, close to the medial surface of the posterior border of the tympanic membrane and on a level with the upper end of the manubrium of the malleus. It traverses the tympanic cavity, between the fibrous and mucous layers of the tympanic membrane, crosses the manubrium of the malleus, and emerges from the cavity through a foramen situated at the inner end of the petrotympanic fissure, and named the **iter chordæ anterius** (*canal of Huguier*). It then descends between the Pterygoideus externus and internus on the medial surface of the spina angularis of the sphenoid, which it sometimes grooves, and joins, at an acute angle, the posterior border of the lingual nerve. It receives a few efferent fibers from the motor root; these enter the submaxillary ganglion, and through it are distributed to the submaxillary and sublingual glands; the majority of its fibers are afferent, and are continued onward through the muscular substance of the tongue to the mucous membrane covering its anterior two-thirds; they constitute the nerve of taste for this portion of the tongue. Before uniting with the lingual nerve the chorda tympani is joined by a small branch from the otic ganglion.

The **Posterior Auricular Nerve** (*n. auricularis posterior*) *arises* close to the stylo-mastoid foramen, and runs upward in front of the mastoid *14*
process; here it is joined by a filament from the auricular branch of the vagus, and communicates with the posterior branch of the great auricular, and with the lesser occipital. As it ascends between the external acoustic meatus and mastoid process it divides into auricular and occipital branches. The **auricular branch** supplies the Auricularis posterior and the intrinsic muscles on the cranial surface of the auricula. The **occipital branch,** the larger, passes backward along the superior nuchal line of the occipital bone, and supplies the Occipitalis.

The **Digastric Branch** (*ramus digastricus*) *arises* close to the stylomastoid foramen, and divides into several filaments, which supply the *15*
posterior belly of the Digastricus; one of these filaments joins the glossopharyngeal nerve.

The **Stylohyoid Branch** (*ramus stylohyoideus*) frequently *arises* in conjunction with the digastric branch; it is long and slender, and enters the *16*
Stylohyoideus about its middle.

The **Temporal Branches** (*rami temporales*) cross the zygomatic arch to the temporal region, supplying the Auriculares anterior and superior, *17*
and joining with the zygomaticotemporal branch of the maxillary, and with the auriculotemporal branch of the mandibular. The more anterior branches supply the Frontalis, the Orbicularis oculi, and the Corrugator, and join the supraorbital and lacrimal branches of the ophthalmic.

The **Zygomatic Branches** (*rami zygomatici; malar branches*) run across the zygomatic bone to the lateral angle of the orbit, where they supply *18*
the Orbicularis oculi, and join with filaments from the lacrimal nerve and the zygomaticofacial branch of the maxillary nerve.

The **Buccal Branches** (*rami buccales; infraorbital branches*), of larger size than the rest, pass horizontally forward to be distributed below the *19*
orbit and around the mouth. The**superficial branches** run beneath the skin and above the superficial muscles of the face, which they supply: some are distributed to the Procerus, joining at the medial angle of the orbit with the infratrochlear and nasociliary branches of the ophthalmic. The **deep branches** pass beneath the Zygomaticus and the Quadratus labii superioris, supplying them and forming an **infraorbital plexus** with the infraorbital branch of the maxillary nerve. These branches also supply the small muscles of the nose. The lower deep branches supply the Buccinator and Orbicularis oris, and join with filaments of the buccinator branch of the mandibular nerve.

The **Mandibular Branch** (*ramus marginalis mandibulæ*) passes forward beneath the Platysma and Triangularis, supplying the muscles of the *20*
lower lip and chin, and communicating with the mental branch of the inferior alveolar nerve.

The **Cervical Branch** (*ramus colli*) runs forward beneath the Platysma, and forms a series of arches across the side of the neck over the suprahyoid region. One branch descends to join the cervical cutaneous nerve from the cervical plexus; others supply the Platysma.

5h. The Acoustic Nerve

(Eighth Nerve) 1

The **acoustic nerve** consists of two distinct sets of fibers which differ in their peripheral endings, central connections, functions, and time of medullation. It is soft in texture and devoid of neurilemma.

Cochlear Nerve.—The cochlear nerve or root, the **nerve of hearing,** arises from bipolar cells in the spiral ganglion of the cochlea, situated near 2
the inner edge of the osseous spiral lamina. The peripheral fibers pass to the organ of Corti. The central ones pass down the modiolus and then through the foramina of the tractus spiralis foraminosus or through the foramen centrale into the lateral or outer end of the internal auditory meatus. The nerve passes along the internal auditory meatus with the vestibular nerve and across the subarachnoid space, just above the flocculus, almost directly medialward toward the inferior peduncle to terminate in the cochlear nucleus.

The cochlear nerve is placed lateral to the vestibular root. Its fibers end in two nuclei: one, the **accessory nucleus,** lies immediately in front of 3
the inferior peduncle; the other, the**tuberculum acusticum,** somewhat lateral to it.

The **striæ medullares** (*striæ acusticæ*) are the axons of the cells of the tuberculum acusticum. They pass over the inferior peduncle, and across 4
the rhomboid fossa to the median sulcus. Here they dip into the substance of the pons, to end around the cells of the superior olivary nuclei of both sides. There are, however, other fibers, and these are both direct and crossed, which pass into the lateral lemniscus. The cells of the accessory nucleus give origin to fibers which run transversely in the pons and constitute the trapezium. Of the trapezoid fibers some end around the cells of the superior olivary nucleus or of the trapezoid nucleus of the same or opposite side, while others, crossed or uncrossed, pass directly into the lateral lemniscus.

If the further connections of the cochlear nerve of one side, say the left, be considered, it is found that they lie lateral to the main sensory tract, 5
the lemniscus, and are therefore termed the **lateral lemniscus.** The fibers comprising the left lateral lemniscus *arise* in the superior olivary and trapezoid nuclei of the same or opposite side, while others are the uninterrupted fibers already alluded to, and these are either crossed or uncrossed, the former being the axons of the cells of the right accessory nucleus or of the cells of the right tuberculum acusticum, while the latter are derived from the cells of the left nuclei. In the upper part of the lateral lemniscus there is a collection of nerve cells, the **nucleus of the lateral lemniscus,** around the cells of which some of the fibers arborize and from the cells of which axons originate to continue upward the tract of the lateral lemniscus. The ultimate ending of the left lateral lemniscus is partly in the opposite medial geniculate body, and partly in the inferior colliculi. From the cells of these bodies new fibers arise and ascend in the occipital part of the internal capsule to reach the posterior three-fifths of the left superior temporal gyrus and the transverse temporal gyri.

Vestibular Nerve.—The vestibular nerve or root, the **nerve of equilibration,** arises from bipolar cells in the vestibular ganglion, **ganglion of Scarpa,** which is situated in the upper part of the outer end of the internal auditory meatus. The peripheral fibers divide into three branches: the superior branch passes through the foramina in the area vestibularis superior and ends in the utricle and in the ampullæ of the superior and lateral semicircular ducts; the fibers of the inferior branch traverse the foramina in the area vestibularis inferior and end in the saccule; the posterior branch runs through the foramen singulare and supplies the ampulla of the posterior semicircular duct.

5i. The Glossopharyngeal Nerve

(N. Glossopharyngeus; Ninth Nerve) *1*

The **glossopharyngeal nerve** (Figs. 791, 792, 793) contains both motor and sensory fibers, and is distributed, as its name implies, to the tongue and pharynx. It is the nerve of ordinary sensation to the mucous membrane of the pharynx, fauces, and palatine tonsil, and the nerve of taste to the posterior part of the tongue. It is attached by three or four filaments to the upper part of the medulla oblongata, in the groove between the olive and the inferior peduncle.

The **sensory fibers** *arise* from the cells of the superior and petrous ganglia, which are situated on the trunk of the nerve, and will be presently *2*
described. When traced into the medulla, some of the sensory fibers, probably sympathetic afferent, end by arborizing around the cells of the upper part of a nucleus which lies beneath the ala cinerea in the lower part of the rhomboid fossa. Many of the fibers, probably the **taste fibers,** contribute to form a strand, named the **fasciculus solitarius,** which descends in the medulla oblongata. Associated with this strand are numerous nerve cells, and around these the fibers of the fasciculus end. The **somatic sensory fibers,** few in number, are said to join the spinal tract of the trigeminal nerve.

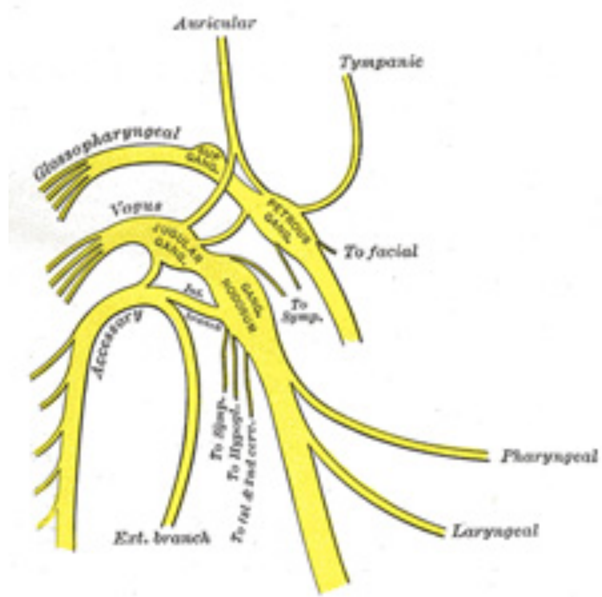


FIG. 791– Plan of upper portions of glossopharyngeal, vagus, and accessory nerves. (See enlarged image)

The **somatic motor fibers** spring from the cells of the **nucleus ambiguus,** which lies some distance from the surface of the rhomboid fossa in 3
the lateral part of the medulla and is continuous below with the anterior gray column of the medulla spinalis. From this nucleus the fibers are first directed backward, and then they bend forward and lateralward to join the fibers of the sensory root. The nucleus ambiguus gives origin to the motor branches of the glossopharyngeal and vagus nerves, and to the cranial part of the accessory nerve.

The **sympathetic efferent fibers** from the nucleus beneath the ala cinerea, the dorsal nucleus, are probably both preganglionic motor fibers and 4
preganglionic secretory fibers of the sympathetic system. The secretory fibers pass to the otic ganglion and from it secondary neurons are distributed to the parotid gland. Some authors describe these fibers as arising from a distinct nucleus the inferior salivatory nucleus, which lies near the dorsal nucleus.

From the medulla oblongata, the glossopharyngeal nerve passes lateralward across the flocculus, and leaves the skull through the central part of 5
the jugular foramen, in a separate sheath of the dura mater, lateral to and in front of the vagus and accessory nerves (Fig. 792). In its passage through the jugular foramen, it grooves the lower border of the petrous part of the temporal bone; and, at its exit from the skull, passes forward between the internal jugular vein and internal carotid artery; it descends in front of the latter vessel, and beneath the styloid process and the muscles connected with it, to the lower border of the Stylopharyngeus. It then curves forward, forming an arch on the side of the neck and lying

upon the Stylopharyngeus and Constrictor pharyngis medius. Thence it passes under cover of the Hyoglossus, and is finally distributed to the palatine tonsil, the mucous membrane of the fauces and base of the tongue, and the mucous glands of the mouth.

In passing through the jugular foramen, the nerve presents two ganglia, the **superior** and the **petrous** (Fig. 791). 6

The **Superior Ganglion** (*ganglion superius; jugular ganglion*) is situated in the upper part of the groove in which the nerve is lodged during its passage through the jugular foramen. It is very small, and is usually regarded as a detached portion of the petrous ganglion. 7

The **Petrous Ganglion** (*ganglion petrosum; inferior ganglion*) is larger than the superior and is situated in a depression in the lower border of the petrous portion of the temporal bone. 8

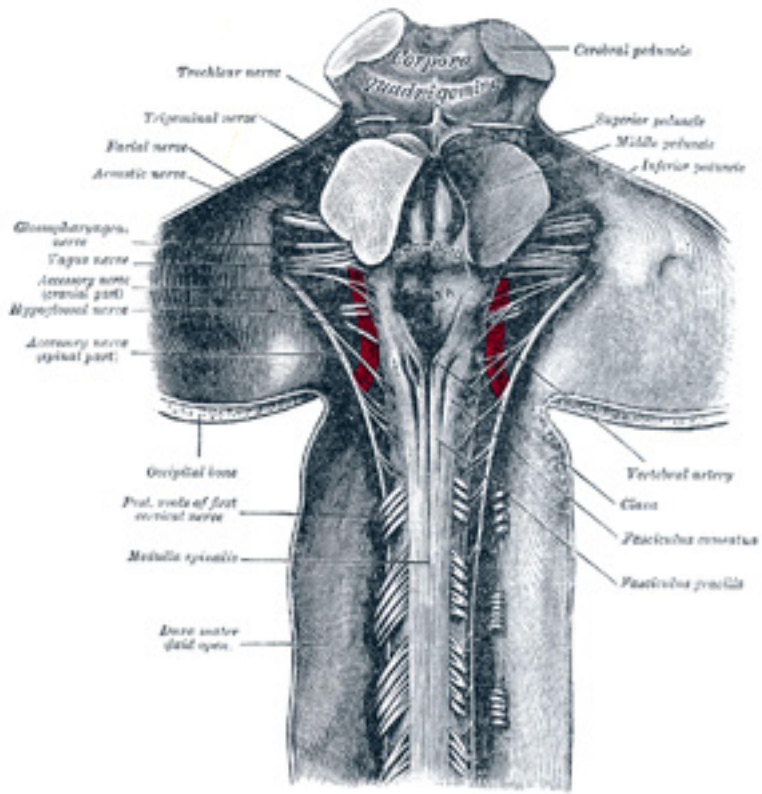


FIG. 792– Upper part of medulla spinalis and hind- and mid-brains; posterior aspect, exposed *in situ*. (See enlarged image)

Branches of Communication.—The glossopharyngeal nerve communicates with the **vagus, sympathetic,** and **facial.** 9

The branches to the vagus are two filaments which *arise* from the petrous ganglion, one passing to the auricular branch, and the other to the jugular ganglion, of the vagus. The petrous ganglion is connected by a filament with the superior cervical ganglion of the sympathetic. The branch of communication with the facial perforates the posterior belly of the Digastricus. It *arises* from the trunk of the glossopharyngeal below the petrous ganglion, and joins the facial just after the exit of that nerve from the stylomastoid foramen. 10

Branches of Distribution.—The branches of distribution of the glossopharyngeal are: the **tympanic, carotid, pharyngeal, muscular, tonsillar,** and **lingual.** 11

The **Tympanic Nerve** (*n. tympanicus; nerve of Jacobson*) *arises* from the petrous ganglion, and ascends to the tympanic cavity through a small canal on the under surface of the petrous portion of the temporal bone on the ridge which separates the carotid canal from the jugular fossa. In the tympanic cavity it divides into branches which form the **tympanic plexus** and are contained in grooves upon the surface of the promontory. This plexus gives off: (1) the lesser superficial petrosal nerve; (2) a branch to join the greater superficial petrosal nerve; and (3) branches to the tympanic cavity, all of which will be described in connection with the anatomy of the middle ear. 12

The **Carotid Branches** (*n. caroticotympanicus superior* and *n. caroticotympanicus inferior*) descend along the trunk of the internal carotid artery as far as its origin, communicating with the pharyngeal branch of the vagus, and with branches of the sympathetic. 13

The **Pharyngeal Branches** (*rami pharyngei*) are three or four filaments which unite, opposite the Constrictor pharyngis medius, with the pharyngeal branches of the vagus and sympathetic, to form the **pharyngeal plexus;** branches from this plexus perforate the muscular coat of the pharynx and supply its muscles and mucous membrane. 14

The **Muscular Branch** (*ramus stylopharyngeus*) is distributed to the Stylopharyngeus. 15

The **Tonsillar Branches** (*rami tonsillares*) supply the palatine tonsil, forming around it a plexus from which filaments are distributed to the soft palate and fauces, where they communicate with the palatine nerves. 16

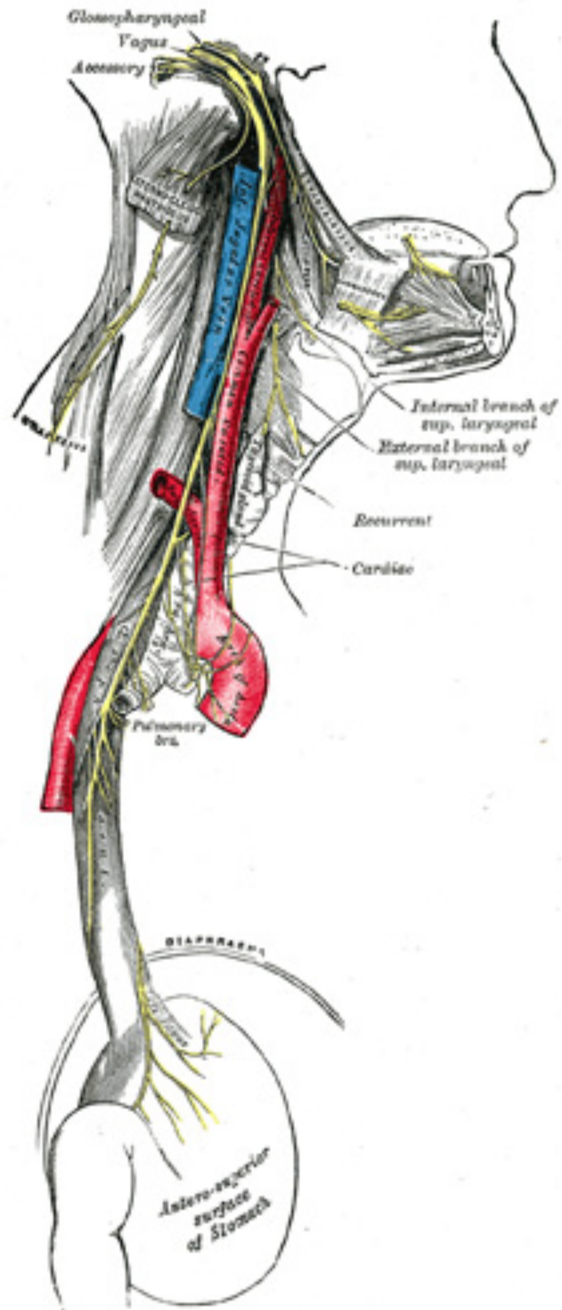

Glossopharyngeal
Vagus
Accessory
Internal branch of sup. laryngeal
External branch of sup. laryngeal
Recurrent
Cardiac
Pulmonary bra.
DIAPHRAGM
Antero-superior surface of Stomach

FIG. 793– Course and distribution of the glossopharyngeal, vagus, and accessory nerves. (See enlarged image)

The **Lingual Branches** (*rami linguales*) are two in number; one supplies the papillæ vallatæ and the mucous membrane covering the base of the tongue; the other supplies the mucous membrane and follicular glands of the posterior part of the tongue, and communicates with the lingual nerve.

5j. The Vagus Nerve

(N. Vagus; Tenth Nerve; Pneumogastric Nerve) 1

The **vagus nerve** (Figs. 791, 792, 793) is composed of both motor and sensory fibers, and has a more extensive course and distribution than any of the other cranial nerves, since it passes through the neck and thorax to the abdomen.

The vagus is attached by eight or ten filaments to the medulla oblongata in the groove between the olive and the inferior peduncle, below the 2
glossopharyngeal. The **sensory fibers** *arise* from the cells of the jugular ganglion and ganglion nodosum of the nerve, and, when traced into the medulla oblongata mostly end by arborizing around the cells of the inferior part of a nucleus which lies beneath the ala cinerea in the lower part of the rhomboid fossa. These are the sympathetic afferent fibers. Some of the sensory fibers of the glossopharyngeal nerve have been seen to end in the upper part of this nucleus. A few of the sensory fibers of the vagus, probably **taste fibers,** descend in the fasciculus solitarius and end around its cells. The **somatic sensory fibers,** few in number, from the posterior part of the external auditory meatus and the back of the ear, probably join the spinal tract of the trigeminal as it descends in the medulla. The **somatic motor fibers** *arise* from the cells of the nucleus ambiguus, already referred to in connection with the motor root of the glossopharyngeal nerve.

The **sympathetic efferent fibers,** distributed probably as preganglionic fibers to the thoracic and abdominal viscera, *i. e.,* as motor fibers to the 3
bronchial tree, inhibitory fibers to the heart, motor fibers to the esophagus, stomach, small intestine and gall passages, and as secretory fibers to the stomach and pancreas, arise from the dorsal nucleus of the vagus.

The filaments of the nerve unite, and form a flat cord, which passes beneath the flocculus to the jugular foramen, through which it leaves the 4
cranium. In emerging through this opening, the vagus is accompanied by and contained in the same sheath of dura mater with the accessory nerve, a septum separating them from the glossopharyngeal which lies in front (Fig. 792). In this situation the vagus presents a well-marked ganglionic enlargement, which is called the **jugular ganglion** (*ganglion of the root*); to it the accessory nerve is connected by one or two filaments. After its exit from the jugular foramen the vagus is joined by the cranial portion of the accessory nerve, and enlarges into a second gangliform swelling, called the **ganglion nodosum** (*ganglion of the trunk*); through this the fibers of the cranial portion of the accessory pass without interruption, being principally distributed to the pharyngeal and superior laryngeal branches of the vagus, but some of its fibers descend in the trunk of the vagus, to be distributed with the recurrent nerve and probably also with the cardiac nerves.

The vagus nerve passes vertically down the neck within the carotid sheath, lying between the internal jugular vein and internal carotid artery as 5
far as the upper border of the thyroid cartilage, and then between the same vein and the common carotid artery to the root of the neck. The further course of the nerve differs on the two sides of the body.

On the *right side,* the nerve passes across the subclavian artery between it and the right innominate vein, and descends by the side of the trachea 6
to the back of the root of the lung, where it spreads out in the **posterior pulmonary plexus.** From the lower part of this plexus two cords descend on the esophagus, and divide to form, with branches from the opposite nerve, the **esophageal plexus.** Below, these branches are collected into a single cord, which runs along the back of the esophagus enters the abdomen, and is distributed to the postero-inferior surface of the stomach, joining the left side of the celiac plexus, and sending filaments to the lienal plexus.

On the *left side,* the vagus enters the thorax between the left carotid and subclavian arteries, behind the left innominate vein. It crosses the left 7
side of the arch of the aorta, and descends behind the root of the left lung, forming there the **posterior pulmonary plexus.**From this it runs along the anterior surface of the esophagus, where it unites with the nerve of the right side in the **esophageal plexus,** and is continued to the stomach, distributing branches over its anterosuperior surface; some of these extend over the fundus, and others along the lesser curvature. Filaments from these branches enter the lesser omentum, and join the hepatic plexus.

The **Jugular Ganglion** (*ganglion jugulare; ganglion of the root*) is of a grayish color, spherical in form, about 4 mm. in diameter. 8

Branches of Communication.—This ganglion is connected by several delicate filaments to the cranial portion of the accessory nerve; it also 9
communicates by a twig with the petrous ganglion of the glossopharyngeal, with the facial nerve by means of its auricular branch, and with the sympathetic by means of an ascending filament from the superior cervical ganglion.

The **Ganglion Nodosum** (*ganglion of the trunk; inferior ganglion*) is cylindrical in form, of a reddish color, and 2.5 cm. in length. Passing 10
through it is the cranial portion of the accessory nerve, which blends with the vagus below the ganglion.

Branches of Communication.—This ganglion is connected with the hypoglossal, the superior cervical ganglion of the sympathetic, and the 11
loop between the first and second cervical nerves.

Branches of Distribution.—The branches of distribution of the vagus are: 12

In the Jugular Fossa…	Meningeal. Auricular.
In the Neck…………	Pharyngeal. Superior laryngeal. Recurrent. Superior cardiac.
In the Thorax………	Inferior cardiac. Anterior bronchial. Posterior bronchial. Esophageal.

Gastric.
In the Abdomen……. Celiac.
Hepatic.

The **Meningeal Branch** (*ramus meningeus; dural branch*) is a recurrent filament given off from the jugular ganglion; it is distributed to the 13
dura mater in the posterior fossa of the base of the skull.

The **Auricular Branch** (*ramus auricularis; nerve of Arnold*) *arises* from the jugular ganglion, and is joined soon after its origin by a filament 14
from the petrous ganglion of the glossopharyngeal; it passes behind the internal jugular vein, and enters the mastoid canaliculus on the lateral wall of the jugular fossa. Traversing the substance of the temporal bone, it crosses the facial canal about 4 mm. above the stylomastoid foramen, and here it gives off an ascending branch which joins the facial nerve. The nerve reaches the surface by passing through the tympanomastoid fissure between the mastoid process and the tympanic part of the temporal bone, and divides into two branches: one joins the posterior auricular nerve, the other is distributed to the skin of the back of the auricula and to the posterior part of the external acoustic meatus.

The **Pharyngeal Branch** (*ramus pharyngeus*), the principal motor nerve of the pharynx, *arises* from the upper part of the ganglion nodosum, 15
and consists principally of filaments from the cranial portion of the accessory nerve. It passes across the internal carotid artery to the upper border of the Constrictor pharyngis medius, where it divides into numerous filaments, which join with branches from the glossopharyngeal, sympathetic, and external laryngeal to form the **pharyngeal plexus.** From the plexus, branches are distributed to the muscles and mucous membrane of the pharynx and the muscles of the soft palate, except the Tensor veli palatini. A minute filament descends and joins the hypoglossal nerve as it winds around the occipital artery.

The **Superior Laryngeal Nerve** (*n. laryngeus superior*) larger than the preceding, *arises* from the middle of the ganglion nodosum and in its 16
course receives a branch from the superior cervical ganglion of the sympathetic. It descends, by the side of the pharynx, behind the internal carotid artery, and divides into two branches, **external** and **internal.**

The **external branch** (*ramus externus*), the smaller, descends on the larynx, beneath the Sternothyreoideus, to supply the Cricothyreoideus. It 17
gives branches to the pharyngeal plexus and the Constrictor pharyngis inferior, and communicates with the superior cardiac nerve, behind the common carotid artery.

The **internal branch** (*ramus internus*) descends to the hyothyroid membrane, pierces it in company with the superior laryngeal artery, and is 18
distributed to the mucous membrane of the larynx. Of these branches some are distributed to the epiglottis, the base of the tongue, and the epiglottic glands; others pass backward, in the aryepiglottic fold, to supply the mucous membrane surrounding the entrance of the larynx, and that lining the cavity of the larynx as low down as the vocal folds. A filament descends beneath the mucous membrane on the inner surface of the thyroid cartilage and joins the recurrent nerve.

The **Recurrent Nerve** (*n. recurrens; inferior or recurrent laryngeal nerve*) *arises,* on the *right side,* in front of the subclavian artery; winds 19
from before backward around that vessel, and ascends obliquely to the side of the trachea behind the common carotid artery, and either in front of or behind the inferior thyroid artery. On the *left* side, it *arises* on the left of the arch of the aorta, and winds below the aorta at the point where the ligamentum arteriosum is attached, and then ascends to the side of the trachea. The nerve on either side ascends in the groove between the trachea and esophagus, passes under the lower border of the Constrictor pharyngis inferior, and enters the larynx behind the articulation of the inferior cornu of the thyroid cartilage with the cricoid; it is distributed to all the muscles of the larynx, excepting the Cricothyreoideus. It communicates with the internal branch of the superior laryngeal nerve, and gives off a few filaments to the mucous membrane of the lower part

of the larynx.

As the recurrent nerve hooks around the subclavian artery or aorta, it gives off several cardiac filaments to the deep part of the cardiac plexus. 20
As it ascends in the neck it gives off branches, more numerous on the left than on the right side, to the mucous membrane and muscular coat of the esophagus; branches to the mucous membrane and muscular fibers of the trachea; and some pharyngeal filaments to the Constrictor pharyngis inferior.

The **Superior Cardiac Branches** (*rami cardiaci superiores; cervical cardiac branches*), two or three in number, *arise* from the vagus, at the 21
upper and lower parts of the neck.

The **upper branches** are small, and communicate with the cardiac branches of the sympathetic. They can be traced to the deep part of the 22
cardiac plexus.

The **lower branch** *arises* at the root of the neck, just above the first rib. That from the right vagus passes in front or by the side of the 23
innominate artery, and proceeds to the deep part of the cardiac plexus; that from the left runs down across the left side of the arch of the aorta, and joins the superficial part of the cardiac plexus.

The **Inferior Cardiac Branches** (*rami cardiaci inferiores; thoracic cardiac branches*), on the right side, *arise* from the trunk of the vagus as it 24
lies by the side of the trachea, and from its recurrent nerve; on the left side from the recurrent nerve only; passing inward, they end in the deep part of the cardiac plexus.

The **Anterior Bronchial Branches** (*rami bronchiales anteriores; anterior or ventral pulmonary branches*), two or three in number, and of 25
small size, are distributed on the anterior surface of the root of the lung. They join with filaments from the sympathetic, and form the **anterior pulmonary plexus.**

The **Posterior Bronchial Branches** (*rami bronchiales posteriores; posterior or dorsal pulmonary branches*), more numerous and larger than 26
the anterior, are distributed on the posterior surface of the root of the lung; they are joined by filaments from the third and fourth (sometimes also from the first and second) thoracic ganglia of the sympathetic trunk, and form the **posterior pulmonary plexus.** Branches from this plexus accompany the ramifications of the bronchi through the substance of the lung.

The **Esophageal Branches** (*rami æsophagei*) are given off both above and below the bronchial branches; the lower are numerous and larger 27
than the upper. They form, together with the branches from the opposite nerve, the **esophageal plexus.** From this plexus filaments are distributed to the back of the pericardium.

The **Gastric Branches** (*rami gastrici*) are distributed to the stomach. The right vagus forms the **posterior gastric plexus** on the postero- 28
inferior surface of the stomach and the left the **anterior gastric plexus** on the antero-superior surface.

The **Celiac Branches** (*rami cæliaci*) are mainly derived from the right vagus: they join the celiac plexus and through it supply branches to the 29
pancreas, spleen, kidneys, suprarenal bodies, and intestine.

The **Hepatic Branches** (*rami hepatici*) *arise* from the left vagus: they join the hepatic plexus and through it are conveyed to the liver. 30

5k. The Accessory Nerve

(N. Accessorius; Eleventh Nerve; Spinal Accessory Nerve) 1

The **accessory nerve** (Figs. 792, 793, 794) consists of two parts: a **cranial** and a **spinal.**

The **Cranial Part** (*ramus internus; accessory portion*) is the smaller of the two. Its fibers*arise* from the cells of the **nucleus ambiguus** and emerge as four or five delicate rootlets from the side of the medulla oblongata, below the roots of the vagus. It runs lateralward to the jugular foramen, where it interchanges fibers with the spinal portion or becomes united to it for a short distance; here it is also connected by one or two filaments with the jugular ganglion of the vagus. It then passes through the jugular foramen, separates from the spinal portion and is continued over the surface of the ganglion nodosum of the vagus, to the surface of which it is adherent, and is distributed principally to the pharyngeal and superior laryngeal branches of the vagus. Through the pharyngeal branch it probably supplies the Musculus uvulæ and Levator veli palatini. Some few filaments from it are continued into the trunk of the vagus below the ganglion, to be distributed with the recurrent nerve and probably also with the cardiac nerves. 2

The **Spinal Part** (*ramus externus; spinal portion*) is firm in texture, and its fibers *arise*from the motor cells in the lateral part of the anterior column of the gray substance of the medulla spinalis as low as the fifth cervical nerve. Passing through the lateral funiculus of the medulla spinalis, they emerge on its surface and unite to form a single trunk, which ascends between the ligamentum denticulatum and the posterior roots of the spinal nerves; enters the skull through the foramen magnum, and is then directed to the jugular foramen, through which it passes, lying in the same sheath of dura mater as the vagus, but separated from it by a fold of the arachnoid. In the jugular foramen, it receives one or two filaments from the cranial part of the nerve, or else joins it for a short distance and then separates fromit again. As its exit from the jugular foramen, it runs backward in front of the internal jugular vein in 66.6 per cent. of cases, and behind in it 33.3 per cent. (Tandler). The nerve then descends obliquely behind the Digastricus and Stylohyoideus to the upper part of the Sternocleidomastoideus; it pierces this muscle, and courses obliquely across the posterior triangle of the neck, to end in the deep surface of the Trapezius. As it traverses the Sternocleidomastoideus it gives several filaments to the muscle, and joins with branches from the second cervical nerve. In the posterior triangle it unites with the second and third cervical nerves, while beneath the Trapezius it forms a plexus with the third and fourth cervical nerves, and from this plexus fibers are distributed to the muscle. 3

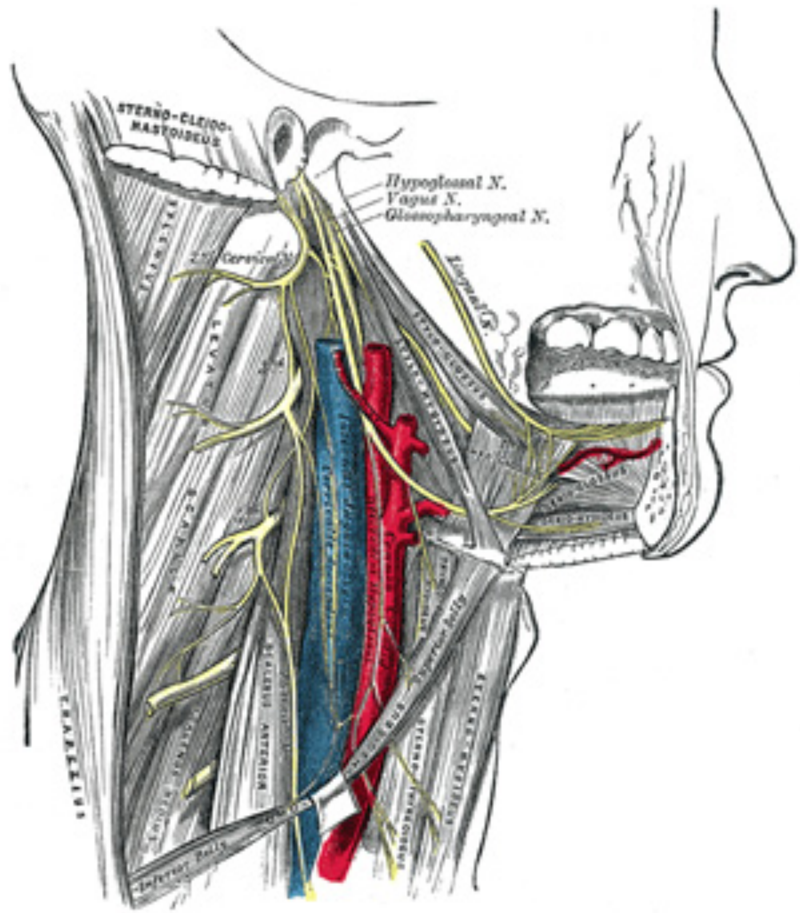


FIG. 794– Hypoglossal nerve, cervical plexus, and their branches. (See enlarged image)

5l. The Hypoglossal Nerve

(N. Hypoglossus; Twelfth Nerve) 1

The **hypoglossal nerve** (Figs. 794, 795) is the motor nerve of the tongue.

Its fibers *arise* from the cells of the **hypoglossal nucleus,** which is an upward prolongation of the base of the anterior column of gray substance 2
of the medulla spinalis. This nucleus is about 2 cm. in length, and its upper part corresponds with the **trigonum hypoglossi,** or lower portion of the medial eminence of the rhomboid fossa (page 779). The lower part of the nucleus extends downward into the closed part of the medulla oblongata, and there lies in relation to the ventro-lateral aspect of the central canal. The fibers run forward through the medulla oblongata, and emerge in the antero-lateral sulcus between the pyramid and the olive.

The rootlets of this nerve are collected into two bundles, which perforate the dura mater separately, opposite the hypoglossal canal in the 3
occipital bone, and unite together after their passage through it; in some cases the canal is divided into two by a small bony spicule. The nerve descends almost vertically to a point corresponding with the angle of the mandible. It is at first deeply seated beneath the internal carotid artery and internal jugular vein, and intimately connected with the vagus nerve; it then passes forward between the vein and artery, and lower down in the neck becomes superficial below the Digastricus. The nerve then loops around the occipital artery, and crosses the external carotid and lingual arteries below the tendon of the Digastricus. It passes beneath the tendon of the Digastricus, the Stylohyoideus, and the Mylohyoideus, lying between the last-named muscle and the Hyoglossus, and communicates at the anterior border of the Hyoglossus with the lingual nerve; it is then continued forward in the fibers of the Genioglossus as far as the tip of the tongue, distributing branches to its muscular substance.

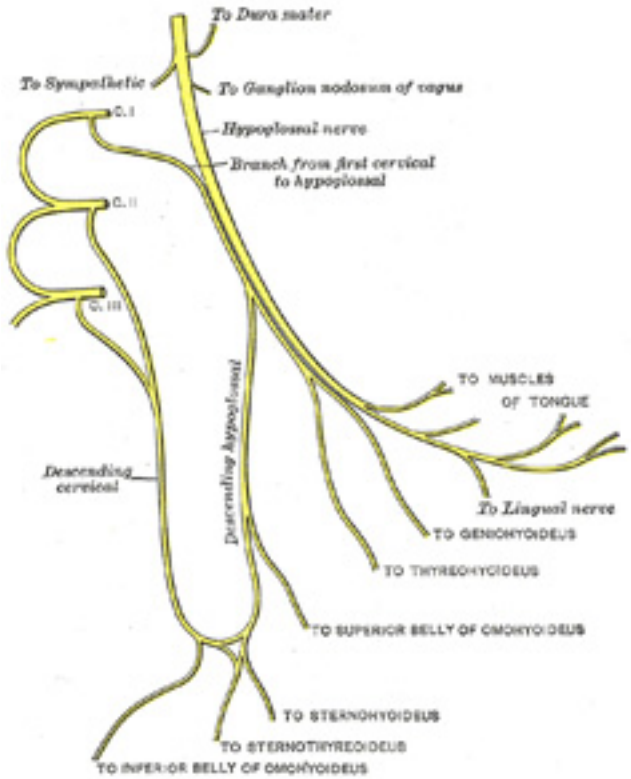


FIG. 795– Plan of hypoglossal nerve. (See enlarged image)

Branches of Communication.—Its branches of communication are, with the 4

Vagus.	First and second cervical nerves.
Sympathetic.	Lingual.

The communications with the vagus take place close to the skull, numerous filaments passing between the hypoglossal and the ganglion nodosum of the vagus through the mass of connective tissue which unites the two nerves. As the nerve winds around the occipital artery it gives 5 off a filament to the pharyngeal plexus.

The communication with the sympathetic takes place opposite the atlas by branches derived from the superior cervical ganglion, and in the same situation the nerve is joined by a filament derived from the loop connecting the first and second cervical nerves. 6

The communications with the lingual take place near the anterior border of the Hyoglossus by numerous filaments which ascend upon the muscle. 7

Branches of Distribution.—The branches of distribution of the hypoglossal nerve are: 8

Meningeal.	Thyrohyoid.
Descending.	Muscular.

Of these branches, the meningeal, descending, thyrohyoid, and the muscular twig to the Geniohyoideus, are probably derived mainly from the branch which passes from the loop between the first and second cervical to join the hypoglossal (Fig. 795). 9

Meningeal Branches (*dural branches*).—As the hypoglossal nerve passes through the hypoglossal canal it gives off, according to Luschka, several filaments to the dura mater in the posterior fossa of the skull. 10

The **Descending Ramus** (*ramus descendens; descendens hypoglossi*), long and slender, quits the hypoglossal where it turns around the occipital artery and descends in front of or in the sheath of the carotid vessels; it gives a branch to the superior belly of the Omohyoideus, and then joins the communicantes cervicales from the second and third cervical nerves; just below the middle of the neck, to form a loop, the **ansa hypoglossi.**From the convexity of this loop branches pass to supply the Sternohyoideus, the Sternothyreoideus, and the inferior belly of the Omohyoideus. According to Arnold, another filament descends in front of the vessels into the thorax, and joins the cardiac and phrenic nerves. 11

The **Thyrohyoid Branch** (*ramus thyreohyoideus*) *arises* from the hypoglossal near the posterior border of the hyoglossus; it runs obliquely across the greater cornu of the hyoid bone, and supplies the Thyreohyoideus muscle. 12

The **Muscular Branches** are distributed to the Styloglossus, Hyoglossus, Geniohyoideus, and Genioglossus. At the under surface of the tongue numerous slender branches pass upward into the substance of the organ to supply its intrinsic muscles. 13

6. The Spinal Nerves

(Nervi Spinales) 1

The **spinal nerves** spring from the medulla spinalis, and are transmitted through the intervertebral foramina. They number thirty-one pairs, which are grouped as follows: Cervical, 8; Thoracic, 12; Lumbar, 5; Sacral, 5; Coccygeal, 1.

The **first cervical nerve** emerges from the vertebral canal between the occipital bone and the atlas, and is therefore called the **suboccipital nerve;** the eighth issues between the seventh cervical and first thoracic vertebræ. 2

Nerve Roots.—Each nerve is attached to the medulla spinalis by two roots, an **anterior** or**ventral,** and a **posterior** or **dorsal,** the latter being characterized by the presence of a ganglion, the **spinal ganglion.** 3

The **Anterior Root** (*radix anterior; ventral root*) emerges from the anterior surface of the medulla spinalis as a number of rootlets or filaments (*fila radicularia*), which coalesce to form two bundles near the intervertebral foramen. 4

The **Posterior Root** (*radix posterior; dorsal root*) is larger than the anterior owing to the greater size and number of its rootlets; these are attached along the posterolateral furrow of the medulla spinalis and unite to form two bundles which join the spinal ganglion. The posterior root of the first cervical nerve is exceptional in that it is smaller than the anterior; it is occasionally wanting. 5

The **Spinal Ganglia** (*ganglion spinale*) are collections of nerve cells on the posterior roots of the spinal nerves. Each ganglion is oval in shape, reddish in color, and its size bears a proportion to that of the nerve root on which it is situated; it is bifid medially where it is joined by the two bundles of the posterior nerve root. The ganglia are usually placed in the intervertebral foramina, immediately outside the points where the nerve roots perforate the dura mater, but there are exceptions to this rule; thus the ganglia of the first and second cervical nerves lie on the vertebral arches of the atlas and axis respectively, those of the sacral nerves are inside the vertebral canal, while that on the posterior root of the coccygeal nerve is placed within the sheath of dura mater. 6

Structure (Fig. 638).—The ganglia consist chiefly of unipolar nerve cells, and from these the fibers of the posterior root take origin—the single process of each cell dividing after a short course into a central fiber which enters the medulla spinalis and a peripheral fiber which runs into the spinal nerve. Two other forms of cells are, however, present, viz.: (*a*) the cells of Dogiel, whose axons ramify close to the cell (type II, of Golgi), and are distributed entirely within the ganglion; and (*b*) multipolar cells similar to those found in the sympathetic ganglia. 7

The ganglia of the first cervical nerve may be absent, while small *aberrant ganglia*consisting of groups of nerve cells are sometimes found on the posterior roots between the spinal ganglia and the medulla spinalis. 8

Each nerve root receives a covering from the pia mater, and is loosely invested by the arachnoid, the latter being prolonged as far as the points where the roots pierce the dura mater. The two roots pierce the dura mater separately, each receiving a sheath from this membrane; where the roots join to form the spinal nerve this sheath is continuous with the epineurium of the nerve. 9

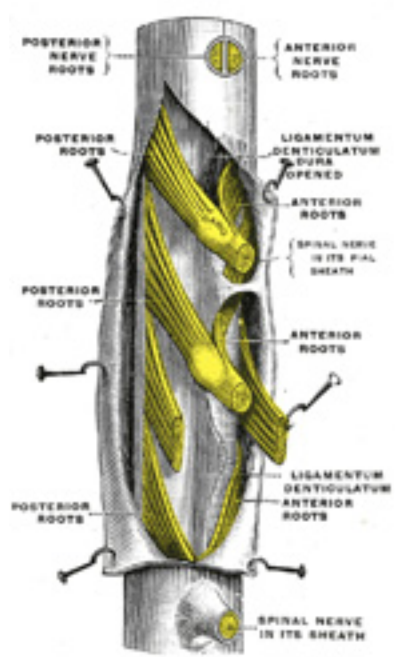


FIG. 796– A portion of the spinal cord, showing its right lateral surface. The dura is opened and arranged to show the nerve roots. (Testut.) (See enlarged image)

Size and Direction.—The roots of the upper four *cervical* nerves are small, those of the lower four are large. The posterior roots of the cervical nerves bear a proportion to the anterior of three to one, which is greater than in the other regions; their individual filaments are also larger than those of the anterior roots. The posterior root of the first cervical is an exception to this rule, being smaller than the anterior root; in eight per cent. of cases it is wanting. The roots of the first and second cervical nerves are short, and run nearly horizontally to their points of exit from the vertebral canal. From the second to the eighth cervical they are directed obliquely downward, the obliquity and length of the roots successively increasing; the distance, however, between the level of attachment of any of these roots to the medulla spinalis and the points of exit of the corresponding nerves never exceeds the depth of one vertebra. 10

The roots of the *thoracic* nerves, with the exception of the first, are of small size, and the posterior only slightly exceed the anterior in thickness. They increase successively in length, from above downward, and in the lower part of the thoracic region descend in contact with the 11 medulla spinalis for a distance equal to the height of at least two vertebræ before they emerge from the vertebral canal.

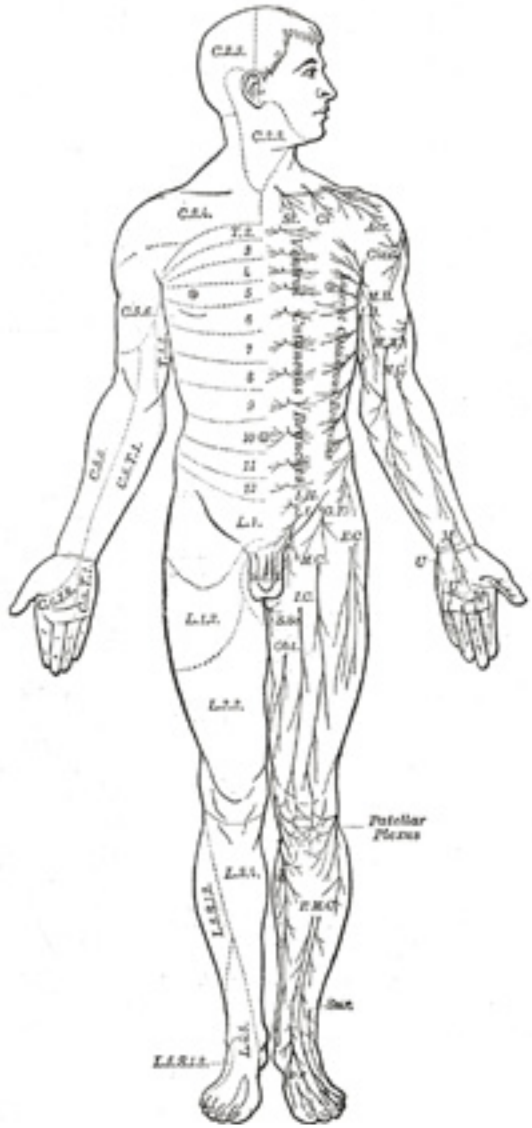
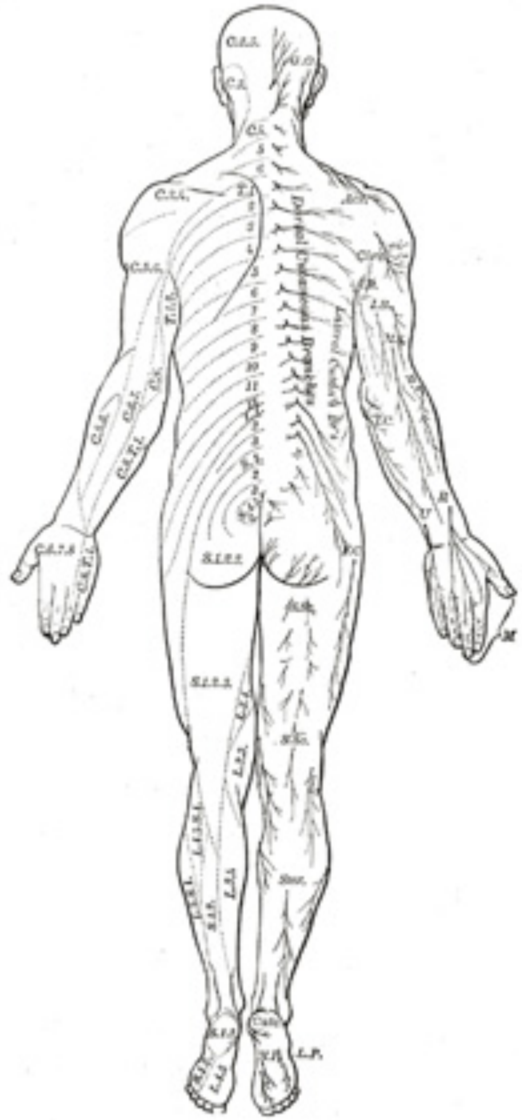

Patellar
Plexus

FIG. 797– Distribution of cutaneous nerves. Ventral aspect. (See enlarged image)

The roots of the lower *lumbar* and upper *sacral* nerves are the largest, and their individual filaments the most numerous of all the spinal nerves, while the roots of the *coccygeal* nerve are the smallest. 12

The roots of the lumbar, sacral, and coccygeal nerves run vertically downward to their respective exits, and as the medulla spinalis ends near the lower border of the first lumbar vertebra it follows that the length of the successive roots must rapidly increase. As already mentioned (page 750), the term **cauda equina** is applied to this collection of nerve roots. 13



Dorsal Cutaneous Branches
Lateral Cutaneous Br's.

FIG. 798– Distribution of cutaneous nerves. Dorsal aspect. (See enlarged image)

From the description given it will be seen that the largest nerve roots, and consequently the largest spinal nerves, are attached to the cervical 14
and lumbar swellings of the medulla spinalis; these nerves are distributed to the upper and lower limbs.

Connections with Sympathetic.—Immediately beyond the spinal ganglion, the anterior and posterior nerve roots unite to form the **spinal** 15
nerve which emerges through the intervertebral foramen. Each spinal nerve receives a branch (**gray ramus communicans**) from the adjacent ganglion of the sympathetic trunk, while the thoracic, and the first and second lumbar nerves each contribute a branch (**white ramus communicans**) to the adjoining sympathetic ganglion. The second, third, and fourth sacral nerves also supply white rami; these, however, are not connected with the ganglia of the sympathetic trunk, but run directly into the pelvic plexuses of the sympathetic.

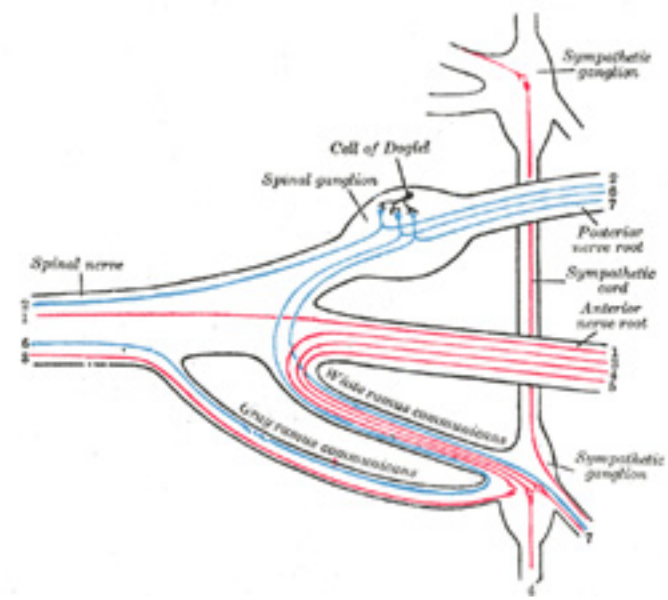


FIG. 799– Scheme showing structure of a typical spinal nerve. 1. Somatic efferent. 2. Somatic afferent. 3,4,5. Sympathetic efferent. 6,7. Sympathetic afferent. (See enlarged image)

Structure.—Each typical spinal nerve contains fibers belonging to two systems, viz., the**somatic,** and the **sympathetic** or **splanchnic,** as well as 16
fibers connecting these systems with each other (Fig. 799).

1. The **somatic fibers** are efferent and afferent. The *efferent fibers* originate in the cells of the anterior column of the medulla spinalis, and run 17
outward through the anterior nerve roots to the spinal nerve. They convey impulses to the voluntary muscles, and are continuous from their origin to their peripheral distribution. The *afferent fibers* convey impressions inward from the skin, etc., and originate in the unipolar nerve cells of the spinal ganglia. The single processes of these cells divide into peripheral and central fibers, and the latter enter the medulla spinalis through the posterior nerve roots.

2. The **sympathetic fibers** are also efferent and afferent. The *efferent* fibers, preganglionic fibers, originate in the lateral column of the medulla 18
spinalis, and are conveyed through the anterior nerve root and the white ramus communicans to the corresponding ganglion of the sympathetic trunk; here they may end by forming synapses around its cells, or may run through the ganglion to end in another of the ganglia of the sympathetic trunk, or in a more distally placed ganglion in one of the sympathetic plexuses. In all cases they end by forming synapses around other nerve cells. From the cells of the ganglia of the sympathetic trunk other fibers, postganglionic fibers, take origin; some of these run through the gray rami communicantes to join the spinal nerves, along which they are carried to the bloodvessels of the trunk and limbs, while others pass to the viscera, either directly or after interruption in one of the distal ganglia. The *afferent* fibers are derived partly from the unipolar cells and partly from the multipolar cells of the spinal ganglia. Their peripheral processes are carred through the white rami communicantes, and after passing through one or more sympathetic ganglia (but always without interruption in them) finally end in the tissues of the viscera. The central processes of the unipolar cells enter the medulla spinalis through the posterior nerve root and form synapses around either somatic or sympathetic efferent neurons, thus completing reflex arcs. The dendrites of the multipolar nerve cells form synapses around the cells of type II (cells of Dogiel) in the spinal ganglia, and by this path the original impulse is transferred from the sympathetic to the somatic system, through which it is conveyed to the sensorium.

Divisions.—After emerging from the intervertebral foramen, each spinal nerve gives off a small **meningeal branch** which reënters the vertebral 19
canal through the intervertebral foramen and supplies the vertebræ and their ligaments, and the bloodvessels of the medulla spinalis and its membranes. The spinal nerve then splits into a **posterior** or **dorsal,** and an**anterior** or **ventral division,** each receiving fibres from both nerve roots.

6a. The Posterior Divisions

(Rami Posteriores) 1

The **posterior divisions** are as a rule smaller than the anterior. They are directed backward, and, with the exceptions of those of the first cervical, the fourth and fifth sacral, and the coccygeal, divide into medial and lateral branches for the supply of the muscles and skin (Figs. 800, 801, 802) of the posterior part of the trunk.

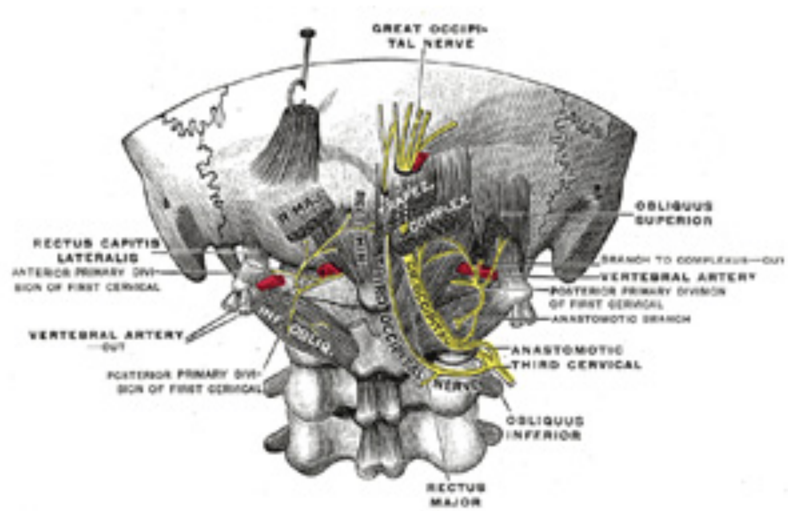


FIG. 800– Posterior primary divisions of the upper three cervical nerves. (Testut.) (See enlarged image)

The Cervical Nerves (Nn. Cervicales)—The **posterior division of the first cervical or suboccipital nerve** is larger than the anterior division, and emerges above the posterior arch of the atlas and beneath the vertebral artery. It enters the suboccipital triangle and supplies the muscles which bound this triangle, viz., the Rectus capitis posterior major, and the Obliqui superior and inferior; it gives branches also to the Rectus capitis posterior minorand the Semispinalis capitis. A filament from the branch to the Obliquus inferior joins the posterior division of the second cervical nerve. *2*

The nerve occasionally gives off a cutaneous branch which accompanies the occipital artery to the scalp, and communicates with the greater and lesser occipital nerves. *3*

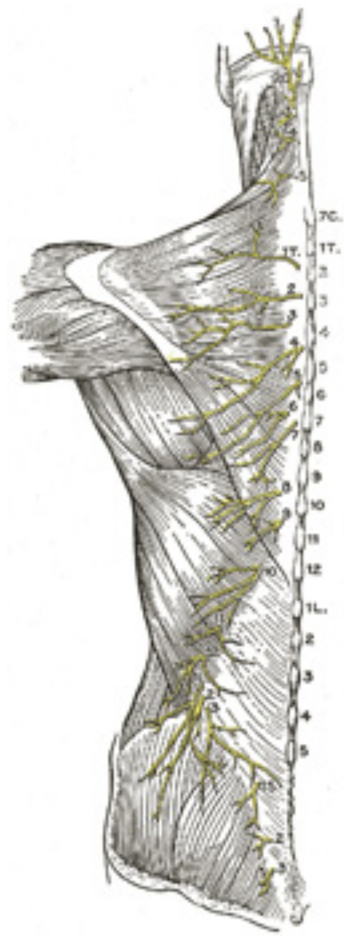


FIG. 801– Diagram of the distribution of the cutaneous branches of the posterior divisions of the spinal nerves. (See enlarged image)

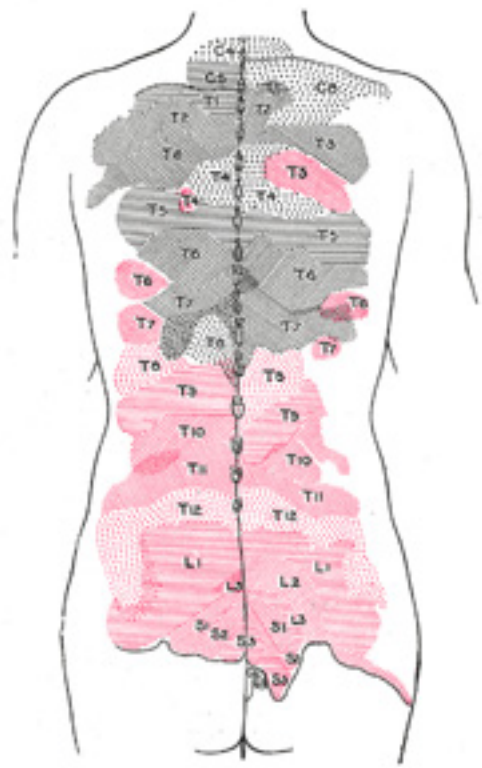


FIG. 802– Areas of distribution of the cutaneous branches of the posterior divisions of the spinal nerves. The areas of the medial branches are in black, those of the lateral in red. (H. M. Johnston.) (See enlarged image)

The **posterior division of the second cervical nerve** is much larger than the anterior division, and is the greatest of all the cervical posterior 4
divisions. It emerges between the posterior arch of the atlas and the lamina of the axis, below the Obliquus inferior. It supplies a twig to this
muscle, receives a communicating filament from the posterior division of the first cervical, and then divides into a large medial and a small
lateral branch.

The **medial branch** (*ramus medialis; internal branch*), called from its size and distribution the **greater occipital nerve** (*n. occipitalis major;* 5
great occipital nerve), ascends obliquely between the Obliquus inferior and the Semispinalis capitis, and pierces the latter muscle and the

Trapezius near their attachments to the occipital bone (Fig. 801). It is then joined by a filament from the medial branch of the posterior division of the third cervical, and, ascending on the back of the head with the occipital artery, divides into branches which communicate with the lesser occipital nerve and supply the skin of the scalp as far forward as the vertex of the skull. It gives off muscular branches to the Semispinalis capitis, and occasionally a twig to the back of the auricula. The **lateral branch** (*ramus lateralis; external branch*) supplies filaments to the Splenius, Longus capitis, and Semispinalis capitis, and is often joined by the corresponding branch of the third cervical.

The **posterior division of the third cervical** is intermediate in size between those of the second and fourth. Its **medial branch** runs between the Semispinalis capitis and cervicis, and, piercing the Splenius and Trapezius, ends in the skin. While under the Trapezius it gives off a branch called the **third occipital nerve,** which pierces the Trapezius and ends in the skin of the lower part of the back of the head (Fig. 801). It lies medial to the greater occipital and communicates with it. The **lateral branch** often joins that of the second cervical. *6*

The posterior division of the suboccipital, and the medial branches of the posterior division of the second and third cervical nerves are sometimes joined by communicating loops to form the *posterior cervical plexus* (Cruveilhier). *7*

The **posterior divisions of the lower five cervical nerves** divide into medial and lateral branches. The **medial branches** of the fourth and fifth run between the Semispinales cervicis and capitis, and, having reached the spinous processes, pierce the Splenius and Trapezius to end in the skin (Fig. 801). Sometimes the branch of the fifth fails to reach the skin. Those of the lower three nerves are small, and end in the Semispinales cervicis and capitis, Multifidus, and Interspinales. The **lateral branches** of the lower five nerves supply the Iliocostalis cervicis, Longissimus cervicis, and Longissimus capitis. *8*

The Thoracic Nerves (Nn. Thoracales)—The **medial branches** (*ramus medialis; internal branch*) of the **posterior divisions of the upper six thoracic nerves** run between the Semispinalis dorsi and Multifidus, which they supply; they then pierce the Rhomboidei and Trapezius, and reach the skin by the sides of the spinous processes (Fig. 801). The medial branches of the **lower six** are distributed chiefly to the Multifidus and Longissimus dorsi, occasionally they give off filaments to the skin near the middle line. *9*

The **lateral branches** (*ramus lateralis; external branch*) increase in size from above downward. They run through or beneath the Longissimus dorsi to the interval between it and the Iliocostales, and supply these muscles; the lower five or six also give off cutaneous branches which pierce the Serratus posterior inferior and Latissimus dorsi in a line with the angles of the ribs (Fig. 801). The lateral branches of a variable number of the upper thoracic nerves also give filaments to the skin. The lateral branch of the twelfth thoracic, after sending a filament medialward along the iliac crest, passes downward to the skin of the buttock. *10*

The medial cutaneous branches of the posterior divisions of the thoracic nerves descend for some distance close to the spinous processes before reaching the skin, while the lateral branches travel downward for a considerable distance—it may be as much as the breadth of four ribs—before they become superficial; the branch from the twelfth thoracic, for instance, reaches the skin only a little way above the iliac crest. 132 *11*

The Lumbar Nerves (Nn. Lumbales)—The **medial branches** of the **posterior divisions of the lumbar nerves** run close to the articular processes of the vertebræ and end in the Multifidus. *12*

The **lateral branches** supply the Sacrospinalis. The upper three give off cutaneous nerves which pierce the aponeurosis of the Latissimus dorsi at the lateral border of the Sacrospinalis and descend across the posterior part of the iliac crest to the skin of the buttock (Fig. 801), some of their twigs running as far as the level of the greater trochanter. *13*

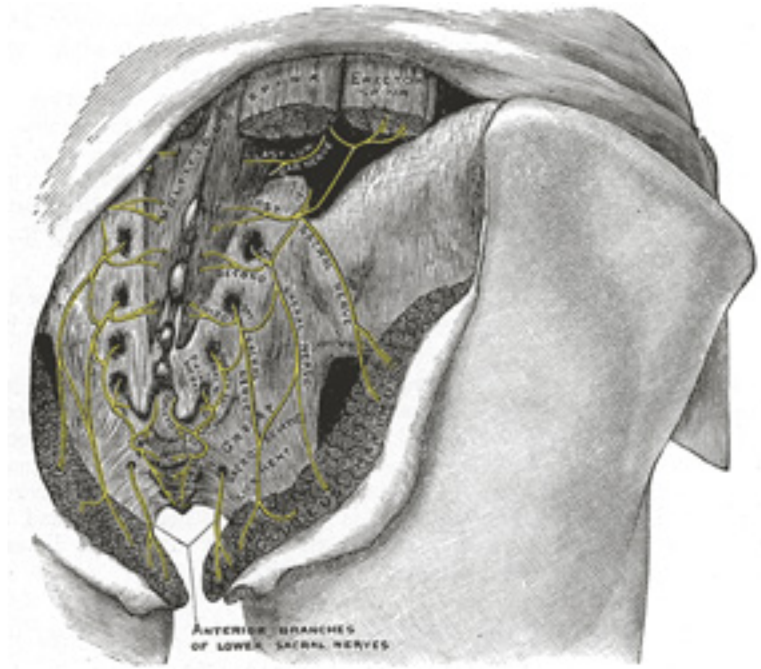


FIG. 803– The posterior divisions of the sacral nerves. (See enlarged image)

The Sacral Nerves (Nn. Sacrales)—The **posterior divisions of the sacral nerves** (*rami posteriores*)(Fig. 803) are small, and diminish in size from above downward; they emerge, except the last, through the posterior sacral foramina. The *upper three* are covered at their points of exit by the Multifidus, and divide into medial and lateral branches. 14

The **medial branches** are small, and end in the Multifidus. 15

The **lateral branches** join with one another and with the lateral branches of the posterior divisions of the last lumbar and fourth sacral to form loops on the dorsal surface of the sacrum. From these loops branches run to the dorsal surface of the sacrotuberous ligament and form a second series of loops under the Glutæus maximus. From this second series cutaneous branches, two or three in number, pierce the Glutæus maximus along a line drawn from the posterior superior iliac spine to the tip of the coccyx; they supply the skin over the posterior part of the buttock. 16

The posterior divisions of the *lower two* sacral nerves are small and lie below the Multifidus. They do not divide into medial and lateral 17 branches, but unite with each other and with the posterior division of the coccygeal nerve to form loops on the back of the sacrum; filaments from these loops supply the skin over the coccyx.

The Coccygeal Nerve (N. Coccygeus)—The **posterior division of the coccygeal nerve**(*ramus posterior*) does not divide into a medial and a lateral branch, but receives, as already stated, a communicating branch from the last sacral; it is distributed to the skin over the back of the coccyx. 18

Note 132. See article by H. M. Johnston, Journal of Anatomy and Physiology, vol. xliii. [back]

6b. The Anterior Divisions

(Rami Anteriores) 1

The **anterior divisions of the spinal nerves** supply the antero-lateral parts of the trunk, and the limbs; they are for the most part larger than the posterior divisions. In the thoracic region they run independently of one another, but in the cervical, lumbar, and sacral regions they unite near their origins to form plexuses.

The Cervical Nerves (Nn. Cervicales)

The anterior divisions of the cervical nerves (*rami anteriores*), with the exception of the first, pass outward between the Intertransversarii anterior and posterior, lying on the grooved upper surfaces of the transverse processes of the vertebræ. The **anterior division of the first** or **suboccipital nerve** issues from the vertebral canal above the posterior arch of the atlas and runs forward around the lateral aspect of its superior articular process, medial to the vertebral artery. In most cases it descends medial to and in front of the Rectus capitis lateralis, but occasionally it pierces the muscle. 2

The anterior divisions of the **upper four cervical nerves** unite to form the **cervical plexus,** and each receives a gray ramus communicans from the superior cervical ganglion of the sympathetic trunk. Those of the **lower four cervical,** together with the greater part of the first thoracic, form the **brachial plexus.** They each receive a gray ramus communicans, those for the fifth and sixth being derived from the middle, and those for the seventh and eighth from the lowest, cervical ganglion of the sympathetic trunk. 3

The Cervical Plexus (*plexus cervicalis*)(Fig. 804).

—The cervical plexus is formed by the anterior divisions of the upper four cervical nerves; each nerve, except the first, divides into an upper and a lower branch, and the branches unite to form three loops. The plexus is situated oppostie the upper four cervical vertebræ, in front of the Levator scapulæ and Scalenus medius, and covered by the Sternocleidomastoideus. 4

Its branches are divided into two groups, **superficial and deep,** and are here given in tabular form; the figures following the names indicate the 5 nerves from which the different branches take origin:

Superficial		Smaller occipital	………………………….	2, C.
		Great auricular	………………………….	2, 3, C.
		Cutaneous cervical	………………………….	2, 3, C.
		Supraclavicular	………………………….	3, 4, C.
Deep	Internal	Communicating	With hypoglossal………..	1, 2, C.
			With vagus………………	1, 2, C.
			With sympathetic………..	1, 2, 3, 4, C.
		Muscular	Rectus capitis lateralis……	1, C.
			Rectus capitis anterior……	1, 2, C.
			Longus capitis……………	1, 2, 3, C.
			Communicantes cervicales..	2, 3, C.
			Phrenic…………………	3, 4, 5, C.
	External	Communicating with accessory………………		2, 3, 4, C.
		Muscular	Sternocleidomastoideus…	2, C.
			Trapezius………………	3, 4, C.
			Levator scapulæ………..	3, 4, C.
			Scalenus medius………..	3, 4, C.

Superficial Branches of the Cervical Plexus (Fig. 805).—The **Smaller Occipital Nerve**(*n. occipitalïs minor; small occipital nerve*) *arises* from the second cervical nerve, sometimes also from the third; it curves around and ascends along the posterior border of the Sternocleidomastoideus. Near the cranium it perforates the deep fascia, and is continued upward along the side of the head behind the auricula, supplying the skin and communicating with the greater occipital, the great auricular, and the posterior auricular branch of the facial. The smaller occipital varies in size, and is sometimes duplicated. *6*

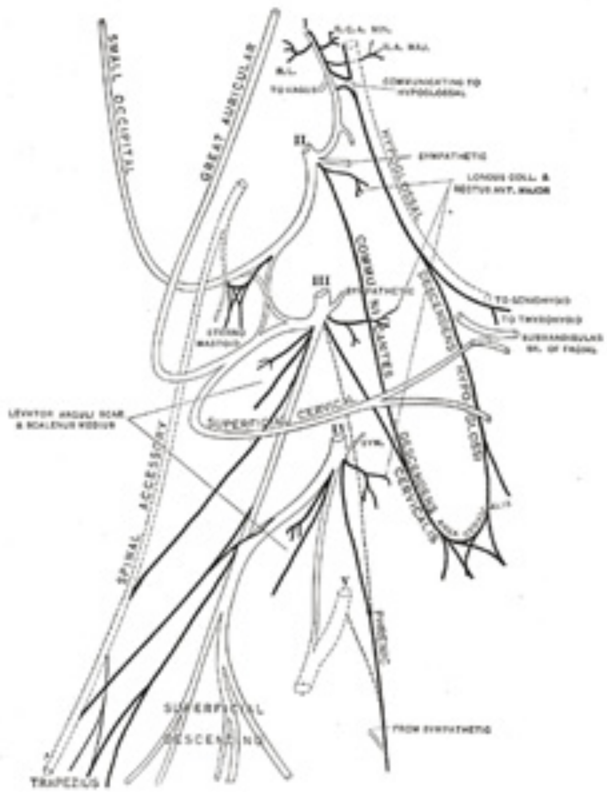


FIG. 804– Plan of the cervical plexus. (Gerrish.) (See enlarged image)

It gives off an **auricular branch,** which supplies the skin of the upper and back part of the auricula, communicating with the mastoid branch of the great auricular. This branch is occasionally derived from the greater occipital nerve. 7

The **Great Auricular Nerve** (*n. auricularis magnus*) is the largest of the ascending branches. It arises from the second and third cervical nerves, winds around the posterior border of the Sternocleidomastoideus, and, after perforating the deep fascia, ascends upon that muscle beneath the Platysma to the parotid gland, where it divides into an anterior and a posterior branch. 8

The **anterior branch** (*ramus anterior; facial branch*) is distributed to the skin of the face over the parotid gland, and communicates in the substance of the gland with the facial nerve. 9

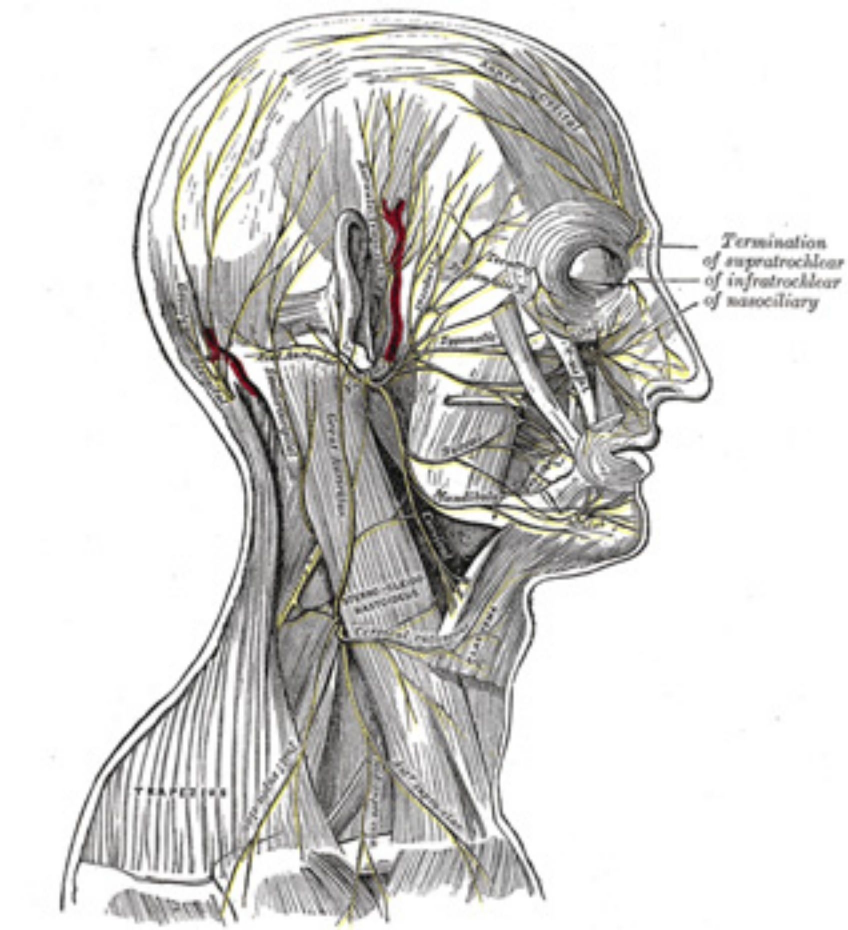


FIG. 805– The nerves of the scalp, face, and side of neck. (See enlarged image)

The **posterior branch** (*ramus posterior; mastoid branch*) supplies the skin over the mastoid process and on the back of the auricula, except at its upper part; a filament pierces the auricula to reach its lateral surface, where it is distributed to the lobule and lower part of the concha. The 10 posterior branch communicates with the smaller occipital, the auricular branch of the vagus, and the posterior auricular branch of the facial.

The **Cutaneous Cervical** (*n. cutaneus colli; superficial or transverse cervical nerve*)*arises* from the second and third cervical nerves, turns 11
around the posterior border of the Sternocleidomastoideus about its middle, and, passing obliquely forward beneath the external jugular vein to the anterior border of the muscle, it perforates the deep cervical fascia, and divides beneath the Platysma into ascending and descending branches, which are distributed to the antero-lateral parts of the neck.

The **ascending branches** (*rami superiores*) pass upward to the submaxillary region, and form a plexus with the cervical branch of the facial 12
nerve beneath the Platysma; others pierce that muscle, and are distributed to the skin of the upper and front part of the neck.

The **descending branches** (*rami inferiores*) pierce the Platysma, and are distributed to the skin of the side and front of the neck, as low as the 13
sternum.

The **Supraclavicular Nerves** (*nn. supraclaviculares; descending branches*) *arise* from the third and fourth cervical nerves; they emerge 14
beneath the posterior border of the Sternocleidomastoideus, and descend in the posterior triangle of the neck beneath the Platysma and deep cervical fascia. Near the clavicle they perforate the fascia and Platysma to become cutaneous, and are arranged, according to their position, into three groups—**anterior, middle** and **posterior.**

The **anterior supraclavicular nerves** (*nn. supraclaviculares anteriores; suprasternal nerves*) cross obliquely over the external jugular vein 15
and the clavicular and sternal heads of the Sternocleidomastoideus, and supply the skin as far as the middle line. They furnish one or two filaments to the sternoclavicular joint.

The **middle supraclavicular nerves** (*nn. supraclaviculares medii; supraclavicular nerves*) cross the clavicle, and supply the skin over the 16
Pectoralis major and Deltoideus, communicating with the cutaneous branches of the upper intercostal nerves.

The **posterior supraclavicular nerves** (*nn. supraclaviculares posteriores; supra-acromial nerves*) pass obliquely across the outer surface of 17
the Trapezius and the acromion, and supply the skin of the upper and posterior parts of the shoulder.

Deep Branches of the Cervical Plexus. INTERNAL SERIES.—The **Communicating Branches** consist of several filaments, which pass from 18
the loop between the first and second cervical nerves to the vagus, hypoglossal, and sympathetic. The branch to the hypoglossal ultimately leaves that nerve as a series of branches, viz., the descending ramus, the nerve to the Thyreohyoideus and the nerve, to the Geniohyoideus (see page 916). A communicating branch also passes from the fourth to the fifth cervical, while each of the first four cervical nerves receives a gray ramus communicans from the superior cervical ganglion of the sympathetic.

Muscular Branches supply the Longus capitis, Rectus capitis anterior, and Rectus capitis lateralis. 19

The **Communicantes Cervicales** (*communicantes hypoglossi*)(Fig. 804) consist usually of two filaments, one derived from the second, and the 20
other from the third cervical. These filaments join to form the **descendens cervicalis,** which passes downward on the lateral side of the internal jugular vein, crosses in front of the vein a little below the middle of the neck, and forms a loop (**ansa hypoglossi**) with the descending ramus of the hypoglossal in front of the sheath of the carotid vessels (see page 916). Occasionally, the loop is formed within the sheath.

The **Phrenic Nerve** (*n. phrenicus; internal respiratory nerve of Bell*) contains motor and sensory fibers in the proportion of about two to one. 21
It *arises* chiefly from the fourth cervical nerve, but receives a branch from the third and another from the fifth; (the fibers from the fifth occasionally come through the nerve to the Subclavius.) It descends to the root of the neck, running obliquely across the front of the Scalenus anterior, and beneath the Sternocleidomastoideus, the inferior belly of the Omohyoideus, and the transverse cervical and transverse scapular

vessels. It next passes in front of the first part of the subclavian artery, between it and the subclavian vein, and, as it enters the thorax, crosses the internal mammary artery near its origin. Within the thorax, it descends nearly vertically in front of the root of the lung, and then between the pericardium and the mediastinal pleura, to the diaphragm, where it divides into branches, which pierce that muscle, and are distributed to its under surface. In the thorax it is accompanied by the pericardiacophrenic branch of the internal mammary artery.

The two phrenic nerves differ in their length, and also in their relations at the upper part of the thorax. 22

The **right nerve** is situated more deeply, and is shorter and more vertical in direction than the left; it lies lateral to the right innominate vein and superior vena cava. 23

The **left nerve** is rather longer than the right, from the inclination of the heart to the left side, and from the diaphragm being lower on this than on the right side. At the root of the neck it is crossed by the thoracic duct; in the superior mediastinal cavity it lies between the left common carotid and left subclavian arteries, and crosses superficial to the vagus on the left side of the arch of the aorta. 24

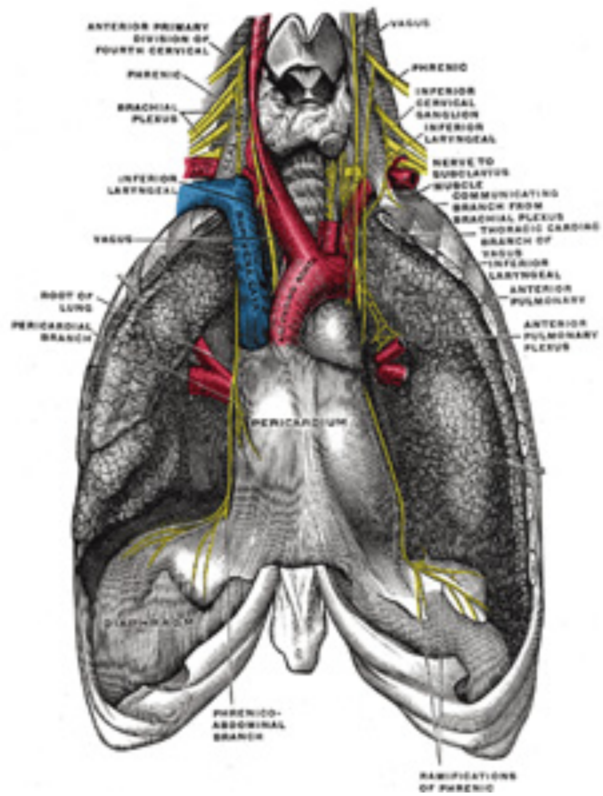


FIG. 806– The phrenic nerve and its relations with the vagus nerve. (See enlarged image)

Each nerve supplies filaments to the pericardium and pleura, and at the root of the neck is joined by a filament from the sympathetic, and, occasionally, by one from the ansa hypoglossi. Branches have been described as passing to the peritoneum. 25

From the *right nerve,* one or two filaments pass to join in a small **phrenic ganglion** with phrenic branches of the celiac plexus; and branches from this ganglion are distributed to the falciform and coronary ligaments of the liver, the suprarenal gland, inferior vena cava, and right atrium. From the *left nerve,* filaments pass to join the phrenic branches of the celiac plexus, but without any ganglionic enlargement; and a twig is distributed to the left suprarenal gland. 26

Deep Branches of the Cervical Plexus. EXTERNAL SERIES.—Communicating Branches.—The external series of deep branches of the cervical plexus communicates with the accessory nerve, in the substance of the Sternocleidomastoideus, in the posterior triangle, and beneath the Trapezius. 27

Muscular Branches are distributed to the Sternocleidomastoideus, Trapezius, Levator scapulæ, and Scalenus medius. 28

The branch for the Sternocleidomastoideus is derived from the second cervical; the Trapezius and Levator scapulæ receive branches from the third and fourth. The Scalenus medius receives twigs either from the third or fourth, or occasionally from both. 29

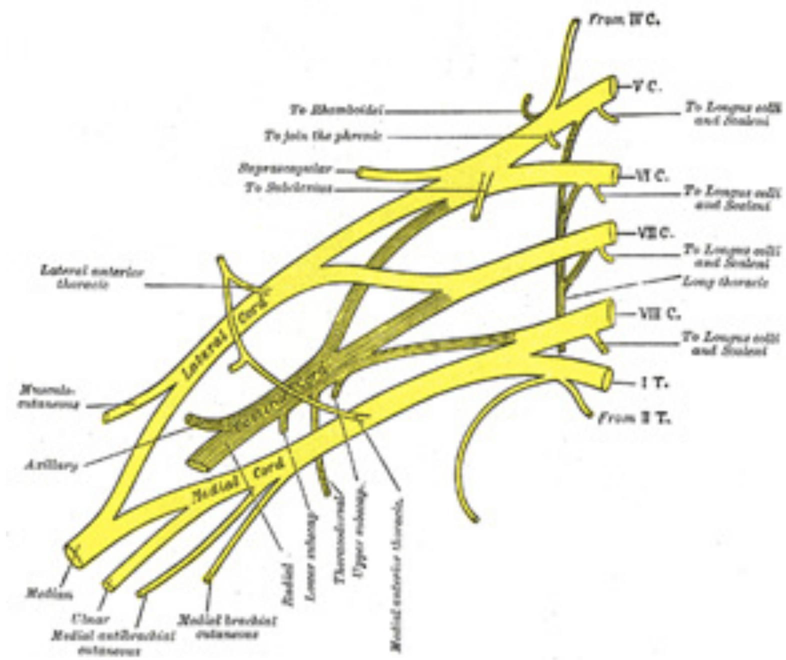


FIG. 807– Plan of brachial plexus. (See enlarged image)

The Branchial Plexus (*plexus brachialis*) (Fig. 807).—The brachial plexus is formed by the union of the anterior divisions of the lower four cervical nerves and the greater part of the anterior division of the first thoracic nerve; the fourth cervical usually gives a branch to the fifth cervical, and the first thoracic frequently receives one from the second thoracic. The plexus extends from the lower part of the side of the neck to 30 the axilla. The nerves which form it are nearly equal in size, but their mode of communication is subject to some variation. The following is, however, the most constant arrangement. The fifth and sixth cervical unite soon after their exit from the intervertebral foramina to form a trunk. The eighth cervical and first thoracic also unite to form one trunk, while the seventh cervicalruns out alone. Three trunks—upper, middle, and lower—are thus formed, and, as they pass beneath the clavicle, each splits into an **anterior** and a **posterior division.** 133 The anterior divisions of the upper and middle trunks unite to form a cord, which is situated on the lateral side of the second part of the axillary artery, and is called the **lateral cord** or**fasciculus of the plexus.** The anterior division of the lower trunk passes down on the medial side of the axillary artery, and forms the **medial cord** or **fasciculus of the brachial plexus.** The posterior divisions of all three trunks unite to form the **posterior cord** or**fasciculus of the plexus,** which is situated behind the second portion of the axillary artery.

Relations.—*In the neck,* the brachial plexus lies in the posterior triangle, being covered by the skin, Platysma, and deep fascia; it is crossed by 31
the supraclavicular nerves, the inferior belly of the Omohyoideus, the external jugular vein, and the transverse cervical artery. It emerges between the Scaleni anterior and medius; its upper part lies above the third part of the subclavian artery, while the trunk formed by the union of the eighth cervical and first thoracic is placed behind the artery; the plexus next passes behind the clavicle, the Subclavius, and the transverse scapular vessels, and lies upon the first digitation of the Serratus anterior, and the Subscapularis. *In the axilla* it is placed lateral to the first portion of the axillary artery; it surrounds the second part of the artery, one cord lying medial to it, one lateral to it, and one behind it; at the lower part of the axilla it gives off its terminal branches to the upper limb.

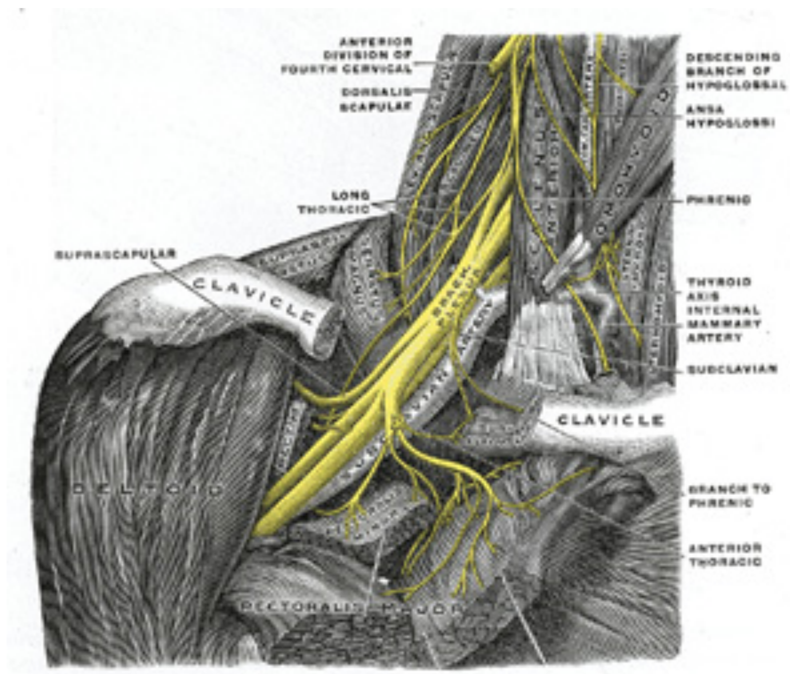


FIG. 808– The right brachial plexus with its short branches, viewed from in front. The Sternomastoid and Trapezius muscles have been completely, the Omohyoid and Subclavius have been partially, removed; a piece has been sawed out of the clavicle; the Pectoralis muscles have been incised and reflected. (Spalteholz.) (See enlarged image)

Branches of Communication.—Close to their exit from the intervertebral foramina the fifth and sixth cervical nerves each receive a gray ramus communicans from the middle cervical ganglion of the sympathetic trunk, and the seventh and eighth cervical similar twigs from the inferior ganglion. The first thoracic nerve receives a gray ramus from, and contributes a white ramus to, the first thoracic ganglion. On the Scalenus anterior the phrenic nerve is joined by a branch from the fifth cervical. 32

Branches of Distribution.—The branches of distribution of the brachial plexus may be arranged into two groups, viz., those given off above and those below the clavicle. 33

Supraclavicular Branches.

Dorsal Scapular……………..	5 C.
Suprascapular……………..	5, 6 C.
Nerve to Subclavius………..	5, 6 C.
Long thoracic………………	5, 6, 7 C.
To Longus colli and Scaleni…	5, 6, 7, 8 C.

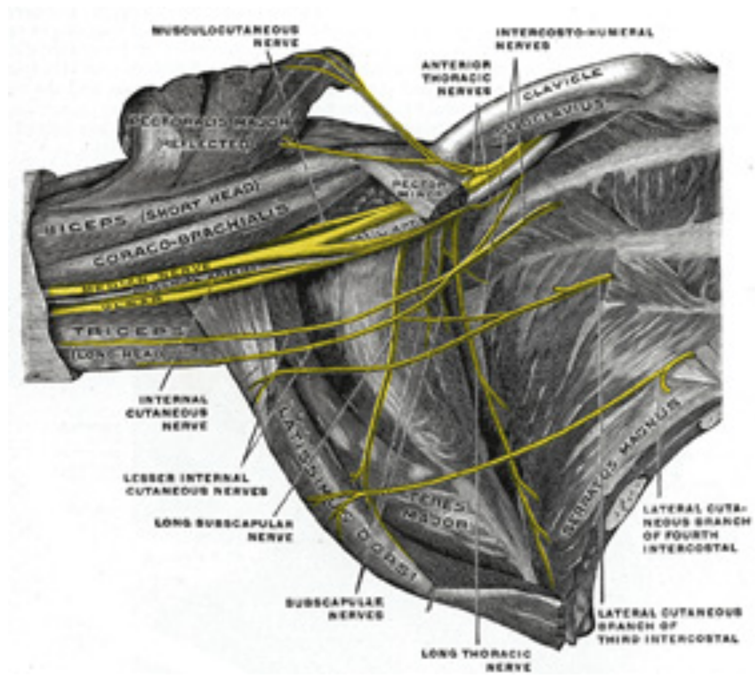


FIG. 809– The right brachial plexus (infraclavicular portion) in the axillary fossa; viewed from below and in front. The Pectoralis major and minor muscles have been in large part removed; their attachments have been reflected. (Spalteholz.) (See enlarged image)

The **Dorsal Scapular Nerve** (*n. dorsalis scapulæ; nerve to the Rhomboidei; posterior scapular nerve*) *arises* from the fifth cervical, pierces the 34
Scalenus medius, passes beneath the Levator scapulæ, to which it occasionally gives a twig, and ends in the Rhomboidei.

35 The **Suprascapular** (*n. suprascapularis*) (Fig. 818) *arises* from the trunk formed by the union of the fifth and sixth cervical nerves. It runs lateralward beneath the Trapezius and the Omohyoideus, and enters the supraspinatous fossa through the suprascapular notch, below, the superior transverse scapular ligament; it then passes beneath the Supraspinatus, and curves around the lateral border of the spine of the scapula to the infraspinatous fossa. In the supraspinatous fossa it gives off two branches to the Supraspinatus muscle, and an articular filament to the shoulder-joint; and in the infraspinatous fossa it gives off two branches to the Infraspinatous muscle, besides some filaments to the shoulder-joint and scapula.

36 The **Nerve to the Subclavius** (*n. subclavius*) is a small filament, which *arises* from the point of junction of the fifth and sixth cervical nerves; it descends to the muscle in front of the third part of the subclavian artery and the lower trunk of the plexus, and is usually connected by a filament with the phrenic nerve.

37 The **Long Thoracic Nerve** (*n. thoracalis longus; external respiratory nerve of Bell; posterior thoracic nerve*) (Fig. 816) supplies the Serratus anterior. It usually *arises* by three roots from the fifth, sixth, and seventh cervical nerves; but the root from the seventh nerve may be absent. The roots from the fifth and sixth nerves pierce the Scalenus medius, while that from the seventh passes in front of the muscle. The nerve descends behind the brachial plexus and the axillary vessels, resting on the outer surface of the Serratus anterior. It extends along the side of the thorax to the lower border of that muscle, supplying filaments to each of its digitations.

38 The branches for the Longus colli and Scaleni arise from the lower four cervical nerves at their exit from the intervertebral foramina.

39 **Infraclavicular Branches.**—The infraclavicular branches are derived from the three cords of the brachial plexus, but the fasciculi of the nerves may be traced through the plexus to the spinal nerves from which they originate. They are as follows:

	Musculocutaneous………..	5, 6, 7 C.
Lateral cord……	Lateral anterior thoracic……	5, 6, 7 C.
	Lateral head of median……..	6, 7 C.
	Medial anterior thoracic	
	Medial antibrachial cutaneous	
Medial cord……	Medial brachial cutaneous….	8 C, 1 T.
	Ulnar	
	Medial head of median	
	Upper subscapular………..	5, 6 C.
	Lower subscapular………..	5, 6 C.
Posterior cord…	Thoracodorsal..……………	5, 6, 7 C.
	Axillary……………………	5, 6 C.
	Radial………………………	6, 7, 8 C, 1 T.

40 The **Anterior Thoracic Nerves** (*nn. thoracales anteriores*) (Fig. 816) supply the Pectorales major and minor.

The **lateral anterior thoracic** (*fasciculus lateralis*) the larger of the two, *arises* from the lateral cord of the brachial plexus, and through it from the fifth, sixth, and seventh cervical nerves. It passes across the axillary artery and vein, pierces the coracoclavicular fascia, and is distributed to the deep surface of the Pectoralis major. It sends a filament to join the medial anterior thoracic and form with it a loop in front of the first part of the axillary artery. *41*

The **medial anterior thoracic** (*fasciculus medialis*) *arises* from the medial cord of the plexus and through it from the eighth cervical and first thoracic. It passes behind the first part of the axillary artery, curves forward between the axillary artery and vein, and unites in front of the artery with a filament from the lateral nerve. It then enters the deep surface of the Pectoralis minor, where it divides into a number of branches, which supply the muscle. Two or three branches pierce the muscle and end in the Pectoralis major. *42*

The **Subscapular Nerves** (*nn. subscapulares*), two in number, spring from the posterior cord of the plexus and through it from the fifth and sixth cervical nerves. *43*

The **upper subscapular** (*short subscapular*), the smaller enters the upper part of the Subscapularis, and is frequently represented by two branches. *44*

The **lower subscapular** supplies the lower part of the Subscapularis, and ends in the Teres major; the latter muscle is sometimes supplied by a separate branch. *45*

The **Thoracodorsal Nerve** (*n. thoracodorsalis; middle or long subscapular nerve*), a branch of the posterior cord of the plexus, derives its fibers from the fifth, sixth, and seventh cervical nerves; it follows the course of the subscapular artery, along the posterior wall of the axilla to the Latissimus dorsi, in which it may be traced as far as the lower border of the muscle. *46*

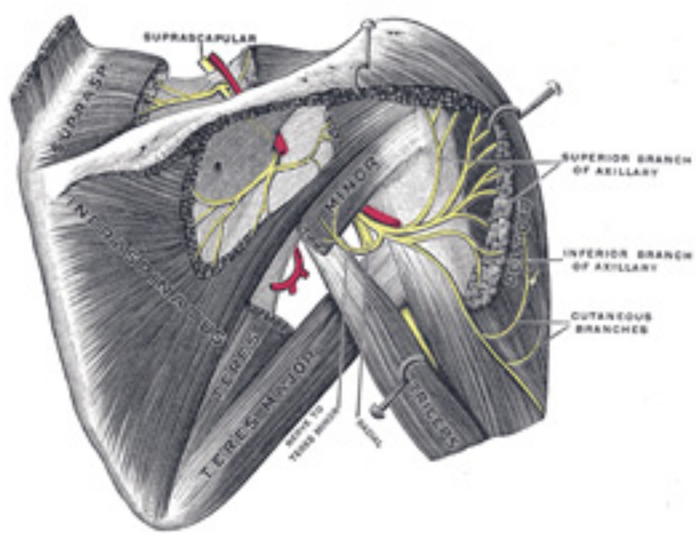


FIG. 810– Suprascapular and axillary nerves of right side, seen from behind. (Testut.) (See enlarged image)

47 The **Axillary Nerve** (*n. axillaris; circumflex nerve*) (Fig. 818) *arises* from the posterior cord of the brachial plexus, and its fibers are derived from the fifth and sixth cervical nerves. It lies at first behind the axillary artery, and in front of the Subscapularis, and passes downward to the lower border of that muscle. It then winds backward, in company with the posterior humeral circumflex artery, through a quadrilateral space bounded above by the Subscapularis, below by the Teres major, medially by the long head of the Triceps brachii, and laterally by the surgical neck of the humerus, and divides into an anterior and a posterior branch.

48 The **anterior branch** (*upper branch*) winds around the surgical neck of the humerus, beneath the Deltoideus, with the posterior humeral circumflex vessels, as far as the anterior border of that muscle, supplying it, and giving off a few small cutaneous branches, which pierce the muscle and ramify in the skin covering its lower part.

49 The **posterior branch** (*lower branch*) supplies the Teres minor and the posterior part of the Deltoideus; upon the branch to the Teres minor an oval enlargement (pseudoganglion) usually exists. The posterior branch then pierces the deep fascia and is continued as the**lateral brachial cutaneous nerve,** which sweeps around the posterior border of the Deltoideus and supplies the skin over the lower two-thirds of the posterior part of this muscle, as well as that covering the long head of the Triceps brachii (Figs 811, 813).

50 The trunk of the axillary nerve gives off an articular filament which enters the shoulder-joint below the Subscapularis.

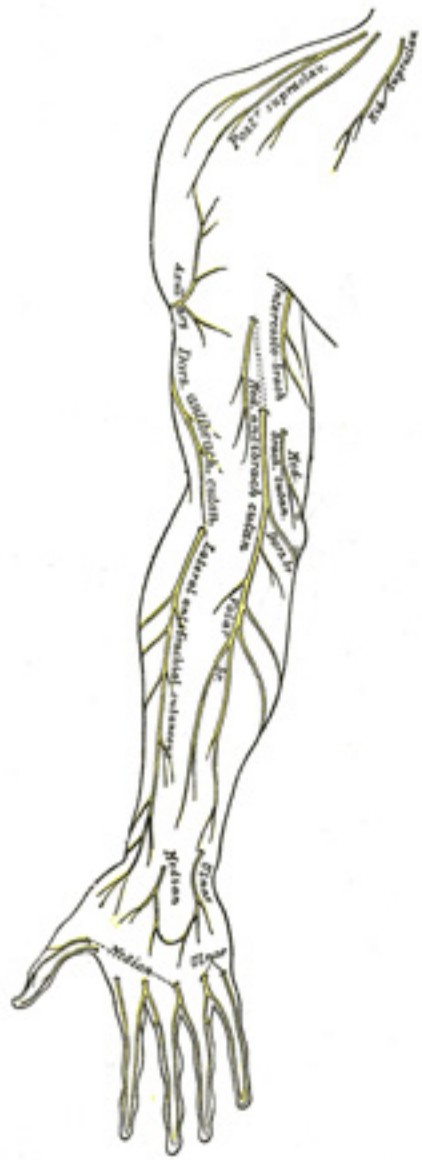

Post^r supraclav.
Mid. supraclav.
Intercosto-brach.
Dors. antibrach. cutan.
Lateral antibrachial cutaneous
Median
Ulnar

FIG. 811– Cutaneous nerves of right upper extremity. Anterior view. (See enlarged image)

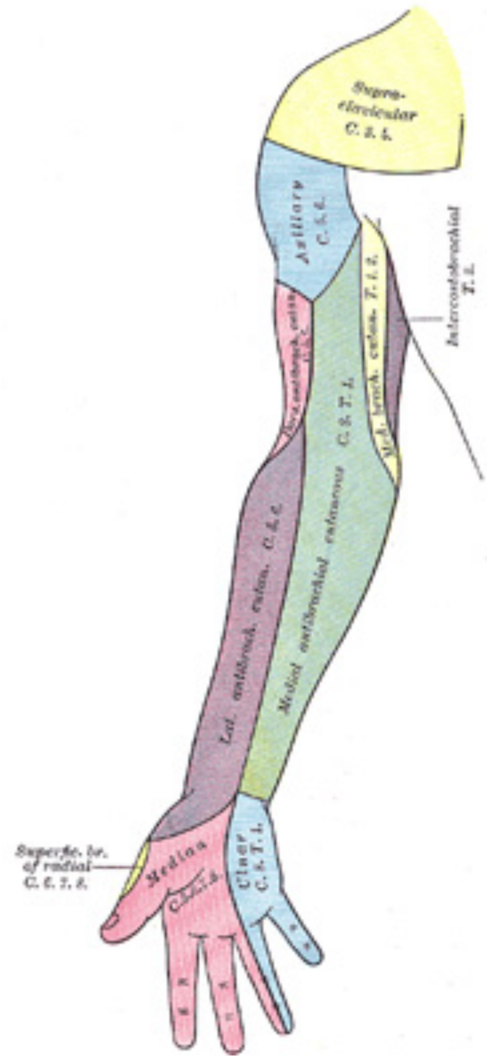
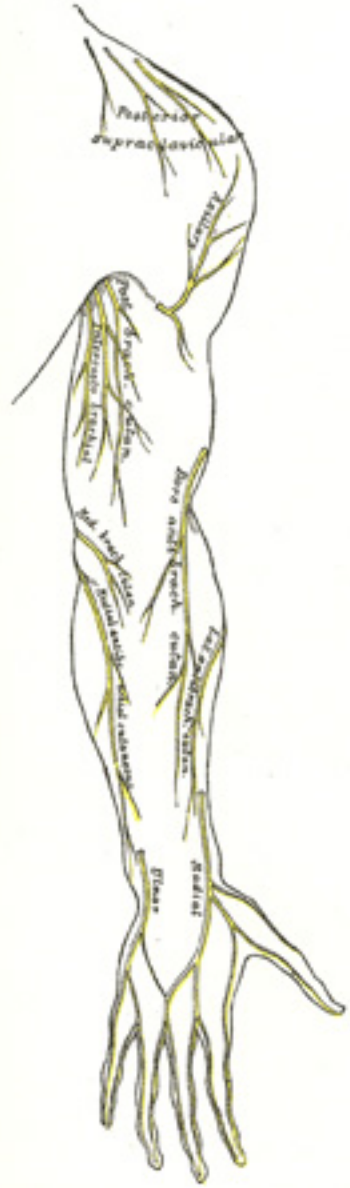


FIG. 812– Diagram of segmental distribution of the cutaneous nerves of the right upper extremity. Anterior view. (See enlarged image)

The **Musculocutaneous Nerve** (*n. musculocutaneus*) (Fig. 816) *arises* from the lateral cord of the brachial plexus, opposite the lower border of 51
the Pectoralis minor, its fibers being derived from the fifth, sixth, and seventh cervical nerves. It pierces the Coracobrachialis muscle and passes obliquely between the Biceps brachii and the Brachialis, to the lateral side of the arm; a little above the elbow it pierces the deep fascia lateral to the tendon of the Biceps brachii and is continued into the forearm as the **lateral antibrachial cutaneous nerve.** In its course through the arm it supplies the Coracobrachialis, Biceps brachii, and the greater part of the Brachialis. The branch to the Coracobrachialis is given off from the nerve close to its origin, and in some instances as a separate filament from the lateral cord of the plexus; it is derived from the seventh, cervical nerve. The branches to the Biceps brachii and Brachialis are given off after the musculocutaneous has pierced the Coracobrachialis; that supplying the Brachialis gives a filament to the elbow-joint. The nerve also sends a small branch to the bone, which enters the nutrient foramen with the accompanying artery.



Posterior
Supraclavicular
Ulnar
Radial

FIG. 813– Cutaneous nerves of right upper extremity. Posterior view. (See enlarged image)

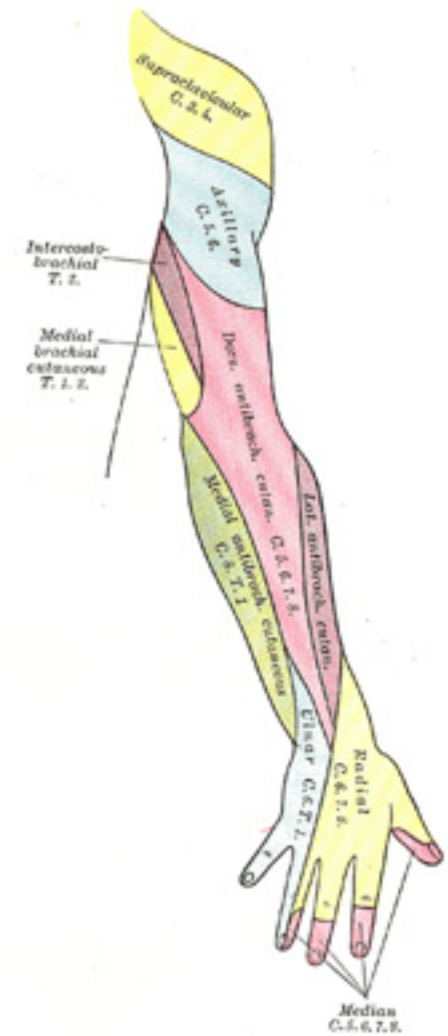


FIG. 814– Diagram of segmental distribution of the cutaneous nerves of the right upper extremity. Posterior view. (See enlarged image)

The **lateral antibrachial cutaneous nerve** (*n. cutaneus antibrachii cutaneous lateralis; branch of musculocutaneous nerve*) passes behind the cephalic vein, and divides, opposite the elbow-joint, into a volar and a dorsal branch (Figs. 811, 813). 52

The **volar branch** (*ramus volaris; anterior branch*) descends along the radial border of the forearm to the wrist, and supplies the skin over the lateral half of its volar surface. At the wrist-joint it is placed in front of the radial artery, and some filaments, piercing the deep fascia, accompany that vessel to the dorsal surface of the carpus. The nerve then passes downward to the ball of the thumb, where it ends in cutaneous filaments. It communicates with the superficial branch of the radial nerve, and with the palmar cutaneous branch of the median nerve. 53

The **dorsal branch** (*ramus dorsalis; posterior branch*) descends, along the dorsal surface of the radial side of the forearm to the wrist. It supplies the skin of the lower two-thirds of the dorso-lateral surface of the forearm, communicating with the superficial branch of the radial nerve and the dorsal antibrachial cutaneous branch of the radial. 54

The musculocutaneous nerve presents frequent irregularities. It may adhere for some distance to the median and then pass outward, beneath the Biceps brachii, instead of through the Coracobrachialis. Some of the fibers of the median may run for some distance in the musculocutaneous and then leave it to join their proper trunk; less frequently the reverse is the case, and the median sends a branch to join the musculocutaneous. The nerve may pass under the Coracobrachialis or through the Biceps brachii. Occasionally it gives a filament to the Pronator teres, and it supplies the dorsal surface of the thumb when the superficial branch of the radial nerve is absent. 55

The **Medial Antibrachial Cutaneous Nerve** (*n. cutaneus antibrachii medialis; internal cutaneous nerve*) (Fig. 816) *arises* from the medial cord of the brachial plexus. It derives its fibers from the eighth cervical and first thoracic nerves, and at its commencement is placed medial to the axillary artery. It gives off, near the axilla, a filament, which pierces the fascia and supplies the integument covering the Biceps brachii, nearly as far as the elbow. The nerve then runs down the ulnar side of the arm medial to the brachial artery, pierces the deep fascia with the basilic vein, about the middle of the arm, and divides into a volar and an ulnar branch. 56

The **volar branch** (*ramus volaris; anterior branch*), the larger, passes usually in front of, but occasionally behind, the vena mediana cubiti (*median basilic vein*). It then descends on the front of the ulnar side of the forearm, distributing filaments to the skin as far as the wrist, and communicating with the palmar cutaneous branch of the ulnar nerve (Fig. 811). 57

The **ulnar branch** (*ramus ulnaris; posterior branch*) passes obliquely downward on the medial side of the basilic vein, in front of the medial epicondyle of the humerus, to the back of the forearm, and descends on its ulnar side as far as the wrist, distributing filaments to the skin. It communicates with the medial brachial cutaneous, the dorsal antibrachial cutaneous branch of the radial, and the dorsal branch of the ulnar (Fig. 813). 58

The **Medial Brachial Cutaneous Nerve** (*n. cutaneus brachii medialis; lesser internal cutaneous nerve; nerve of Wrisberg*) is distributed to the skin on the ulnar side of the arm (Figs. 811, 813). It is the smallest branch of the brachial plexus, and *arising* from the medial cord receives its fibers from the eighth cervical and first thoracic nerves. It passes through the axilla, at first lying behind, and then medial to the axillary vein, and communicates with the intercostobrachial nerve. It descends along the medial side of the brachial artery to the middle of the arm, where it pierces the deep fascia, and is distributed to the skin of the back of the lower third of the arm, extending as far as the elbow, where some filaments are lost in the skin in front of the medial epicondyle, and others over the olecranon. It communicates with the ulnar branch of the medial antibrachial cutaneous nerve. 59

In some cases the medial brachial cutaneous and intercostobrachial are connected by two or three filaments, which form a plexus in the axilla. 60

In other cases the intercostobrachial is of large size, and takes the place of the medial brachial cutaneous, receiving merely a filament of communication from the brachial plexus, which represents the latter nerve; in a few cases, this filament is wanting.

The **Median Nerve** (*n. medianus*) (Fig. 816) extends along the middle of the arm and forearm to the hand. It *arises* by two roots, one from the lateral and one from the medial cord of the brachial plexus; these embrace the lower part of the axillary artery, uniting either in front of or lateral to that vessel. Its fibers are derived from the sixth, seventh, and eighth cervical and first thoracic nerves. As it descends through the arm, it lies at first lateral to the brachial artery; about the level of the insertion of the Coracobrachialis it crosses the artery, usually in front of, but occasionally behind it, and lies on its medial side at the bend of the elbow, where it is situated behind the lacertus fibrosus (*bicipital fascia*), and is separated from the elbow-joint by the Brachialis. **In the forearm** it passes between the two heads of the Pronator teres and crosses the ulnar artery, but is separated from this vessel by the deep head of the Pronator teres. It descends beneath the Flexor digitorum sublimis, lying on the Flexor digitorum profundus, to within 5 cm. of the transverse carpal ligament; here it becomes more superficial, and is situated between the tendons of the Flexor digitorum sublimis and Flexor carpi radialis. In this situation it lies behind, and rather to the radial side of, the tendon of the Palmaris longus, and is covered by the skin and fascia. It then passes behind the transverse carpal ligament into the palm of the hand. In its course through the forearm it is accompanied by the median artery, a branch of the volar interroseous artery. *61*

Branches.—With the exception of the nerve to the Pronator teres, which sometimes arises above the elbow-joint, the median nerve gives off no branches in the arm. As it passes in front of the elbow, it supplies one or two twigs to the joint. *62*

In the forearm its branches are: **muscular, volar interosseous,** and **palmar.** *63*

The **muscular branches** (*rami musculares*) are derived from the nerve near the elbow and supply all the superficial muscles on the front of the forearm, except the Flexor carpi ulnaris. *64*

The **volar interosseous nerve** (*n. interosseus [antibrachii] volaris; anterior interosseous nerve*) supplies the deep muscles on the front of the forearm, except the ulnar half of the Flexor digitorum profundus. It accompanies the volar interosseous artery along the front of the interosseous membrane, in the interval between the Flexor pollicis longus and Flexor digitorum profundus, supplying the whole of the former and the radial half of the latter, and ending below in the Pronator quadratus and wrist-joint. *65*

The **palmar branch** (*ramus cutaneus palmaris n. mediani*) of the median nerve *arises* at the lower part of the forearm. It pierces the volar carpal ligament, and divides into a lateral and a medial branch; the lateral branch supplies the skin over the ball of the thumb, and communicates with the volar branch of the lateral antibrachial cutaneous nerve; the medial branch supplies the skin of the palm and communicates with the palmar cutaneous branch of the ulnar. *66*

In the palm of the hand the median nerve is covered by the skin and the palmar aponeurosis, and rests on the tendons of the Flexor muscles. Immediately after emerging from under the transverse carpal ligament the nerve becomes enlarged and flattened and splits into a smaller, lateral, and a larger, medial portion. The **lateral portion** supplies a short, stout branch to certain of the muscles of the ball of the thumb, viz., the Abductor brevis, the Opponens, and the superficial head of the Flexor brevis, and then divides into three **proper volar digital nerves;** two of these supply the sides of the thumb, while the third gives a twig to the first Lumbricalis and is distributed to the radial side of the index finger. The **medial portion** of the nerve divides into two **common volar digital nerves.**The first of these gives a twig to the second Lumbricalis and runs toward the cleft between the index and middle fingers, where it divides into two proper digital nerves for the adjoining sides of these digits; the second runs toward the cleft between the middle and ring fingers, and splits into two proper digital nerves for the adjoining sides of these *67* digits; it communicates with a branch from the ulnar nerve and sometimes sends a twig to the third Lumbricalis.

Each proper digital nerve, opposite the base of the first phalanx, gives off a dorsal branch which joins the dorsal digital nerve from the 68
superficial branch of the radial nerve, and supplies the integument on the dorsal aspect of the last phalanx. At the end of the digit, the proper digital nerve divides into two branches, one of which supplies the pulp of the finger, the other ramifies around and beneath the nail. The proper digital nerves, as they run along the fingers, are placed superficial to the corresponding arteries.

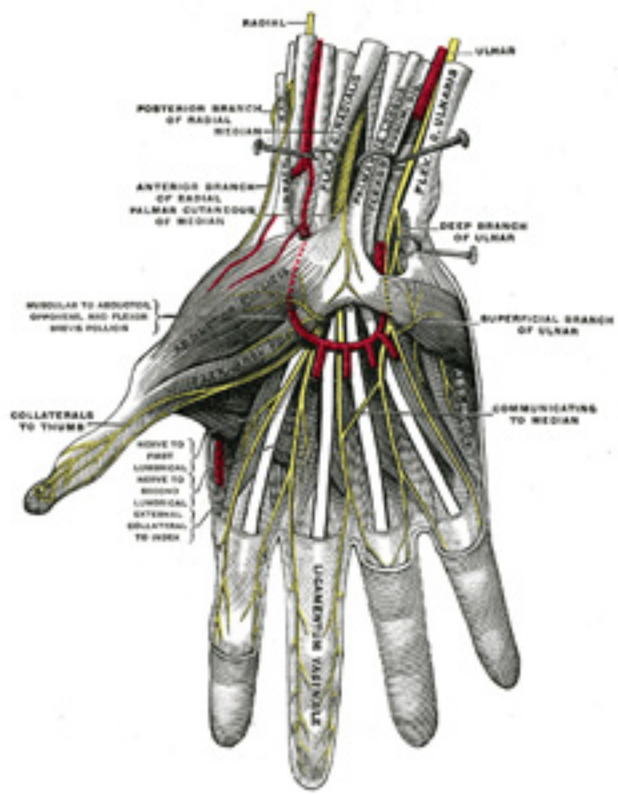
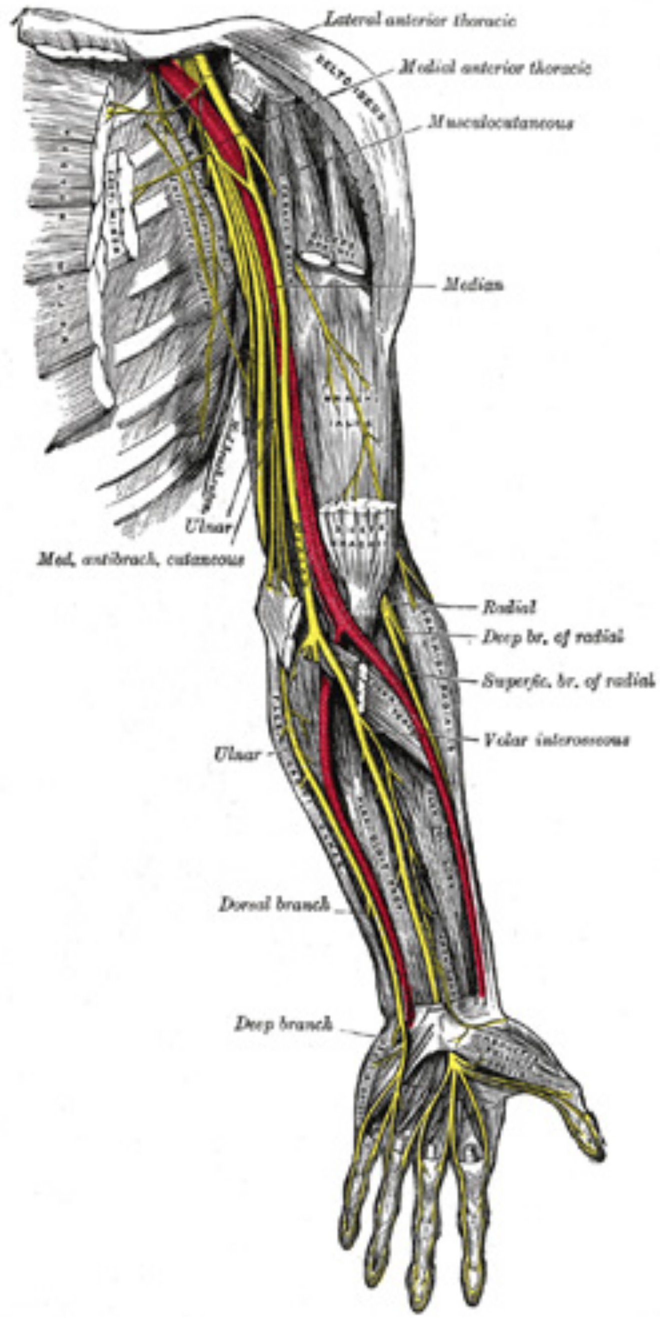


FIG. 815– Superficial palmar nerves. (Testut.) (See enlarged image)

The **Ulnar Nerve** (*n. ulnaris*) (Fig. 816) is placed along the medial side of the limb, and is distributed to the muscles and skin of the forearm 69 and hand. It *arises* from the medial cord of the brachial plexus, and derives its fibers from the eighth cervical and first thoracic nerves. It is smaller than the median, and lies at first behind it, but diverges from it in its course down the arm. At its origin it lies medial to the axillary artery, and bears the same relation to the brachial artery as far as the middle of the arm. Here it pierces the medial intermuscular septum, runs obliquely across the medial head of the Triceps brachii, and descends to the groove between the medial epicondyle and the olecranon, accompanied by the superior ulnar collateral artery. **At the elbow,** it rests upon the back of the medial epicondyle, and enters the forearm between the two heads of the Flexor carpi ulnaris. **In the forearm,** it descends along the ulnar side lying upon the Flexor digitorum profundus; its upper half is covered by the Flexor carpi ulnaris, its lower half lies on the lateral side of the muscle, covered by the integument and fascia. In the upper third of the forearm, it is separated from the ulnar artery by a considerable interval, but in the rest of its extent lies close to the medial side of the artery. About 5 cm. above the wrist it ends by dividing into a dorsal and a volar branch.



Lateral anterior thoracic
Medial anterior thoracic
Musculocutaneous
Median
Ulnar
Med. antibrach. cutaneous
Radial
Deep br. of radial
Superfic. br. of radial
Volar interosseous
Ulnar
Dorsal branch
Deep branch

FIG. 816– Nerves of the left upper extremity. (See enlarged image)

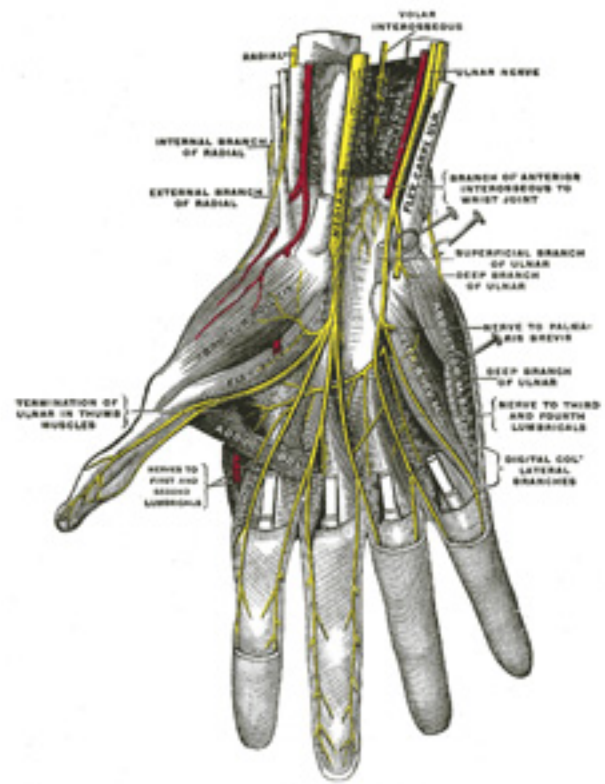


FIG. 817– Deep palmar nerves. (Testut.) (See enlarged image)

The branches of the ulnar nerve are: **articular** to the elbow-joint, **muscular, palmar cutaneous, dorsal,** and **volar.** *70*

The **articular branches** to the elbow-joint are several small filaments which *arise* from the nerve as it lies in the groove between the medial *71* epicondyle and olecranon.

The **muscular branches** (*rami musculares*) two in number, *arise* near the elbow: one supplies the Flexor carpi ulnaris; the other, the ulnar half of the Flexor digitorum profundus. 72

The **palmar cutaneous branch** (*ramus cutaneus palmaris*) *arises* about the middle of the forearm, and descends on the ulnar artery, giving off some filaments to the vessel. It perforates the volar carpal ligament and ends in the skin of the palm, communicating with the palmar branch of the median nerve. 73

The **dorsal branch** (*ramus dorsalis manus*) *arises* about 5 cm. above the wrist; it passes backward beneath the Flexor carpi ulnaris, perforates the deep fascia, and, running along the ulnar side of the back of the wrist and hand, divides into two dorsal digital branches; one supplies the ulnar side of the little finger; the other, the adjacent sides of the little and ring fingers. It also sends a twig to join that given by the superficial branch of the radial nerve for the adjoining sides of the middle and ring fingers, and assists in supplying them. A branch is distributed to the metacarpal region of the hand, communicating with a twig of the superficial branch of the radial nerve (Fig. 813). 74

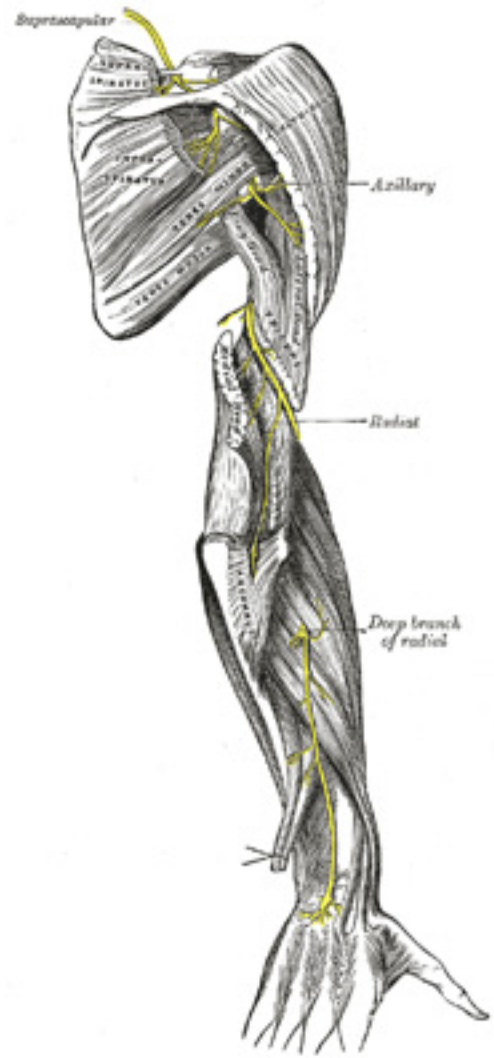


FIG. 818– The suprascapular, axillary, and radial nerves. (See enlarged image)

On the little finger the dorsal digital branches extend only as far as the base of the terminal phalanx, and on the ring finger as far as the base of the second phalanx; the more distal parts of these digits are supplied by dorsal branches derived from the proper volar digital branches of the ulnar nerve. *75*

The **volar branch** (*ramus volaris manus*) crosses the transverse carpal ligament on the lateral side of the pisiform bone, medial to and a little behind the ulnar artery. It ends by dividing into a superficial and a deep branch. *76*

The **superficial branch** (*ramus superficialis* [*n. ulnaris*] supplies the Palmaris brevis, and the skin on the ulnar side of the hand, and divides into a proper volar digital branch for the ulnar side of the little finger, and a common volar digital branch which gives a communicating twig to the median nerve and divides into two proper digital nerves for the adjoining sides of the little and ring fingers (Fig. 811). The proper digital branches are distributed to the fingers in the same manner as those of the median. *77*

The **deep branch** (*ramus profundus*) accompanied by the deep branch of the ulnar artery, passes between the Abductor digiti quinti and Flexor digiti quinti brevis; it then perforates the Opponens digiti quinti and follows the course of the deep volar arch beneath the Flexor tendons. At its origin it supplies the three short muscles of the little finger. As it crosses the deep part of the hand, it supplies all the Interossei and the third and fourth Lumbricales; it ends by supplying the Adductores pollicis and the medial head of the Flexor pollicis brevis. It also sends articular filaments to the wrist-joint. *78*

It has been pointed out that the ulnar part of the Flexor digitorum profundus is supplied by the ulnar nerve; the third and fourth Lumbricales, which are connected with the tendons of this part of the muscle, are supplied by the same nerve. In like manner the lateral part of the Flexor digitorum profundus and the first and second Lumbricales are supplied by the median nerve; the third Lumbricalis frequently receives an additional twig from the median nerve. *79*

The **Radial Nerve** (*n. radialis; musculospiral nerve*) (Fig. 818), the largest branch of the brachial plexus, is the continuation of the posterior cord of the plexus. Its fibres are derived from the fifth, sixth, seventh, and eighth cervical and first thoracic nerves. It descends behind the first part of the axillary artery and the upper part of the brachial artery, and in front of the tendons of the Latissimus dorsi and Teres major. It then winds around from the medial to the lateral side of the humerus in a groove with the a. profunda brachii, between the medial and lateral heads of the Triceps brachii. It pierces the lateral intermuscular septum, and passes between the Brachialis and Brachioradialis to the front of the lateral epicondyle, where it divides into a superficial and a deep branch. *80*

The **branches** of the musculospiral nerve are: *81*

Muscular.	Superficial.
Cutaneous.	Deep.

The **muscular branches** (*rami musculares*) supply the Triceps brachii, Anconæus, Brachioradialis, Extensor carpi radialis longus, and Brachialis, and are grouped as medial, posterior, and lateral. *82*

The medial muscular branches supply the medial and long heads of the Triceps brachii. That to the medial head is a long, slender filament, which lies close to the ulnar nerve as far as the lower third of the arm, and is therefore frequently spoken of as the **ulnar collateral nerve.** *83*

The posterior muscular branch, of large size, *arises* from the nerve in the groove between the Triceps brachii and the humerus. It divides into filaments, which supply the medial and lateral heads of the Triceps brachii and the Anconæus muscles. The branch for the latter muscle is a long, *84* slender filament, which descends in the substance of the medial head of the Triceps brachii.

The lateral muscular branches supply the Brachioradialis, Extensor carpi radialis longus, and the lateral part of the Brachialis. 85

The **cutaneous branches** are two in number, the posterior brachial cutaneous and the dorsal antibrachial cutaneous. 86

The **posterior brachial cutaneous nerve** (*n. cutaneus brachii posterior; internal cutaneous branch of musculospiral*) *arises* in the axilla, with the medial muscular branch. It is of small size, and passes through the axilla to the medial side of the area supplying the skin on its dorsal surface nearly as far as the olecranon. In its course it crosses behind, and communicates with, the intercostobrachial. 87

The **dorsal antibrachial cutaneous nerve** (*n. cutaneus antibrachii dorsalis; external cutaneous branch of musculospiral*) *perforates* the lateral head of the Triceps brachii at its attachment to the humerus. The **upper** and smaller branch of the nerve passes to the front of the elbow, lying close to the cephalic vein, and supplies the skin of the lower half of the arm (Fig. 811). The **lower** branch pierces the deep fascia below the insertion of the Deltoideus, and descends along the lateral side of the arm and elbow, and then along the back of the forearm to the wrist, supplying the skin in its course, and joining, near its termination, with the dorsal branch of the lateral antibrachial cutaneous nerve (Fig. 813). 88

The **Superficial Branch of the Radial Nerve** (*ramus superficialis radial nerve*) passes along the front of the radial side of the forearm to the commencement of its lower third. It lies at first slightly lateral to the radial artery, concealed beneath the Brachioradialis. In the middle third of the forearm, it lies behind the same muscle, close to the lateral side of the artery. It quits the artery about 7 cm. above the wrist, passes beneath the tendon of the Brachioradialis, and, piercing the deep fascia, divides into two branches (Fig. 813). 89

The lateral branch, the smaller, supplies the skin of the radial side and ball of the thumb, joining with the volar branch of the lateral antibrachial cutaneous nerve. 90

The medial branch communicates, above the wrist, with the dorsal branch of the lateral antibrachial cutaneous, and, on the back of the hand, with the dorsal branch of the ulnar nerve. It then divides into four digital nerves, which are distributed as follows: the first supplies the ulnar side of the thumb; the second, the radial side of the index finger; the third, the adjoining sides of the index and middle fingers; the fourth communicates with a filament from the dorsal branch of the ulnar nerve, and supplies the adjacent sides of the middle and ring fingers. 134 91

The **Deep Branch of the Radial Nerve** (*n. interosseus dorsalis; dorsal or posterior interosseous nerve*) winds to the back of the forearm around the lateral side of the radius between the two planes of fibers of the Supinator, and is prolonged downward between the superficial and deep layers of muscles, to the middle of the forearm. Considerably diminished in size, it descends, as the **dorsal interosseous nerve,** on the interosseous membrane, in front of the Extensor pollicis longus, to the back of the carpus, where it presents a gangliform enlargement from which filaments are distributed to the ligaments and articulations of the carpus. It supplies all the muscles on the radial side and dorsal surface of the forearm, excepting the Anconæus, Brachioradialis, and Extenosr carpi radialis longus. 92

Note 133. The posterior division of the lower trunk is very much smaller than the others, and is frequently derived entirely from the eighth cervical nerve. [back]

Note 134. According to Hutchison, the digital nerve to the thumb reaches only as high as the root of the nail; the one to the forefinger as high as the middle of the second phalanx; and the one to the middle and ring fingers not higher than the first phalangeal joint.—London Hosp. Gaz., iii, 319. [back]

6c. The Thoracic Nerves

(NN. Thoracales) *1*

The **anterior divisions of the thoracic nerves** (*rami anteriores; ventral divisions*) are twelve in number on either side. Eleven of them are situated between the ribs, and are therefore termed **intercostal;** the twelfth lies below the last rib. Each nerve is connected with the adjoining ganglion of the sympathetic trunk by a gray and a white ramus communicans. The intercostal nerves are distributed chiefly to the parietes of the thorax and abdomen, and differ from the anterior divisions of the other spinal nerves, in that each pursues an independent course, *i. e.,* there is no plexus formation. The first two nerves supply fibers to the upper limb in addition to their thoracic branches; the next four are limited in their distribution to the parietes of the thorax; the lower five supply the parietes of the thorax and abdomen. The twelfth thoracic is distributed to the abdominal wall and the skin of the buttock.

The First Thoracic Nerve.—The anterior division of the first thoracic nerve divides into two branches: one, the larger, leaves the thorax in front *2*
of the neck of the first rib, and enters the brachial plexus; the other and smaller branch, the **first intercostal nerve,** runs along the first intercostal space, and ends on the front of the chest as the first anterior cutaneous branch of the thorax. Occasionally this anterior cutaneous branch is wanting. The first intercostal nerve as a rule gives off no lateral cutaneous branch; but sometimes it sends a small branch to communicate with the intercostobrachial. From the second thoracic nerve it frequently receives a connecting twig, which ascends over the neck of the second rib.

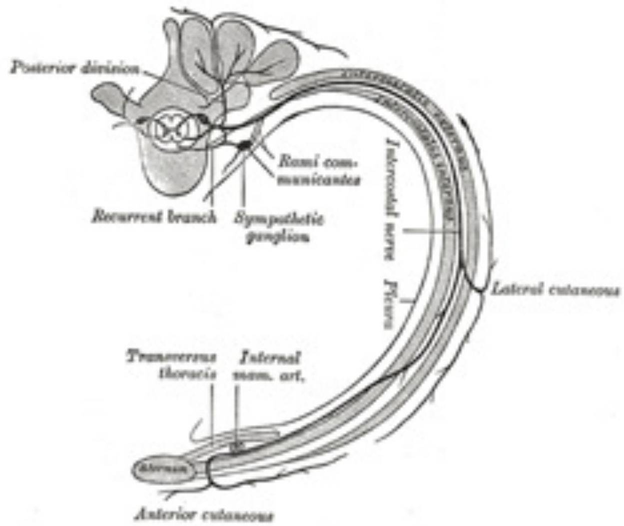


FIG. 819– Diagram of the course and branches of a typica intercostal nerve. (See enlarged image)

The Upper Thoracic Nerves (*nn. intercostales*).—The anterior divisions of the second, third, fourth, fifth, and sixth thoracic nerves, and the small branch from the first thoracic, are confined to the parietes of the thorax, and are named **thoracic intercostal nerves.** They pass forward (Fig. 819) in the intercostal spaces below the intercostal vessels. At the back of the chest they lie between the pleura and the posterior intercostal membranes, but soon pierce the latter and run between the two planes of Intercostal muscles as far as the middle of the rib. They then enter the substance of the Intercostales interni, and, running amidst their fibers as far as the costal cartilages, they gain the inner surfaces of the muscles and lie between them and the pleura. Near the sternum, they cross in front of the internal mammary artery and Transversus thoracis muscle, pierce the Intercostales interni, the anterior intercostal membranes, and Pectoralis major, and supply the integument of the front of the thorax and over the mamma, forming the anterior cutaneous branches of the thorax; the branch from the second nerve unites with the anterior supraclavicular nerves of the cervical plexus. 3

Branches.—Numerous slender muscular filaments supply the Intercostales, the Subcostales, the Levatores costarum, the Serratus posterior superior, and the Transversus thoracis. At the front of the thorax some of these branches cross the costal cartilages from one intercostal space to another. 4

Lateral cutaneous branches (*rami cutanei laterales*) are derived from the intercostal nerves, about midway between the vertebræ and sternum; 5

they pierce the Intercostalesexterni and Serratus anterior, and divide into anterior and posterior branches. The **anterior branches** run forward to the side and the forepart of the chest, supplying the skin and the mamma; those of the fifth and sixth nerves supply the upper digitations of the Obliquus externus abdominis. The **posterior branches** run backward, and supply the skin over the scapula and Latissimus dorsi.

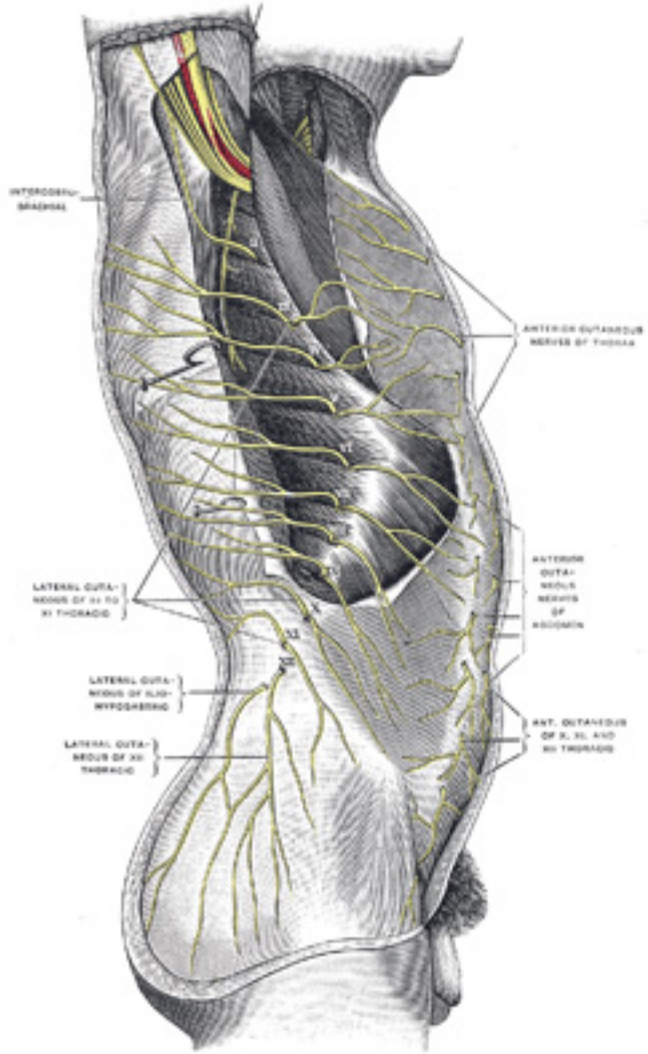


FIG. 820– Cutaneous distribution of thoracic nerves. (Testut.) (See enlarged image)

The lateral cutaneous branch of the second intercostal nerve does not divide, like the others, into an anterior and a posterior branch; it is named 6
the **intercostobrachial nerve**(Fig. 816). It pierces the Intercostalis externus and the Serratus anterior, crosses the axilla to the medial side of the arm, and joins with a filament from the medial brachial cutaneous nerve. It then pierces the fascia, and supplies the skin of the upper half of the medial and posterior part of the arm, communicating with the posterior brachial cutaneous branch of the radial nerve. The size of the intercostobrachial nerve is in inverse proportion to that of the medial brachial cutaneous nerve. A second intercostobrachial nerve is frequently given off from the lateral cutaneous branch of the third intercostal; it supplies filaments to the axilla and medial side of the arm.

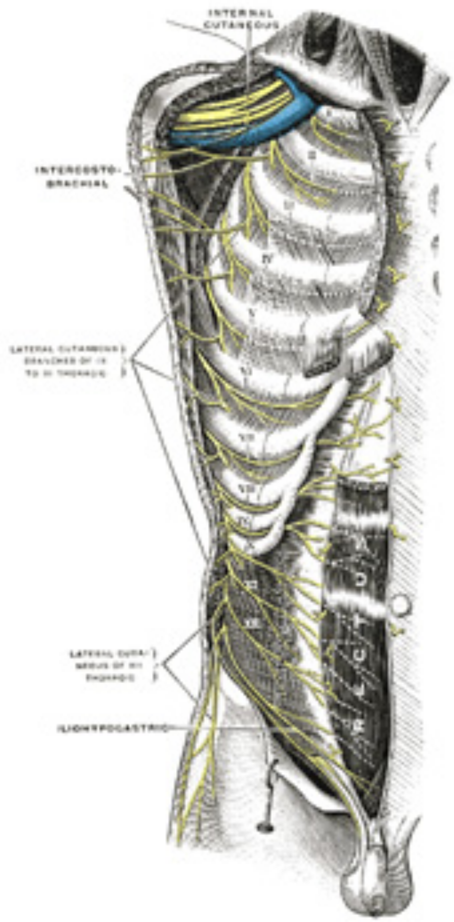


FIG. 821– Intercostal nerves, the superficial muscles having been removed. (Testut). (See enlarged image)

The Lower Thoracic Nerves.—The anterior divisions of the seventh, eighth, ninth, tenth, and eleventh thoracic nerves are continued anteriorly 7
from the intercostal spaces into the abdominal wall; hence they are named **thoracicoabdominal intercostal nerves.** They have the same

arrangement as the upper ones as far as the anterior ends of the intercostal spaces, where they pass behind the costal cartilages, and between the Obliquus internus and Transversus abdominis, to the sheath of the Rectus abdominis, which they perforate. They supply the Rectus abdominis and end as the **anterior cutaneous branches** of the abdomen; they supply the skin of the front of the abdomen. The lower intercostal nerves supply the Intercostales and abdominal muscles; the last three send branches to the Serratus posterior inferior. About the middle of their course they give off **lateral cutaneous branches.** These pierce the Intercostales externi and the Obliquus externus abdominis, in the same line as the lateral cutaneous branches of the upper thoracic nerves, and divide into anterior and posterior branches, which are distributed to the skin of the abdomen and back; the anterior branches supply the digitations of the Obliquus externus abdominis, and extend downward and forward nearly as far as the margin of the Rectus abdominis; the posterior branches pass backward to supply the skin over the Latissimus dorsi.

The anterior division of the **twelfth thoracic nerve** is larger than the others; it runs along the lower border of the twelfth rib, often gives a communicating branch to the first lumbar nerve, and passes under the lateral lumbocostal arch. It then runs in front of the Quadratus lumborum, perforates the Transversus, and passes forward between it and the Obliquus internus to be distributed in the same manner as the lower intercostal nerves. It communicates with the iliohypogastric nerve of the lumbar plexus, and gives a branch to the Pyramidalis. The **lateral cutaneous branch** of the last thoracic nerve is large, and does not divide into an anterior and a posterior branch. It perforates the Obliqui internus and externus, descends over the iliac crest in front of the lateral cutaneous branch of the iliohypogastric (Fig. 819), and is distributed to the skin of the front part of the gluteal region, some of its filaments extending as low as the greater trochanter.

6d. The Lumbosacral Plexus

(Plexus Lumbosacralis) 1

The anterior divisions of the lumbar, sacral, and coccygeal nerves form the lumbosacral plexus, the first lumbar nerve being frequently joined by a branch from the twelfth thoracic. For descriptive purposes this plexus is usually divided into three parts—the **lumbar, sacral,** and **pudendal plexuses.**

The Lumbar Nerves (Nn. Lumbales)

The **anterior divisions of the lumbar nerves** (*rami anteriores*) increase in size from above downward. They are joined, near their origins, 2
by *gray rami communicantes* from the lumbar ganglia of the sympathetic trunk. These rami consist of long, slender branches which accompany the lumbar arteries around the sides of the vertebral bodies, beneath the Psoas major. Their arrangement is somewhat irregular: one ganglion may give rami to two lumbar nerves, or one lumbar nerve may receive rami from two ganglia. The first and second, and sometimes the third and fourth lumbar nerves are each connected with the lumbar part of the sympathetic trunk by a *white ramus communicans*.

The nerves pass obliquely outward behind the Psoas major, or between its fasciculi, distributing filaments to it and the Quadratus lumborum. 3
The first three and the greater part of the fourth are connected together in this situation by anastomotic loops, and form the**lumbar plexus.** The smaller part of the fourth joins with the fifth to form the **lumbosacral trunk,** which assists in the formation of the sacral plexus. The fourth nerve is named the**nervus furcalis,** from the fact that it is subdivided between the two plexuses. 135

The Lumbar Plexus 136 (***plexus lumbalis***) (**Figs. 822, 823, 824**).—The lumbar plexus is formed by the loops of communication between the anterior divisions of the first three and the greater part of the fourth lumbar nerves; the first lumbar often receives a branch from the last thoracic nerve. It is situated in the posterior part of the Psoas major, in front of the transverse processes of the lumbar vertebræ. *4*

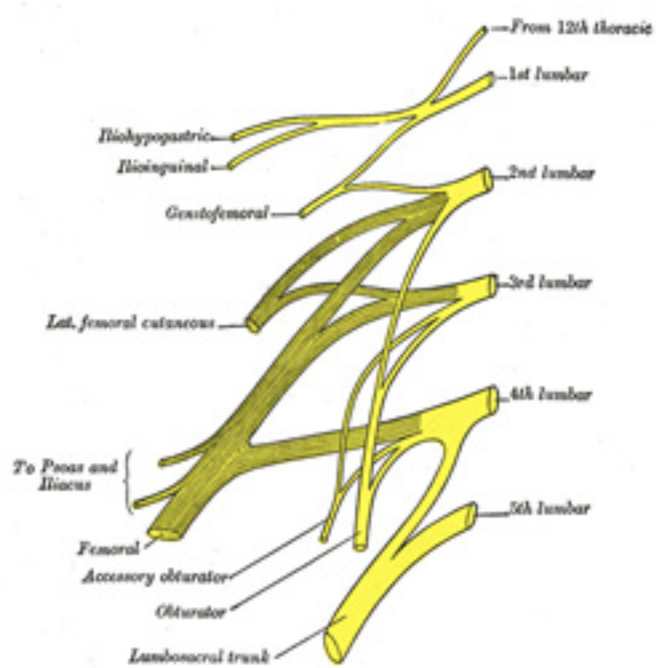


FIG. 822– Plan of lumbar plexus. (See enlarged image)

The mode in which the plexus is arranged varies in different subjects. It differs from the brachial plexus in not forming an intricate interlacement, but the several nerves of distribution *arise* from one or more of the spinal nerves, in the following manner: the first lumbar nerve, frequently supplemented by a twig from the last thoracic, splits into an upper and lower branch; the upper and larger branch divides into the iliohypogastric and ilioinguinal nerves; the lower and smaller branch unites with a branch of the second lumbar to form the genitofemoral nerve. The remainder of the second nerve, and the third and fourth nerves, divide into ventral and dorsal divisions. The ventral division of the second unites with the ventral divisions of the third and fourth nerves to form the obturator nerve. The dorsal divisions of the second and third nerves divide into two branches, a smaller branch from each uniting to form the lateral femoral cutaneous nerve, and a larger branch from each joining *5* with the dorsal division of the fourth nerve to form the femoral nerve. The accessory obturator, when it exists, is formed by the union of two small branches given off from the third and fourth nerves.

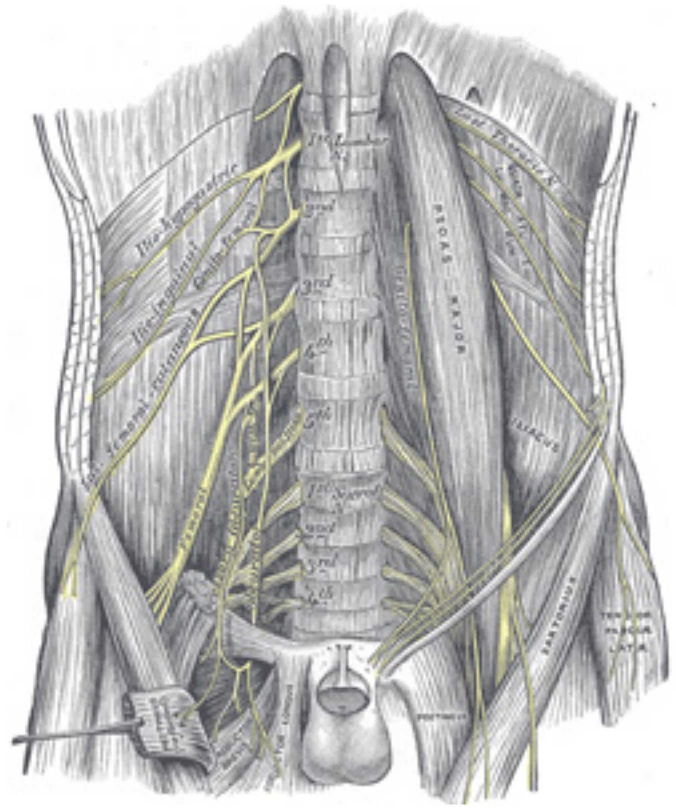


FIG. 823– The lumbar plexus and its branches. (See enlarged image)

The **branches** of the lumbar plexus may therefore be arranged as follows: *6*

Iliohypogastric	1 L.
Ilioinguinal	1 L.

Genitofemoral	1, 2 L.
	Dorsal divisions.
Lateral femoral cutaneous	2, 3 L.
Femoral	2, 3, 4 L.
	Ventral divisions.
Obturator	2, 3, 4 L.
Accessory obturator	3, 4 L.

The **Iliohypogastric Nerve** (*n. iliohypogastricus*) *arises* from the first lumbar nerve. It emerges from the upper part of the lateral border of the Psoas major, and crosses obliquely in front of the Quadratus lumborum to the iliac crest. It then perforates the posterior part of the Transversus abdominis, near the crest of the ilium, and divides between that muscle and the Obliquus internus abdominis into a **lateral** and an **anterior cutaneous branch.** *7*

The **lateral cutaneous branch** (*ramus cutaneus lateralis; iliac branch*) pierces the Obliqui internus and externus immediately above the iliac crest, and is distributed to the skin of the gluteal region, behind the lateral cutaneous branch of the last thoracic nerve(Fig. 830); the size of this branch bears an inverse proportion to that of the lateral cutaneous branch of the last thoracic nerve. *8*

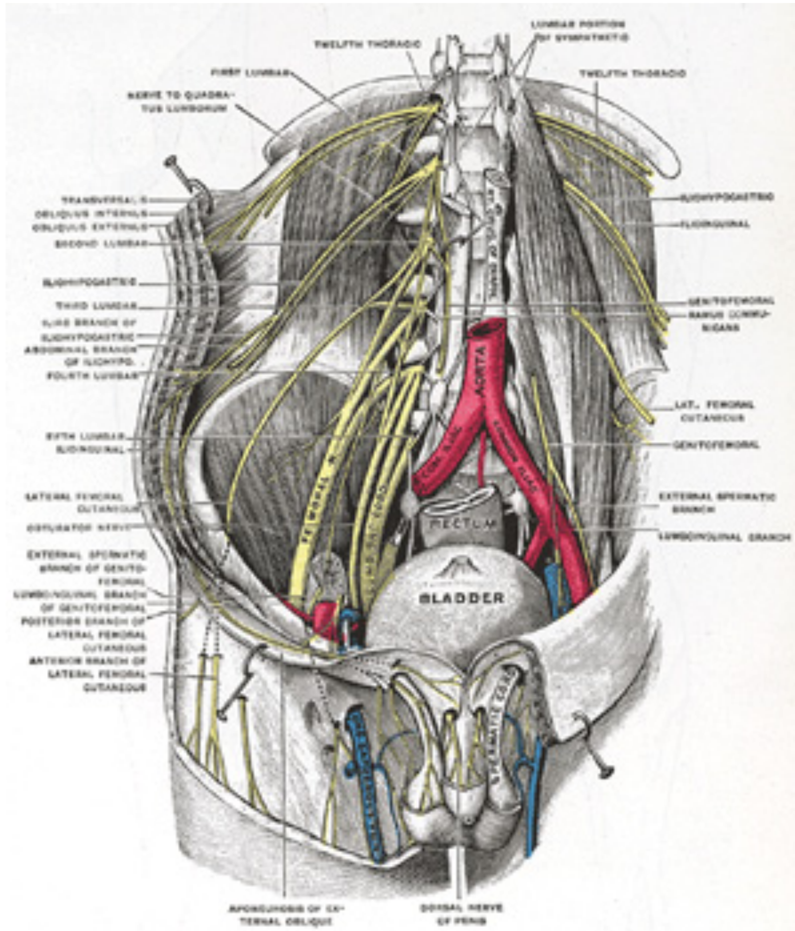


FIG. 824– Deep and superficial dissection of the lumbar plexus. (Testut.) (See enlarged image)

The **anterior cutaneous branch** (*ramus cutaneus anterior; hypogastric branch*) (Fig. 825) continues onward between the Obliquus internus and Transversus. It then pierces the Obliquus internus, becomes cutaneous by perforating the aponeurosis of the Obliquus externus about 2.5 cm. above the subcutaneous inguinal ring, and is distributed to the skin of the hypogastric region. *9*

The iliohypogastric nerve communicates with the last thoracic and ilioinguinal nerves. *10*

The **Ilioinguinal Nerve** (*n. ilioinguinalis*), smaller than the preceding, *arises* with it from the first lumbar nerve. It emerges from the lateral *11*
border of the Psoas major just below the iliohypogastric, and, passing obliquely across the Quadratus lumborum and Iliacus, perforates the Transversus abdominis, near the anterior part of the iliac crest, and communicates with the iliohypogastric nerve between the Transversus and the Obliquus internus. The nerve then pierces the Obliquus internus, distributing filaments to it, and, accompanying the spermatic cord through the subcutaneous inguinal ring, is distributed to the skin of the upper and medial part of the thigh, to the skin over the root of the penis and upper part of the scrotum in the male, and to the skin covering the mons pubis and labium majus in the female. The size of this nerve is in inverse proportion to that of the iliohypogastric. Occasionally it is very small, and ends by joining the iliohypogastric; in such cases, a branch from the iliohypogastric takes the place of the ilioinguinal, or the latter nerve may be altogether absent.


Sural
Deep peroneal

FIG. 825– Cutaneous nerves of right lower extremity. Front view. (See enlarged image)

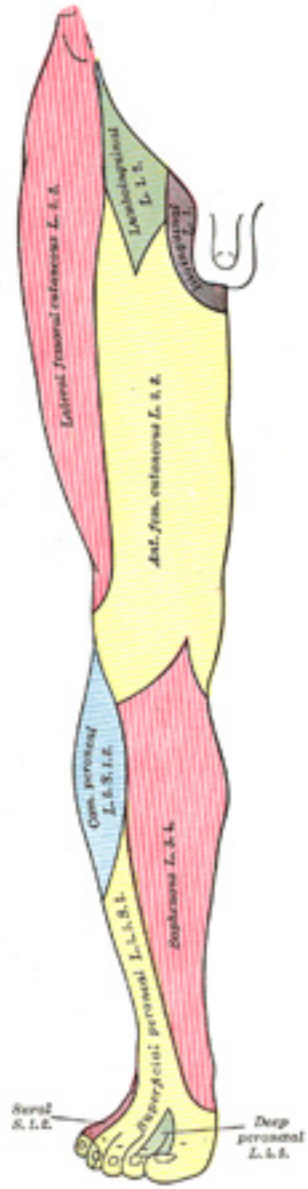

Lateral femoral cutaneous L. 2. 3.
Lumboinguinal L. 1. 2.
Ant. fem. cutaneous L. 2. 3.
Com. peroneal L. 4. 5. S. 1. 2.
Saphenous L. 3. 4.
Superficial peroneal L. 4. 5. S. 1.
Sural S. 1. 2.
Deep peroneal L. 4. 5.

FIG. 826– Diagram of segmental distribution of the cutaneous nerves of the right lower extremity. Front view. (See enlarged image)

The **Genitofemoral Nerve** (*n. genitofemoralis; genitocrural nerve*) *arises* from the first and second lumbar nerves. It passes obliquely through 12
the substance of the Psoas major, and emerges from its medial border, close to the vertebral column, opposite the fibrocartilage between the third
and fourth lumbar vertebræ; it then descends on the surface of the Psoas major, under cover of the peritoneum, and divides into the external
spermatic and lumboinguinal nerves. Occasionally these two nerves emerge separately through the substance of the Psoas.

The **external spermatic nerve** (*n. spermaticus externus; genital branch of genitofemoral*) passes outward on the Psoas major, and pierces the 13
fascia transversalis, or passes through the abdominal inguinal ring; it then descends behind the spermatic cord to the scrotum, supplies the
Cremaster, and gives a few filaments to the skin of the scrotum. In the female, it accompanies the round ligament of the uterus, and is lost upon
it.

The **lumboinguinal nerve** (*n. lumboinguinalis; femoral or crural branch of genitofemoral*) descends on the external iliac artery, sending a few 14
filaments around it, and, passing beneath the inguinal ligament, enters the sheath of the femoral vessels, lying superficial and lateral to the
femoral artery. It pierces the anterior layer of the sheath of the vessels and the fascia lata, and supplies the skin of the anterior surface of the
upper part of the thigh (Fig. 825). On the front of the thigh it communicates with the anterior cutaneous branches of the femoral nerve. A few
filaments from the lumboinguinal nerve may be traced to the femoral artery.

The **Lateral Femoral Cutaneous Nerve** (*n. cutaneus femoralis lateralis; external cutaneous nerve*) *arises* from the dorsal divisions of the 15
second and third lumbar nerves. It emerges from the lateral border of the Psoas major about its middle, and crosses the Iliacus obliquely, toward
the anterior superior iliac spine. It then passes under the inguinal ligament and over the Sartorius muscle into the thigh, where it divides into two
branches, and**anterior** and a **posterior** (Fig. 825).

The **anterior branch** becomes superficial about 10 cm. below the inguinal ligament, and divides into branches which are distributed to the skin 16
of the anterior and lateral parts of the thigh, as far as the knee. The terminal filaments of this nerve frequently communicate with the anterior
cutaneous branches of the femoral nerve, and with the infrapatellar branch of the saphenous nerve, forming with them the **patellar plexus.**

The **posterior branch** pierces the fascia lata, and subdivides into filaments which pass backward across the lateral and posterior surfaces of the 17
thigh, supplying the skin from the level of the greater trochanter to the middle of the thigh.

The **Obturator Nerve** (*n. obturatorius*) *arises* from the ventral divisions of the second, third, and fourth lumbar nerves; the branch from the 18
third is the largest, while that from the second is often very small. It descends through the fibers of the Psoas major, and emerges from its medial
border near the brim of the pelvis; it then passes behind the common iliac vessels, and on the lateral side of the hypogastric vessels and ureter,
which separate it from the ureter, and runs along the lateral wall of the lesser pelvis, above and in front of the obturator vessels, to the upper part
of the obturator foramen. Here it enters the thigh, and divides into an anterior and a posterior branch, which are separated at first by some of the
fibers of the Obturator externus, and lower down by the Adductor brevis.

The **anterior branch** (*ramus anterior*) (Fig. 827) leaves the pelvis in front of the Obturator externus and descends in front of the Adductor 19
brevis, and behind the Pectineus and Adductor longus; at the lower border of the latter muscle it communicates with the anterior cutaneous and
saphenous branches of the femoral nerve, forming a kind of plexus. It then descends upon the femoral artery, to which it is finally distributed.
Near the obturator foramen the nerve gives off an articular branch to the hipjoint. Behind the Pectineus, it distributes branches to the Adductor

longus and Gracilis, and usually to the Adductor brevis, and in rare cases to the Pectineus; it receives a communicating branch from the accessory obturator nerve when that nerve is present.

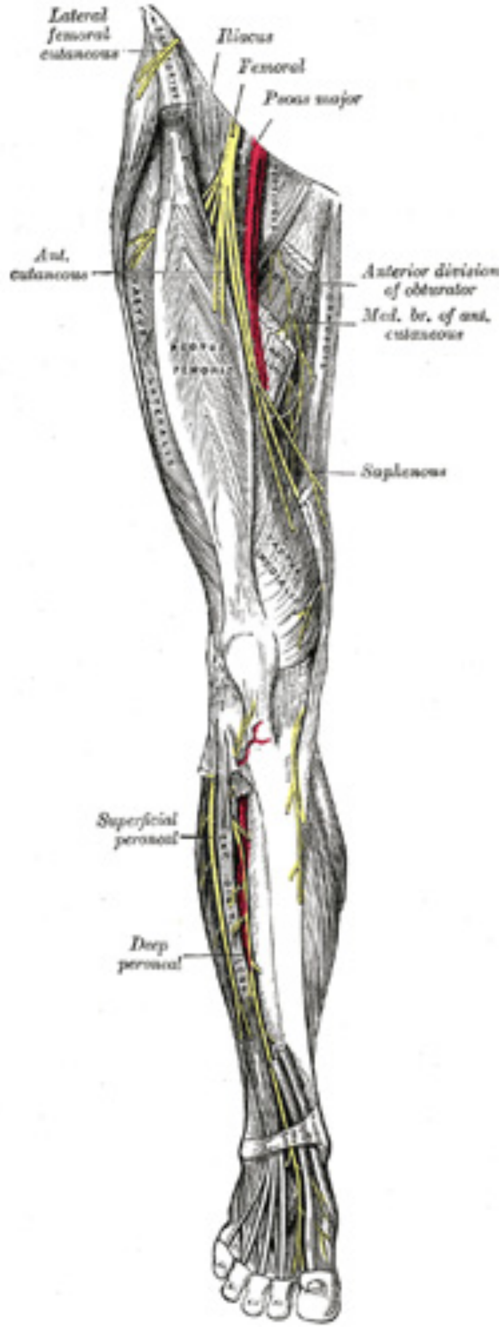

Lateral femoral cutaneous
Iliacus
Femoral
Psoas major
Ant. cutaneous
Anterior division of obturator
Med. br. of ant. cutaneous
Saphenous
Superficial peroneal
Deep peroneal

FIG. 827– Nerves of the right lower extremity. Front view. (See enlarged image)

Occasionally the communicating branch to the anterior cutaneous and saphenous branches of the femoral is continued down, as a cutaneous 20 branch, to the thigh and leg. When this is so, it emerges from beneath the lower border of the Adductor longus, descends along the posterior margin of the Sartorius to the medial side of the knee, where it pierces the deep fascia, communicates with the saphenous nerve, and is distributed to the skin of the tibial side of the leg as low down as its middle.

The **posterior branch** (*ramus posterior*) pierces the anterior part of the Obturator externus, and supplies this muscle; it then passes behind the 21 Adductor brevis on the front of the Adductor magnus, where it divides into numerous muscular branches which are distributed to the Adductor magnus and the Adductor brevis when the latter does not receive a branch from the anterior division of the nerve. It usually gives off an articular filament to the knee-joint.

The **articular branch for the knee-joint** is sometimes absent; it either perforates the lower part of the Adductor magnus, or passes through the 22 opening which transmits the femoral artery, and enters the popliteal fossa; it then descends upon the popliteal artery, as far as the back part of the knee-joint, where it perforates the oblique popliteal ligament, and is distributed to the synovial membrane. It gives filaments to the popliteal artery.

The **Accessory Obturator Nerve** (*n. obturatorius accessorius*) (Fig. 823) is present in about 29 per cent. of cases. It is of small size, 23 and *arises* from the ventral divisions of the third and fourth lumbar nerves. It descends along the medial border of the Psoas major, crosses the superior ramus of the pubis, and passes under the Pectineus, where it divides into numerous branches. One of these supplies the Pectineus, penetrating its deep surface, another is distributed to the hip-joint; while a third communicates with the anterior branch of the obturator nerve. Occasionally the accessory obturator nerve is very small and is lost in the capsule of the hip-joint. When it is absent, the hip-joint receives two branches from the obturator nerve.

The **Femoral Nerve** (*n. femoralis; anterior crural nerve*) (Fig. 827), the largest branch of the lumbar plexus, *arises* from the dorsal divisions of 24 the second, third, and fourth lumbar nerves. It descends through the fibers of the Psoas major, emerging from the muscle at the lower part of its lateral border, and passes down between it and the Iliacus, behind the iliac fascia; it then runs beneath the inguinal ligament, into the thigh, and splits into an anterior and a posterior division. Under the inguinal ligament, it is separated from the femoral artery by a portion of the Psoas major.

Within the abdomen the femoral nerve gives off small branches to the Iliacus, and a branch which is distributed upon the upper part of the 25 femoral artery; the latter branch may arise in the thigh.

In the thigh the anterior division of the femoral nerve gives off anterior cutaneous and muscular branches. The anterior cutaneous branches 26 comprise the intermediate and medial cutaneous nerves (Fig. 825).

The **intermediate cutaneous nerve** (*ramus cutaneus anterior; middle cutaneous nerve*) pierces the fascia lata (and generally the Sartorius) 27 about 7.5 cm. below the inguinal ligament, and divides into two branches which descend in immediate proximity along the forepart of the thigh, to supply the skin as low as the front of the knee. Here they communicate with the medial cutaneous nerve and the infrapatellar branch of the saphenous, to form the patellar plexus. In the upper part of the thigh the lateral branch of the intermediate cutaneous communicates with the lumboinguinal branch of the genitofemoral nerve.

The **medial cutaneous nerve** (*ramus cutaneus anterior; internal cutaneous nerve*) passes obliquely across the upper part of the sheath of the femoral artery, and divides in front, or at the medial side of that vessel, into two branches, an anterior and a posterior. The **anterior branch** runs downward on the Sartorius, perforates the fascia lata at the lower third of the thigh, and divides into two branches: one supplies the integument as low down as the medial side of the knee; the other crosses to the lateral side of the patella, communicating in its course with the infrapatellar branch of the saphenous nerve. The **posterior branch**descends along the medial border of the Sartorius muscle to the knee, where it pierces the fascia lata, communicates with the saphenous nerve, and gives off several cutaneous branches. It then passes down to supply the integument of the medial side of the leg. Beneath the fascia lata, at the lower border of the Adductor longus, it joins to form a plexiform net-work (**subsartorial plexus**) with branches of the saphenous and obturator nerves. When the communicating branch from the obturator nerve is large and continued to the integument of the leg, the posterior branch of the medial cutaneous is small, and terminates in the plexus, occasionally giving off a few cutaneous filaments. The medial cutaneous nerve, before dividing, gives off a few filaments, which pierce the fascia lata, to supply the integument of the medial side of the thigh, accompanying the long saphenous vein. One of these filaments passes through the saphenous opening; a second becomes subcutaneous about the middle of the thigh; a third pierces the fascia at its lower third. 28

MUSCULAR BRANCHES (*rami musculares*).—The **nerve to the Pectineus** *arises*immediately below the inguinal ligament, and passes behind the femoral sheath to enter the anterior surface of the muscle; it is often duplicated. The **nerve to the Sartorius** *arises* in common with the intermediate cutaneous. 29

The posterior division of the femoral nerve gives off the saphenous nerve, and muscular and articular branches. 30

The **Saphenous Nerve** (*n. saphenus; long or internal saphenous nerve*) (Fig. 827) is the largest cutaneous branch of the femoral nerve. It approaches the femoral artery where this vessel passes beneath the Sartorius, and lies in front of it, behind the aponeurotic covering of the adductor canal, as far as the opening in the lower part of the Adductor magnus. Here it quits the artery, and emerges from behind the lower edge of the aponeurotic covering of the canal; it descends vertically along the medial side of the knee behind the Sartorius, pierces the fascia lata, between the tendons of the Sartorius and Gracilis, and becomes subcutaneous. The nerve then passes along the tibial side of the leg, accompanied by the great saphenous vein, descends behind the medial border of the tibia, and, at the lower third of the leg, divides into two branches: one continues its course along the margin of the tibia, and ends at the ankle; the other passes in front of the ankle, and is distributed to the skin on the medial side of the foot, as far as the ball of the great toe, communicating with the medial branch of the superficial peroneal nerve. 31

BRANCHES.

—The saphenous nerve, about the middle of the thigh, gives off a branch which joins the subsartorial plexus. 32

At the medial side of the knee it gives off a large **infrapatellar branch,** which pierces the Sartorius and fascia lata, and is distributed to the skin in front of the patella. This nerve communicates above the knee with the anterior cutaneous branches of the femoral nerve; below the knee, with other branches of the saphenous; and, on the lateral side of the joint, with branches of the lateral femoral cutaneous nerve, forming a plexiform net-work, the**plexus patellæ.** The infrapatellar branch is occasionally small, and ends by joining the anterior cutaneous branches of the femoral, which supply its place in front of the knee. 33

Below the knee, the branches of the saphenous nerve are distributed to the skin of the front and medial side of the leg, communicating with the cutaneous branches of the femoral, or with filaments from the obturator nerve. 34

The **muscular branches** supply the four parts of the Quadriceps femoris. The branch to the Rectus femoris enters the upper part of the deep surface of the muscle, and supplies a filament to the hip-joint. The branch to the Vastus lateralis, of large size, accompanies the descending branch of the lateral femoral circumflex artery to the lower part of the muscle. It gives off an articular filament to the knee-joint. The branch to the Vastus medialis descends lateral to the femoral vessels in company with the saphenous nerve. It enters the muscle about its middle, and gives off a filament, which can usually be traced downward, on the surface of the muscle, to the knee-joint. The branches to the Vastus intermedius, two or three in number, enter the anterior surface of the muscle about the middle of the thigh; a filament from one of these descends through the muscle to the Articularis genu and the knee-joint. The **articular branch to the hip-joint** is derived from the nerve to the Rectus femoris. *35*

The **articular branches to the knee-joint** are three in number. One, a long slender filament, is derived from the nerve to the Vastus lateralis; it penetrates the capsule of the joint on its anterior aspect. Another, derived from the nerve to the Vastus medialis, can usually be traced downward on the surface of this muscle to near the joint; it then penetrates the muscular fibers, and accompanies the articular branch of the highest genicular artery, pierces the medial side of the articular capsule, and supplies the synovial membrane. The third branch is derived from the nerve to the Vastus intermedius. *36*

Note 135. In most cases the fourth lumbar is the *nervus furcalis;* but this arrangement is frequently departed from. The third is occasionally the lowest nerve which enters the lumbar plexus, giving at the same time some fibers to the sacral plexus, and thus forming the nervus furcalis; or both the third and fourth may be furcal nerves. When this occurs, the plexus is termed *high* or *prefixed*. More frequently the fifth nerve is divided between the lumbar and sacral plexuses, and constitutes the nervus furcalis; and when this takes place, the plexus is distinguished as a *low* or *postfixed* plexus. These variations necessarily produce corresponding modifications in the sacral plexus. [back]

Note 136. Bardeen, Amer. Jour. Anat., 1907, vol. vi. [back]

6e. The Sacral and Coccygeal Nerves

(NN. Sacrales et Coccygeus) *1*

The **anterior divisions of the sacral and coccygeal nerves** (*rami anteriores*) form the sacral and pudendal plexuses. The anterior divisions of the upper four sacral nerves enter the pelvis through the anterior sacral foramina, that of the fifth between the sacrum and coccyx, while that of the coccygeal nerve curves forward below the rudimentary transverse process of the first piece of the coccyx. The first and second sacral nerves are large; the third, fourth, and fifth diminish progressively from above downward. Each receives a gray ramus communicans from the corresponding ganglion of the sympathetic trunk, while from the third and frequently from the second and the fourth sacral nerves, a white ramus communicans is given to the pelvic plexuses of the sympathetic.

The Sacral Plexus (*plexus sacralis*) (Fig. 828).—The sacral plexus is formed by the lumbosacral trunk, the anterior division of the first, and portions of the anterior divisions of the second and third sacral nerves. *2*

The lumbosacral trunk comprises the whole of the anterior division of the fifth and a part of that of the fourth lumbar nerve; it appears at the medial margin of the Psoas major and runs downward over the pelvic brim to join the first sacral nerve. The anterior division of the third sacral *3* nerve divides into an upper and a lower branch, the former entering the sacral and the latter the pudendal plexus.

The nerves forming the sacral plexus converge toward the lower part of the greater sciatic foramen, and unite to form a flattened band, from the 4
anterior and posterior surfaces of which several branches arise. The band itself is continued as the **sciatic nerve.** which splits on the back of the thigh into the **tibial** and **common peroneal nerves;** these two nerves sometimes arise separately from the plexus, and in all cases their independence can be shown by dissection.

Relation.—The sacral plexus lies on the back of the pelvis between the Piriformis and the pelvic fascia (Fig. 829); in front of it are the 5
hypogastric vessels, the ureter and the sigmoid colon. The superior gluteal vessels run between the lumbosacral trunk and the first sacral nerve, and the inferior gluteal vessels between the second and third sacral nerves.

All the nerves entering the plexus, with the exception of the third sacral, split into ventral and dorsal divisions, and the nerves arising from these 6
are as follows:

	Ventral divisions.	Dorsal divisions.
Nerve to Quadratus femoris and Gemellus inferior	4, 5 L, 1 S.	
Nerve to Obturator internus and Gemellus superior	5 L, 1, 2 S.	
Nerve to Piriformis……………………………………………………		(1) 2 S.
Superior gluteal……………………………………………………		4, 5 L, 1 S.
Inferior gluteal……………………………………………………...		5 L, 1, 2 S.
Posterior femoral cutaneous………………………	2, 3 S………	1, 2 S.
Sciatic Tibial……………………………………	4, 5 L, 1, 2, 3 S.	
Sciatic Common peroneal………………………	………………	4, 5 L, 1, 2 S.

The **Nerve to the Quadratus Femoris and Gemellus Inferior** *arises* from the ventral divisions of the fourth and fifth lumbar and first sacral 7
nerves: it leaves the pelvis through the greater sciatic foramen, below the Piriformis, and runs down in front of the sciatic nerve, the Gemelli, and the tendon of the Obturator internus, and enters the anterior surfaces of the muscles; it gives an articular branch to the hip-joint.

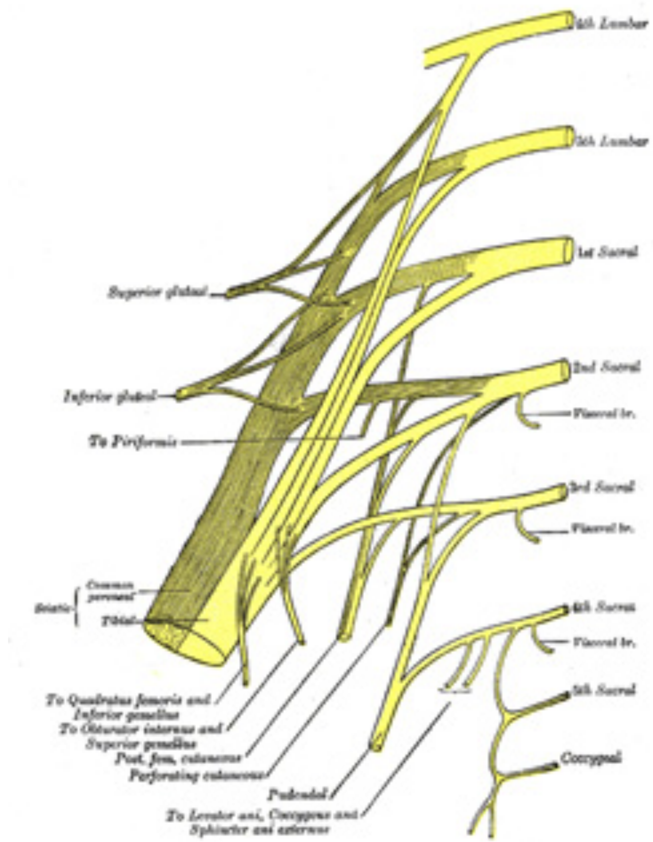


FIG. 828– Plan of sacral and pudendal plexuses. (See enlarged image)

The **Nerve to the Obturator Internus and Gemellus Superior** *arises* from the ventral divisions of the fifth lumbar and first and second sacral nerves. It leaves the pelvis through the greater sciatic foramen below the Piriformis, and gives off the branch to the Gemellus superior, which enters the upper part of the posterior surface of the muscle. It then crosses the ischial spine, reënters the pelvis through the lesser sciatic foramen, and pierces the pelvic surface of the Obturator internus. 8

The **Nerve to the Piriformis** *arises* from the dorsal division of the second sacral nerve, or the dorsal divisions of the first and second sacral 9 nerves, and enters the anterior surface of the muscle; this nerve may be double.

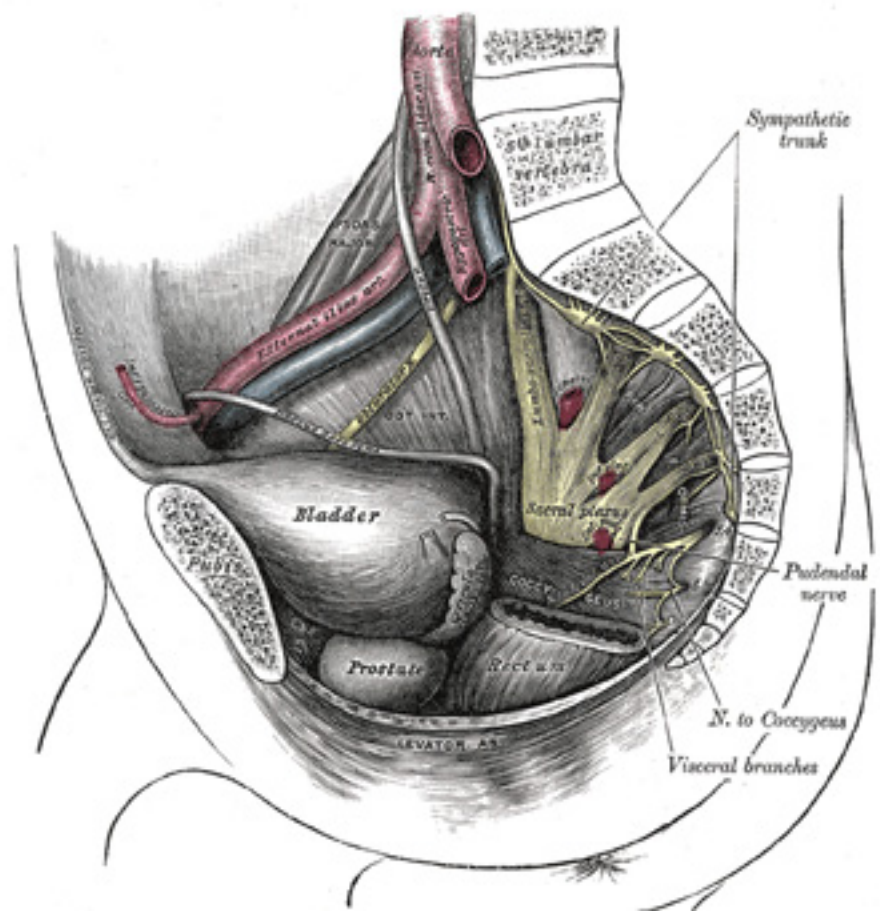


FIG. 829– Dissection of side wall of pelvis showing sacral and pudendal plexuses. (Testut.) (See enlarged image)

The **Superior Gluteal Nerve** (*n. glutæus superior*) *arises* from the dorsal divisions of the fourth and fifth lumbar and first sacral nerves: it 10 leaves the pelvis through the greater sciatic foramen above the Piriformis, accompanied by the superior gluteal vessels, and divides into a superior and an inferior branch. The **superior branch** accompanies the upper branch of the deep division of the superior gluteal artery and ends in the Glutæus minimus. The**inferior branch** runs with the lower branch of the deep division of the superior gluteal artery across the Glutæus minimus; it gives filaments to the Glutæi medius and minimus, and ends in the Tensor fasciæ latæ.

The **Inferior Gluteal Nerve** (*n. glutæus inferior*) *arises* from the dorsal divisions of the fifth lumbar and first and second sacral nerves: it 11
leaves the pelvis through the greater sciatic foramen, below the Piriformis, and divides into branches which enter the deep surface of the Glutæus maximus.

The **Posterior Femoral Cutaneous Nerve** (*n. cutaneus femoralis posterior; small sciatic nerve*) is distributed to the skin of the perineum and 12
posterior surface of the thigh and leg. It*arises* partly from the dorsal divisions of the first and second, and from the ventral divisions of the second and third sacral nerves, and issues from the pelvis through the greater sciatic foramen below the Piriformis. It then descends beneath the Glutæus maximus with the inferior gluteal artery, and runs down the back of the thigh beneath the fascia lata, and over the long head of the Biceps femoris to the back of the knee; here it pierces the deep fascia and accompanies the small saphenous vein to about the middle of the back of the leg, its terminal twigs communicating with the sural nerve.

Its branches are all cutaneous, and are distributed to the gluteal region, the perineum, and the back of the thigh and leg. 13

The **gluteal branches** (*nn. clunium inferiores*), three or four in number, turn upward around the lower border of the Glutæus maximus, and 14
supply the skin covering the lower and lateral part of that muscle.

The **perineal branches** (*rami perineales*) are distributed to the skin at the upper and medial side of the thigh. One long perineal 15
branch, **inferior pudendal** (*long scrotal nerve*), curves forward below and in front of the ischial tuberosity, pierces the fascia lata, and runs forward beneath the superficial fascia of the perineum to the skin of the scrotum in the male, and of the labium majus in the female. It communicates with the inferior hemorrhoidal and posterior scrotal nerves.

The **branches to the back of the thigh and leg** consist of numerous filaments derived from both sides of the nerve, and distributed to the skin 16
covering the back and medial side of the thigh, the popliteal fossa, and the upper part of the back of the leg (Fig. 830).

The **Sciatic** (*n. ischiadicus; great sciatic nerve*) (Fig. 832) supplies nearly the whole of the skin of the leg, the muscles of the back of the thigh, 17
and those of the leg and foot. It is the largest nerve in the body, measuring 2 cm. in breadth, and is the continuation of the flattened band of the sacral plexus. It passes out of the pelvis through the greater sciatic foramen, below the Piriformis muscle. It descends between the greater trochanter of the femur and the tuberosity of the ischium, and along the back of the thigh to about its lower third, where it divides into two large branches, the tibial and common peroneal nerves. This division may take place at any point between the sacral plexus and the lower third of the thigh. When it occurs at the plexus, the common peroneal nerve usually pierces the Piriformis.

In the upper part of its course the nerve rests upon the posterior surface of the ischium, the nerve to the Quadratus femoris, the Obturator 18
internus and Gemelli, and the Quadratus femoris; it is accompanied by the posterior femoral cutaneous nerve and the inferior gluteal artery, and is covered by the Glutæus maximus. Lower down, it lies upon the Adductor magnus, and is crossed obliquely by the long head of the Biceps femoris.

The nerve gives off articular and muscular branches. 19

The **articular branches** (*rami articulares*) *arise* from the upper part of the nerve and supply the hip-joint, perforating the posterior part of its 20
capsule; they are sometimes derived from the sacral plexus.

The **muscular branches** (*rami musculares*) are distributed to the Biceps femoris, Semitendinosus, Semimembranosus, and Adductor magnus. The nerve to the short head of the Biceps femoris comes from the common peroneal part of the sciatic, while the other muscular branches *arise* from the tibial portion, as may be seen in those cases where there is a high division of the sciatic nerve. *21*

The **Tibial Nerve** (*n. tibialis; internal popliteal nerve*) (Fig. 832) the larger of the two terminal branches of the sciatic, *arises* from the anterior branches of the fourth and fifth lumbar and first, second, and third sacral nerves. It descends along the back of the thigh and through the middle of the popliteal fossa, to the lower part of the Popliteus muscle, where it passes with the popliteal artery beneath the arch of the Soleus. It then runs along the back of the leg with the posterior tibial vessels to the interval between the medial malleolus and the heel, where it divides beneath the laciniate ligament into the medial and lateral plantar nerves. In the thigh it is overlapped by the hamstring muscles above, and then becomes more superficial, and lies lateral to, and some distance from, the popliteal vessels;opposite the knee-joint, it is in close relation with these vessels, and crosses to the medial side of the artery. In the leg it is covered in the upper part of its course by the muscles of the calf; lower down by the skin, the superficial and deep fasciæ. It is placed on the deep muscles, and lies at first to the medial side of the posterior tibial artery, but soon crosses that vessel and descends on its lateral side as far as the ankle. In the lower third of the leg it runs parallel with the medial margin of the tendo calcaneus. *22*


Sacral
Last thoracic
Post. femoral cutan.
Post femoral cutan.
Sural

FIG. 830– Cutaneous nerves of right lower extremity. Posterior view. 137 (See enlarged image)

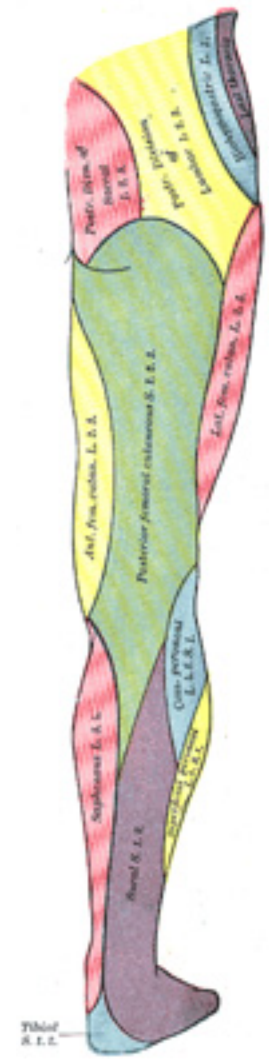


FIG. 831– Diagram of the segmental distribution of the cutaneous nerves of the right lower extremity. Posterior view. (See enlarged image)

The **branches** of this nerve are: **articular, muscular, medial sural cutaneous, medial calcaneal, medial** and **lateral plantar.** 23

Articular branches (*rami articulares*), usually three in number, supply the knee-joint; two of these accompany the superior and inferior medial genicular arteries; and a third, the middle genicular artery. Just above the bifurcation of the nerve an articular branch is given off to the ankle-joint. 24

Muscular branches (*rami musculares*), four or five in number, *arise* from the nerve as it lies between the two heads of the Gastrocnemius muscle; they supply that muscle, and the Plantaris, Soleus, and Popliteus. The branch for the Popliteus turns around the lower border and is distributed to the deep surface of the muscle. Lower down, muscular branches *arise*separately or by a common trunk and supply the Soleus, Tibialis posterior, Flexor digitorum longus, and Flexor hallucis longus; the branch to the last muscle accompanies the peroneal artery; that to the Soleus enters the deep surface of the muscle. 25

The **medial sural cutaneous nerve** (*n. cutaneus suræ medialis; n. communicans tibialis*) descends between the two heads of the Gastrocnemius, and, about the middle of the back of the leg, pierces the deep fascia, and unites with the anastomotic ramus of the common peroneal to form the sural nerve (Fig. 830). 26

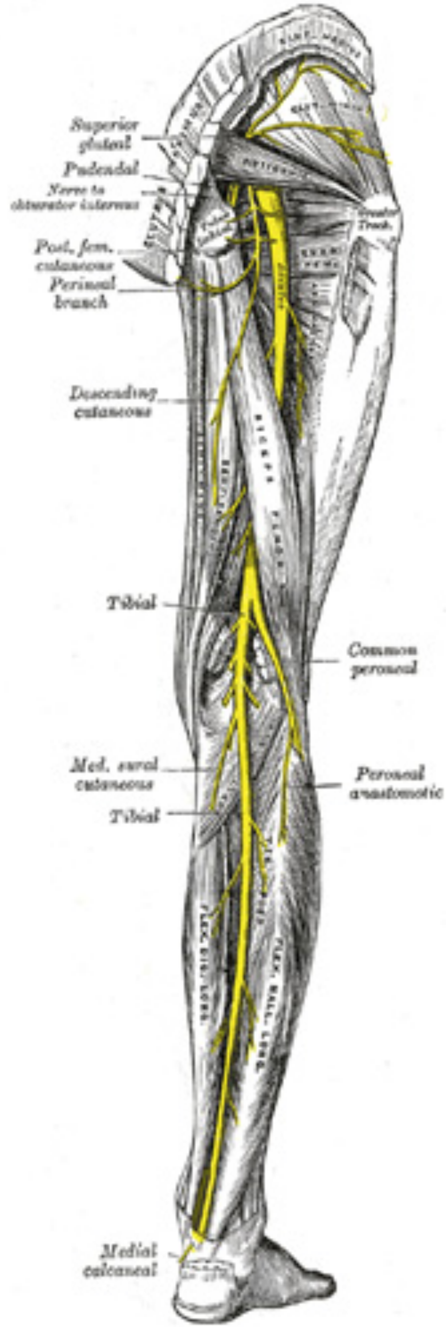

Superior
gluteal
Pudendal
Nerve to
obturator internus
Post. fem.
cutaneous
Perineal
branch
Descending
cutaneous
Tibial
Common
peroneal
Med. sural
cutaneous
Peroneal
anastomotic
Tibial
Medial
calcaneal

FIG. 832– Nerves of the right lower extremity Posterior view. (See enlarged image)

The **sural nerve** (*n. suralis; short saphenous nerve*), formed by the junction of the medial sural cutaneous with the peroneal anastomotic branch, passes downward near the lateral margin of the tendo calcaneus, lying close to the small saphenous vein, to the interval between the lateral malleolus and the calcaneus. It runs forward below the lateral malleolus, and is continued as the **lateral dorsal cutaneous nerve** along the lateral side of the foot and little toe, communicating on the dorsum of the foot with the intermediate dorsal cutaneous nerve, a branch of the superficial peroneal. In the leg, its branches communicate with those of the posterior femoral cutaneous. 27

The **medial calcaneal branches** (*rami calcanei mediales; internal calcaneal branches*) perforate the laciniate ligament, and supply the skin of the heel and medial side of the sole of the foot. 28

The **medial plantar nerve** (*n. plantaris medialis; internal plantar nerve*) (Fig. 833), the larger of the two terminal divisions of the tibial nerve, accompanies the medial plantar artery. From its origin under the laciniate ligament it passes under cover of the Abductor hallucis, and, appearing between this muscle and the Flexor digitorum brevis, gives off a proper digital plantar nerve and finally divides opposite the bases of the metatarsal bones into three common digital plantar nerves. 29

BRANCHES.—The branches of the medial plantar nerve are: (1) **cutaneous,** (2) **muscular,**(3) **articular,** (4) a **proper digital nerve** to the medial side of the great toe, and (5) three**common digital nerves.** 30

The **cutaneous branches** pierce the plantar aponeurosis between the Abductor hallucis and the Flexor digitorum brevis and are distributed to the skin of the sole of the foot. 31

The **muscular branches** supply the Abductor hallucis, the Flexor digitorum brevis, the Flexor hallucis brevis, and the first Lumbricalis; those for the Abductor hallucis and Flexor digitorum brevis arise from the trunk of the nerve near its origin and enter the deep surfaces of the muscles; the branch of the Flexor hallucis brevis springs from the proper digital nerve to the medial side of the great toe, and that for the first Lumbricalis from the first common digital nerve. 32

The **articular branches** supply the articulations of the tarsus and metatarsus. 33

The **proper digital nerve of the great toe** (*nn. digitales plantares proprii; plantar digital branches*) supplies the Flexor hallucis brevis and the skin on the medial side of the great toe. 34

The **three common digital nerves** (*nn. digitales plantares communes*) pass between the divisions of the plantar aponeurosis, and each splits into two proper digital nerves—those of the first common digital nerve supply the adjacent sides of the great and second toes; those of the second, the adjacent sides of the second and third toes; and those of the third, the adjacent sides of the third and fourth toes. The third common digital nerve receives a communicating branch from the lateral plantar nerve; the first gives a twig to the first Lumbricalis. Each proper digital nerve gives off cutaneous and articular filaments; and opposite the last phalanx sends upward a dorsal branch, which supplies the structures around the nail, the continuation of the nerve being distributed to the ball of the toe. It will be observed that these digital nerves are similar in their distribution to those of the median nerve in the hand. 35

The **Lateral Plantar Nerve** (*n. plantaris lateralis; external plantar nerve*) (Fig. 833)supplies the skin of the fifth toe and lateral half of the fourth, as well as most of the deep muscles, its distribution being similar to that of the ulnar nerve in the hand. It passes obliquely forward with 36 the lateral plantar artery to the lateral side of the foot, lying between the Flexor digitorum brevis and Quadratus plantæ and, in the interval between the former muscle and the Abductor digiti quinti, divides into a superficial and a deep branch. Before its division, it supplies the Quadratus plantæ and Abductor digiti quinti.

The **superficial branch** (*ramus superficialis*) splits into a proper and a common digital nerve; the proper digital nerve supplies the lateral side 37
of the little toe, the Flexor digiti quinti brevis, and the two Interossei of the fourth intermetatarsal space; the common digital nerve communicates with the third common digital branch of the medial plantar nerve and divides into two proper digital nerves which supply the adjoining sides of the fourth and fifth toes.

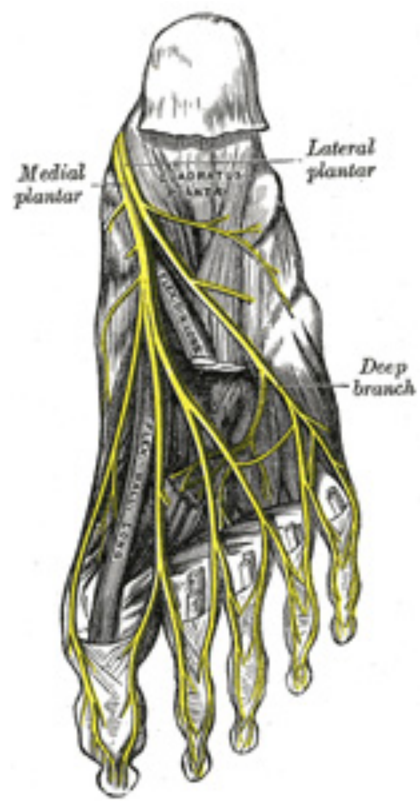


FIG. 833– The plantar nerves. (See enlarged image)

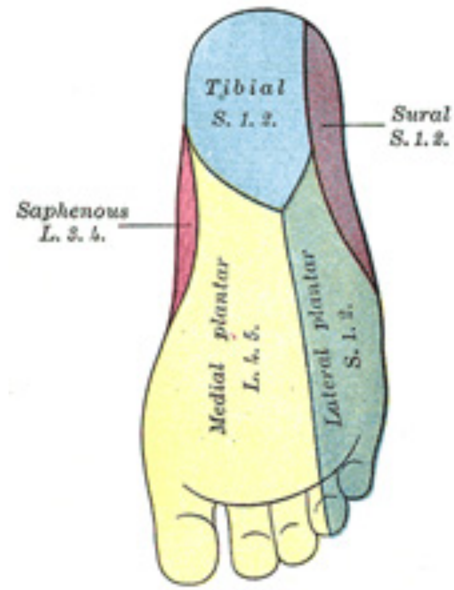


FIG. 834– Diagram of the segmental distribution of the cutaneous nerves of the sole of the foot. (See enlarged image)

The **deep branch** (*ramus profundus; muscular branch*) accompanies the lateral plantar artery on the deep surface of the tendons of the Flexor 38
muscles and the Adductor hallucis, and supplies all the Interossei (except those in the fourth metatarsal space), the second, third, and fourth Lumbricales, and the Adductor hallucis.

The **Common Peroneal Nerve** (*n. peronæus communis; external popliteal nerve; peroneal nerve*) (Fig. 832), about one-half the size of the 39
tibial, is derived from the dorsal branches of the fourth and fifth lumbar and the first and second sacral nerves. It descends obliquely along the lateral side of the popliteal fossa to the head of the fibula, close to the medial margin of the Biceps femoris muscle. It lies between the tendon of the Biceps femoris and lateral head of the Gastrocnemius muscle, winds around the neck of the fibula, between the Peronæus longus and the bone, and divides beneath the muscle into the superficial and deep peroneal nerves. Previous to its division it gives off articular and lateral sural cutaneous nerves.

The **articular branches** (*rami articulares*) are three in number; two of these accompany the superior and inferior lateral genicular arteries to 40
the knee; the upper one occasionally*arises* from the trunk of the sciatic nerve. The third (*recurrent*) articular nerve is given off at the point of

division of the common peroneal nerve; it ascends with the anterior recurrent tibial artery through the Tibialis anterior to the front of the knee.

The **lateral sural cutaneous nerve** (*n. cutaneus suræ lateralis; lateral cutaneous branch*) supplies the skin on the posterior and lateral surfaces of the leg; one branch, the **peroneal anastomotic** (*n. communicans fibularis*), *arises* near the head of the fibula, crosses the lateral head of the Gastrocnemius to the middle of the leg, and joins with the medial sural cutaneous to form the sural nerve. The peroneal anastomotic is occasionally continued down as a separate branch as far as the heel. *41*

The **Deep Peroneal Nerve** (*n. peronæus profundus; anterior tibial nerve*) (Fig. 827)begins at the bifurcation of the common peroneal nerve, between the fibula and upper part of the Peronæus longus, passes obliquely forward beneath the Extensor digitorum longus to the front of the interosseous membrane, and comes into relation with the anterior tibial artery above the middle of the leg; it then descends with the artery to the front of the ankle-joint, where it divides into a lateral and a medial terminal branch. It lies at first on the lateral side of the anterior tibial artery, then in front of it, and again on its lateral side at the ankle-joint. *42*

In the leg, the deep peroneal nerve supplies **muscular branches** to the Tibialis anterior, Extensor digitorum longus, Peronæus tertius, and Extensor hallucis prop ius, and an**articular branch** to the ankle-joint. *43*

The **lateral terminal branch** (*external or tarsal branch*) passes across the tarsus, beneath the Extensor digitorum brevis, and, having become enlarged like the dorsal interosseous nerve at the wrist, supplies the Extensor digitorumbrevis. From the enlargement three minute **interosseous branches** are given off, which supply the tarsal joints and the metatarsophalangeal joints of the second, third, and fourth toes. The first of these sends a filament to the second Interosseus dorsalis muscle. *44*

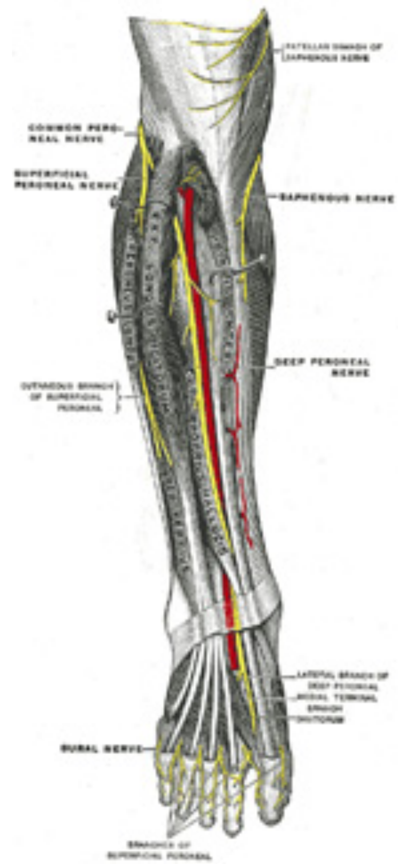


FIG. 835– Deep nerves of the front of the leg. (Testut.) (See enlarged image)

The **medial terminal branch** (*internal branch*) accompanies the dorsalis pedis artery along the dorsum of the foot, and, at the first interosseous 45
space, divides into two **dorsal digital nerves** (*nn. digitales dorsales hallucis lateralis et digiti secundi medialis*) which supply the adjacent sides of the great and second toes, communicating with the medial dorsal cutaneous branch of the superficial peroneal nerve. Before it divides it gives off to the first space an **interosseous branch** which supplies the metatarsophalangeal joint of the great toe and sends a filament to the first Interosseous dorsalis muscle.

The **Superficial Peroneal Nerve** (*n. peronæus superficialis; musculocutaneous nerve*) (Figs. 827, 835) supplies the Peronei longus and brevis and the skin over the greater part of the dorsum of the foot. It passes forward between the Peronæi and the Extensor digitorum longus, pierces the deep fascia at the lower third of the leg, and divides into a medial and an intermediate dorsal cutaneous nerve. In its course between the muscles, the nerve gives off muscular branches to the Peronæi longus and brevis, and cutaneous filaments to the integument of the lower part of the leg. 46

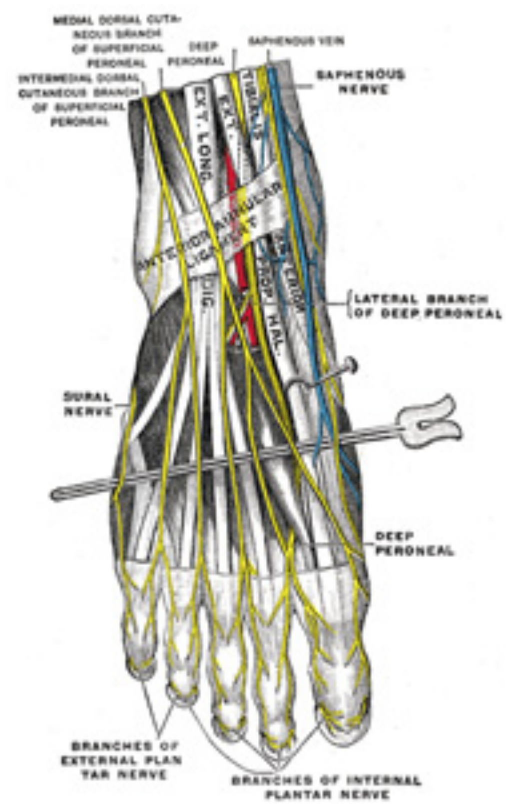


FIG. 836– Nerves of the dorsum of the foot. (Testut.) (See enlarged image)

The **medial dorsal cutaneous nerve** (*n. cutaneus dorsalis medialis; internal dorsal cutaneous branch*) passes in front of the ankle-joint, and divides into two dorsal **digital branches,** one of which supplies the medial side of the great toe, the other, the adjacent side of the second and 47 third toes. It also supplies the integument of the medial side of the foot and ankle, and communicates with the saphenous nerve, and with the deep peroneal nerve (Fig. 825).

The **intermediate dorsal cutaneous nerve** (*n. cutaneus dorsalis intermedius; external dorsal cutaneous branch*), the smaller, passes along the lateral part of the dorsum of the foot, and divides into **dorsal digital branches,** which supply the contiguous sides of the third and fourth, and of the fourth and fifth toes. It also supplies the skin of the lateral side of the foot and ankle, and communicates with the sural nerve (Fig. 825). The branches of the superficial peroneal nerve supply the skin of the dorsal surfaces of all the toes excepting the lateral side of the little toe, and the adjoining sides of the great and second toes, the former being supplied by the lateral dorsal cutaneous nerve from the sural nerve, and the latter by the medial branch of the deep peroneal nerve. Frequently some of the lateral branches of the superficial peroneal are absent, and their places are then taken by branches of the sural nerve. 48

The Pudendal Plexus (*plexus pudendus*) (Fig. 828).—The pudendal plexus is not sharply marked off from the sacral plexus, and as a consequence some of the branches which spring from it may *arise* in conjunction with those of the sacral plexus. It lies on the posterior wall of the pelvis, and is usually formed by branches from the anterior divisions of the second and third sacral nerves, the whole of the anterior divisions of the fourth and fifth sacral nerves, and the coccygeal nerve. 49

It gives off the following branches: 50

Perforating cutaneous…	2, 3 S.
Pudendal………………	2, 3, 4 S.
Visceral………………	3, 4 S.
Muscular………………	4 S.
Anococcygeal………..	4, 5 S. and Cocc.

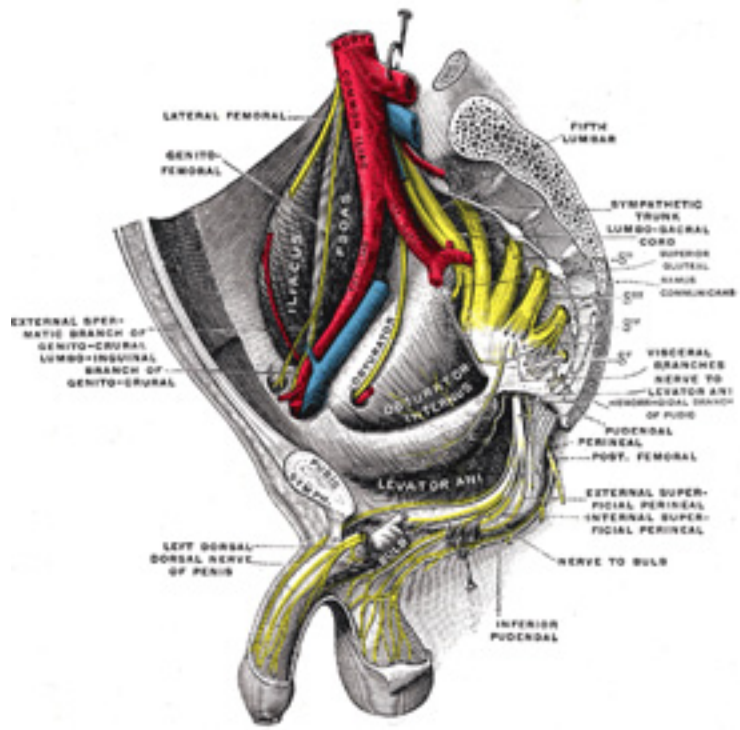


FIG. 837– Sacral plexus of the right side. (Testut). (See enlarged image)

The **Perforating Cutaneous Nerve** (*n. clunium inferior medialis*) usually *arises* from the posterior surface of the second and third sacral nerves. It pierces the lower part of the sacrotuberous ligament, and winding around the inferior border of the Glutæus maximus supplies the skin covering the medial and lower parts of that muscle. *51*

The perforating cutaneous nerve may arise from the pudendal or it may be absent; in the latter case its place may be taken by a branch from the posterior femoral cutaneous nerve or by a branch from the third and fourth, or fourth and fifth, sacral nerves. *52*

The **Pudendal Nerve** (*n. pudendus; internal pudic nerve*) derives its fibers from the ventral branches of the second, third, and fourth sacral nerves. It passes between the Piriformis and Coccygeus muscles and leaves the pelvis through the lower part of the greater sciatic foramen. It then crosses the spine of the ischium, and reënters the pelvis through the lesser sciatic foramen. It accompanies the internal pudendal vessels upward and forward along the lateral wall of the ischiorectal fossa, being contained in a sheath of the obturator fascia termed **Alcock's** *53*

canal, and divides into two terminal branches, viz., the**perineal nerve,** and the **dorsal nerve of the penis** or **clitoris.** Before its division it gives off the **inferior hemorrhoidal nerve.**

The **inferior hemorrhoidal nerve** (*n. hæmorrhoidalis inferior*) occasionally *arises*directly from the sacral plexus; it crosses the ischiorectal fossa, with the inferior hemorrhoidal vessels, toward the anal canal and the lower end of the rectum, and is distributed to the Sphincter ani externus and to the integument around the anus. Branches of this nerve communicate with the perineal branch of the posterior femoral cutaneous and with the posterior scrotal nerves at the forepart of the perineum. *54*

The **perineal nerve** (*n. perinei*), the inferior and larger of the two terminal branches of the pudendal, is situated below the internal pudendal artery. It accompanies the perineal artery and divides into **posterior scrotal** (or **labial**) and **muscular branches.** *55*

The **posterior scrotal** (**or labial**) **branches** (*nn. scrotales* (*or labiales*) *posteriores; superficial peroneal nerves*) are two in number, medial and lateral. They pierce the fascia of the urogenital diaphragm, and run forward along the lateral part of the urethral triangle in company with the posterior scrotal branches of the perineal artery; they are distributed to the skin of the scrotum and communicate with the perineal branch of the posterior femoral cutaneous nerve. These nerves supply the labium majus in the female. *56*

The **muscular branches** are distributed to the Transversus perinæi superficialis, Bulbocavernous, Ischiocavernosus, and Constrictor urethræ. A branch, the **nerve to the bulb,** given off from the nerve to the Bulbocavernosus, pierces this muscle, and supplies the corpus cavernosum urethræ, ending in the mucous membrane of the urethra. *57*

The **dorsal nerve of the penis** (*n. dorsalis penis*) is the deepest division of the pudendal nerve; it accompanies the internal pudendal artery along the ramus of the ischium; it then runs forward along the margin of the inferior ramus of the pubis, between the superior and inferior layers of the fascia of the urogenital diaphragm. Piercing the inferior layer it gives a branch to the corpus cavernosum penis, and passes forward, in company with the dorsal artery of the penis, between the layers of the suspensory ligament, on to the dorsum of the penis, and ends on the glans penis. In the female this nerve is very small, and supplies the**clitoris** (*n. dorsalis clitoridis*). *58*

The **Visceral Branches** *arise* from the third and fourth, and sometimes from the second, sacral nerves, and are distributed to the bladder and rectum and, in the female, to the vagina; they communicate with the pelvic plexuses of the sympathetic. *59*

The **Muscular Branches** are derived from the fourth sacral, and supply the Levator ani, Coccygeus, and Sphincter ani externus. The branches to the Levator ani and Coccygeus enter their pelvic surfaces; that to the Sphincter ani externus (perineal branch) reaches the ischiorectal fossa by piercing the Coccygeus or by passing between it and the Levator ani. Cutaneous filaments from this branch supply the skin between the anus and the coccyx. *60*

Anococcygeal Nerves (*nn. anococcygei*).—The fifth sacral nerve receives a communicating filament from the fourth, and unites with the coccygeal nerve to form the**coccygeal plexus.** From this plexus the anococcygeal nerves take origin; they consist of a few fine filaments which pierce the sacrotuberous ligament to supply the skin in the region of the coccyx. *61*

Note 137. N. B.—In this diagram the medial sura cutaneous and peroneal anastomotic are not in their normal position. They have been displaced by the removal of the superficial muscles. [back]

7. The Sympathetic Nerves

The **sympathetic nervous system** (Fig. 838) innervates all the smooth muscles and the various glands of the body, and the striated muscle of the *1*
heart. The efferent sympathetic fibers which leave the central nervous system in connection with certain of the cranial and spinal nerves all end in sympathetic ganglia and are known as **preganglionic fibers.** From these ganglia postganglionic fibers arise and conduct impulses to the different organs. In addition, afferent or sensory fibers connect many of these structures with the central nervous system.

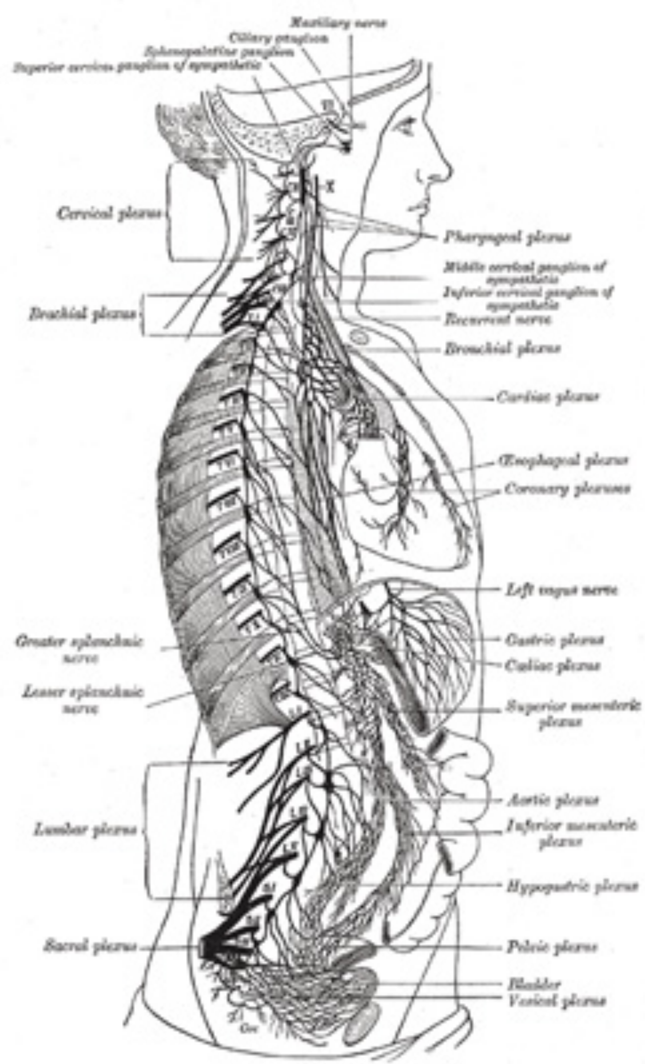


FIG. 838– The right sympathetic chain and its connections with the thoracic, abdominal, and pelvic plexuses. (After Schwalbe.) (See enlarged

image)

The peripheral portion of the sympathetic nervous system is characterized by the presence of numerous ganglia and complicated plexuses. These ganglia are connected with the central nervous system by three groups of sympathetic efferent or preganglionic fibers, *i. e.*,the **cranial,** the **thoracolumbar,** and the **sacral.** These outflows of sympathetic fibers are separated by intervals where no connections exist. The cranial and sacral sympathetics are often grouped together owing to the resemblance between the reactions produced by stimulating them and by the effects of certain drugs. Acetyl-choline, for example, when injected intravenously in very small doses, produces the same effect as the stimulation of the cranial or sacral sympathetics, while the introduction of adrenalin produces the same effect as the stimulation of the thoracolumbar sympathetics. Much of our present knowledge of the sympathetic nervous system has been acquired through the application of various drugs, especially nicotine which paralyzes the connections or synapses between the preganglionic and postganglionic fibers of the sympathetic nerves. When it is injected into the general circulation all such synapses are paralyzed; when it is applied locally on a ganglion only the synapses occurring in that particular ganglion are paralyzed. 2

Langley, 138 who has contributed greatly to our knowledge, adopted a terminology somewhat different from that used here and still different from that used by the pharmacologists. This has led to considerable confusion, as shown by the arrangement of the terms in the following columns. Gaskell has used the term involuntary nervous system. 139 3

Gray.	Langley.	Meyer and Gottlieb. 140
Sympathetic nervous system.	Autonomic nervous system.	Vegetative nervous system.
Cranio-sacral sympathetics.	Parasympathetics.	Autonomic.
Oculomotor sympathetics.	Tectal autonomics.	Cranial autonomics.
Facial Fsympathetics.		
Glossopharyngeal sympathetics.	Bulbar autonomics.	
Vagal sympathetics.		
Sacral sympathetics.	Sacral autonomics.	Sacral autonomics.
Thoracolumbar sympathetics.	Sympathetic.	Sympathetic.
	Thoracic autonomic.	
Enteric.	Enteric.	Enteric.

The Cranial Sympathetics—The **cranial sympathetics** include sympathetic efferent fibers in the oculomotor, facial, glossopharyngeal and vagus nerves, as well as sympathetic afferent in the last three nerves. 4

The **Sympathetic Efferent Fibers of the Oculomotor Nerve** probably arise from cells in the anterior part of the oculomotor nucleus which is 5
located in the tegmentum of the mid-brain. These preganglionic fibers run with the third nerve into the orbit and pass to the ciliary ganglion where they terminate by forming synapses with sympathetic motor neurons whose axons, postganglionic fibers, proceed as the short ciliary nerves to the eyeball. Here they supply motor fibers to the Ciliaris muscle and the Sphincter pupillæ muscle. So far as known there are no sympathetic afferent fibers connected with the nerve.

The **Sympathetic Efferent Fibers of the Facial Nerve** are supposed to arise from the small cells of the facial nucleus. According to some 6
authors the fibers to the salivary glands arise from a special nucleus, the superior salivatory nucleus, consisting of cells scattered in the reticular formation, dorso-medial to the facial nucleus. These preganglionic fibers are distributed partly through the chorda tympani and lingual nerves to the submaxillary ganglion where they terminate about the cell bodies of neurons whose axons as postganglionic fibers conduct secretory and vasodilotar impulses to the submaxillary and sublingual glands. Other preganglionic fibers of the facial nerve pass via the great superficial petrosal nerve to the sphenopalatine ganglion where they form synapses with neurons whose postganglionic fibers are distributed with the superior maxillary nerve as vasodilator and secretory fibers to the mucous membrane of the nose, soft palate, tonsils, uvula, roof of the mouth, upper lips and gums, parotid and orbital glands.

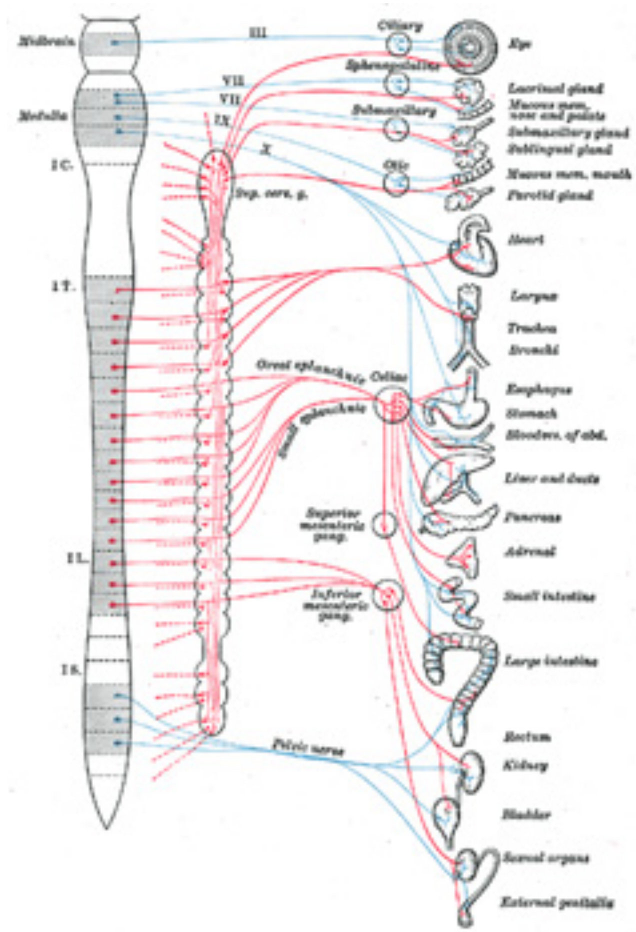


FIG. 839– Diagram of efferent sympathetic nervous system. Blue, cranial and sacral outflow. Red, thoracohumeral outflow. — —, Postganglionic fibers to spinal and cranial nerves to supply vasomotors to head, trunk and limbs, motor fibers to smooth muscles of skin and fibers to sweat glands. (Modified after Meyer and Gottlieb.) (See enlarged image)

There are supposed to be a few sympathetic afferent fibers connected with the facial nerve, whose cell bodies lie in the geniculate ganglion, but 7 very little is known about them.

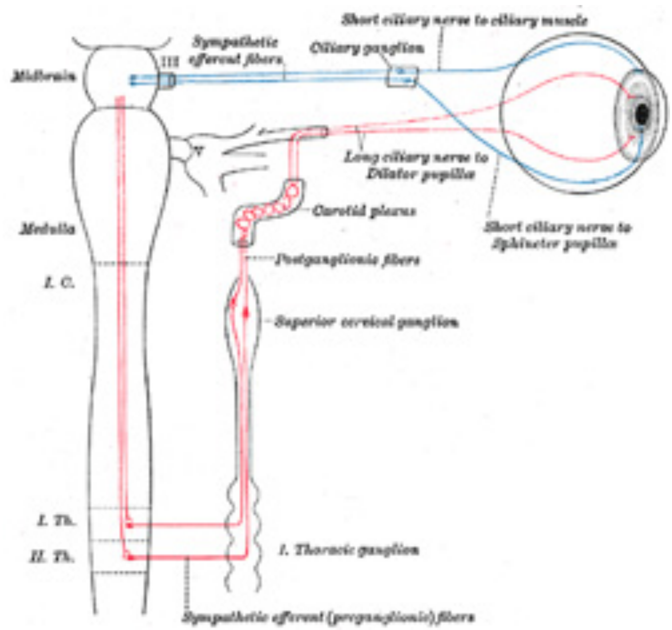


FIG. 840– Sympathetic connections of the ciliary and superior cervical ganglia. (See enlarged image)

The **Sympathetic Afferent Fibers of the Glossopharyngeal Nerve** are supposed to arise either in the dorsal nucleus (nucleus ala cinerea) or in a distinct nucleus, the inferior salivatory nucleus, situated near the dorsal nucleus. These preganglionic fibers pass into the tympanic branch of the glossopharyngeal and then with the small superficial petrosal nerve to the otic ganglion. Postganglionic fibers, vasodilator and secretory fibers, are distributed to the parotid gland, to the mucous membrane and its glands on the tongue, the floor of the mouth, and the lower gums. *8*

Sympathetic Afferent Fibers, whose cells of origin lie in the superior or inferior ganglion of the trunk, are supposed to terminate in the dorsal nucleus. Very little is known of the peripheral distribution of these fibers. *9*

The **Sympathetic Efferent Fibers of the Vagus Nerve** are supposed to arise in the dorsal nucleus (nucleus ala cinerea). These preganglionic fibers are all supposed to end in sympathetic ganglia situated in or near the organs supplied by the vagus sympathetics. The inhibitory fibers to the heart probably terminate in the small ganglia of the heart wall especially the atrium, from which inhibitory postganglionic fibers are distributed to the musculature. The preganglionic motor fibers to the esophagus, the stomach, the small intestine, and the greater part of the large *10* intestine are supposed to terminate in the plexuses of Auerbach, from which postganglionic fibers are distributed to the smooth muscles of these organs. Other fibers pass to the smooth muscles of the bronchial tree and to the gall-bladder and its ducts. In addition the vagus is believed to contain secretory fibers to the stomach and pancreas. It probably contains many other efferent fibers than those enumerated above.

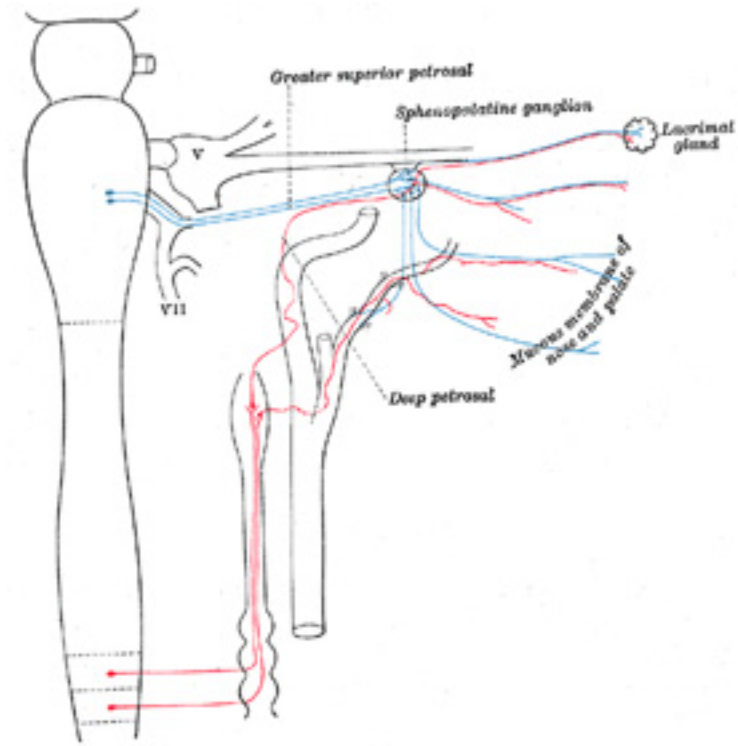


FIG. 841– Sympathetic connections of the sphenopalatine and superior cervical ganglia. (See enlarged image)

Sympathetic Afferent Fibers of the Vagus, whose cells of origin lie in the jugular ganglion or the ganglion nodosum, probably terminate in 11
the dorsal nucleus of the medulla oblongata or according to some authors in the nucleus of the tractus solitarius. Peripherally the fibers are supposed to be distributed to the various organs supplied by the sympathetic efferent fibers.

The Sacral Sympathetics—The **Sacral Sympathetic Efferent Fibers** leave the spinal cord with the anterior roots of the second, third and fourth sacral nerves. These small medullated preganglionic fibers are collected together in the pelvis into the nervus erigentes or pelvic nerve which proceeds to the hypogastric or pelvic plexuses from which postganglionic fibers are distributed to the pelvic viscera. Motor fibers pass to the smooth muscle of the descending colon, rectum, anus and bladder. Vasodilators are distributed to these organs and to the external genitalia, while inhibitory fibers probably pass to the smooth muscles of the external genitalia. **Afferent sympathetic fibers** conduct impulses from the pelvic viscera to the second, third and fourth sacral nerves. Their cells of origin lie in the spinal ganglia. *12*

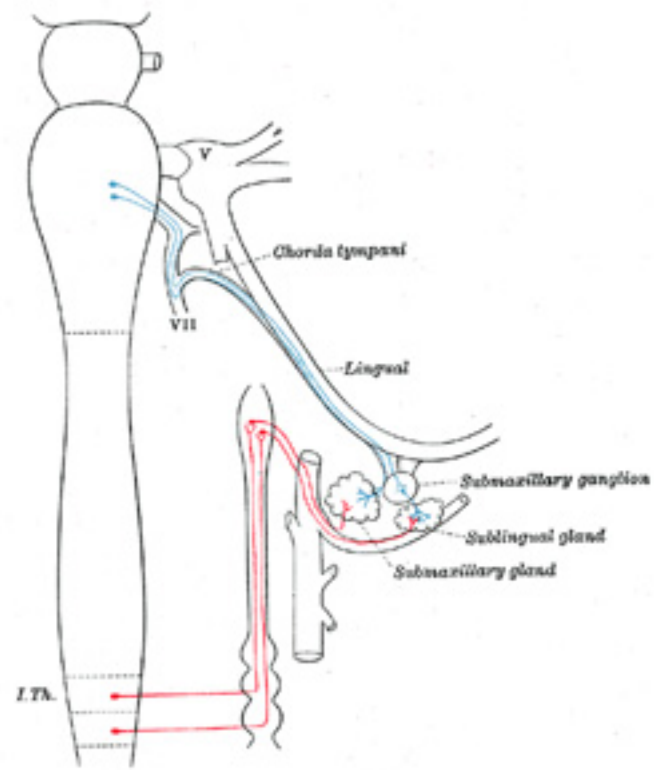


FIG. 842– Sympathetic connections of the submaxillary and superior cervical ganglia. (See enlarged image)

The Thoracolumbar Sympathetics—The **thoracolumbar sympathetic fibers** arise from the dorso-lateral region of the anterior column of the gray matter of the spinal cord and pass with the anterior roots of all the thoracic and the upper two or three lumbar spinal nerves. These preganglionic fibers enter the white rami communicantes and proceed to the sympathetic trunk where many of them end in its ganglia, others pass to the prevertebral plexuses and terminate in its collateral ganglia. The postganglionic fibers have a wide distribution. The **vasoconstrictor fibers** to the bloodvessels of the skin of the trunk and limbs, for example, leave the spinal cord as preganglionic fibers in all the thoracic and the upper two or three lumbar spinal nerves and terminate in the ganglia of the sympathetic trunk, either in the ganglion directly connected with its ramus or in neighboring ganglia. Postganglionic fibers arise in these ganglia, pass through gray rami communicantes to all the spinal nerves, and are distributed with their cutaneous branches, ultimately leaving these branches to join the small arteries. The postganglionic fibers do not necessarily return to the same spinal nerves which contain the corresponding preganglionic fibers. The vasoconstrictor fibers to the head come from the upper thoracic nerves, the preganglionic fibers end in the superior cervical ganglion. The postganglionic fibers pass through the internal carotid nerve and branch from it to join the sensory branches of the various cranial nerves, especially the trigeminal nerve; other fibers to the deep structures and the salivary glands probably accompany the arteries. *13*

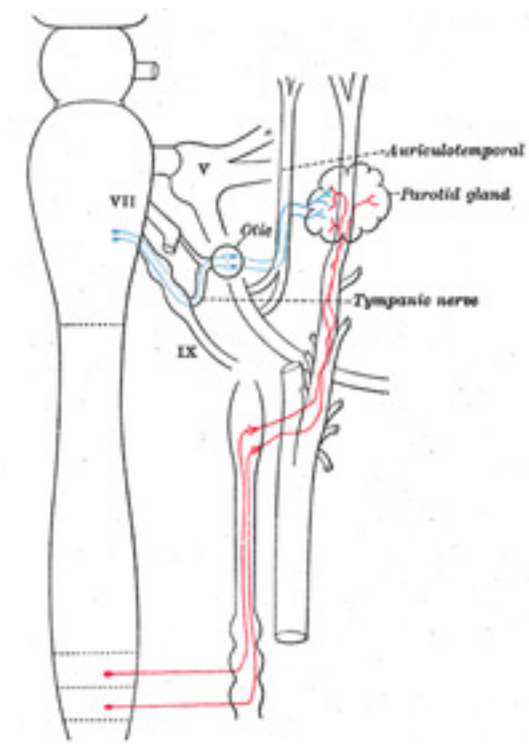


FIG. 843– Sympathetic connections of the otic and superior cervical ganglia. (See enlarged image)

The postganglionic vasoconstrictor fibers to the bloodvessels of the abdominal viscera arise in the prevertebral or collateral ganglia in which terminate many preganglionic fibers. Vasoconstrictor fibers to the pelvic viscera arise from the inferior mesenteric ganglia. *14*

The pilomotor fibers to the hairs and the motor fibers to the sweat glands apparently have a distribution similar to that of the vasoconstrictors of the skin. *15*

A vasoconstrictor center has been located by the physiologists in the neighborhood of the facial nucleus. Axons from its cells are supposed to descend in the spinal cord to terminate about cell bodies of the preganglionic fibers located in the dorsolateral portion of the anterior column of the thoracic and upper lumbar region. *16*

The motor supply to the dilator pupillæ muscle of the eye comes from preganglionicsympathetic fibers which leave the spinal cord with the *17* anterior roots of the upper thoracic nerves. These fibers pass to the sympathetic trunk through the white rami communicantes and terminate in the superior cervical ganglion. Postganglionic fibers from the superior cervical ganglion pass through the internal carotid nerve and the ophthalmic division of the trigeminal nerve to the orbit where the long ciliary nerves conduct the impulses to the eyeball and the dilator pupillæ muscle. The cell bodies of these preganglionic fibers are connected with fibers which descend from the mid-brain.

Other postganglionic fibers from the superior cervical ganglion are distributed as secretory fibers to the salivary glands, the lacrimal glands and to the small glands of the mucous membrane of the nose, mouth and pharynx. *18*

The thoracic sympathetics supply accelerator nerves to the heart. They are supposed to emerge from the spinal cord in the anterior roots of the upper four or five thoracic nerves and pass with the white rami to the first thoracic ganglion, here some terminate, others pass in the ansa subclavia to the inferior cervical ganglion. The postganglionic fibers pass from these ganglia partly through the ansa subclavia to the heart, on their way they intermingle with sympathetic fibers from the vagus to form the cardiac plexus. *19*

Inhibitory fibers to the smooth musculature of the stomach, the small intestine and most of the large intestine are supposed to emerge in the anterior roots of the lower thoracic and upper lumbar nerves. These fibers pass through the white rami and sympathetic trunk and are conveyed by the splanchnic nerves to the prevertebral plexus where they terminate in the collateral ganglia. From the celiac and superior mesenteric ganglia postganglionic fibers (inhibitory) are distributed to the stomach, the small intestine and most of the large intestine. Inhibitory fibers to the descending colon, the rectum and Internal sphincter ani are probably postganglionic fibers from the inferior mesenteric ganglion. *20*

The thoracolumbar sympathetics are characterized by the presence of numerous ganglia which may be divided into two groups, **central** and **collateral.** *21*

The **central ganglia** are arranged in two vertical rows, one on either side of the middle line, situated partly in front and partly at the sides of the vertebral column. Each ganglion is joined by intervening nervous cords to adjacent ganglia so that two chains, the**sympathetic trunks,** are formed. The **collateral ganglia** are found in connection with three great **prevertebral plexuses,** placed within the thorax, abdomen, and pelvis respectively. *22*

The **sympathetic trunks** (*truncus sympathicus; gangliated cord*) extend from the base of the skull to the coccyx. The cephalic end of each is continued upward through the carotid canal into the skull, and forms a plexus on the internal carotid artery; the caudal ends of the trunks converge and end in a single ganglion, the **ganglion impar,** placed in front of the coccyx. The ganglia of each trunk are distinguished as **cervical, thoracic, lumbar,** and**sacral** and, except in the neck, they closely correspond in number to the vertebræ. They are arranged thus: *23*

Cervical portion	3 ganglia
Thoracic portion	12 ganglia
Lumbar portion	4 ganglia
Sacral portion	4 or 5 ganglia

In the neck the ganglia lie in front of the transverse processes of the vertebræ; **in the thoracic region** in front of the heads of the ribs; **in the lumbar region** on the sides of the vertebral bodies; and **in the sacral region** in front of the sacrum. *24*

Connections with the Spinal Nerves.—Communications are established between the sympathetic and spinal nerves through what are known as the **gray** and **white rami communicantes** (Fig. 799); the gray rami convey sympathetic fibers into the spinal nerves and the white rami transmit *25* spinal fibers into the sympathetic. Each spinal nerve receives a gray ramus communicans from the sympathetic trunk, but white rami are not supplied by all the spinal nerves. White rami are derived from the first thoracic to the first lumbar nerves inclusive, while the visceral branches which run from the second, third, and fourth sacral nerves directly to the pelvic plexuses of the sympathetic belong to this category. The fibers which reach the sympathetic through the white rami communicantes are medullated; those which spring from the cells of the sympathetic ganglia are almost entirely non-medullated. The sympathetic nerves consist of efferent and afferent fibers, the origin and course of which are described on page 920).

The **three great gangliated plexuses** (*collateral ganglia*) are situated in front of the vertebral column in the thoracic, abdominal, and pelvic regions, and are named, respectively, the **cardiac,** the **solar** or **epigastric,** and the **hypogastric plexuses.** They consist of collections of nerves and ganglia; the nerves being derived from the sympathetic trunks and from the cerebrospinal nerves. They distribute branches to the viscera. *26*

Development.—The ganglion cells of the sympathetic system are derived from the cells of the neural crests. As these crests move forward along the sides of the neural tube and become segmented off to form the spinal ganglia, certain cells detach themselves from the ventral margins of the crests and migrate toward the sides of the aorta, where some of them are grouped to form the ganglia of the sympathetic trunks, while others undergo a further migration and form the ganglia of the prevertebral and visceral plexuses. The ciliary, sphenopalatine, otic, and submaxillary ganglia which are found on the branches of the trigeminal nerve are formed by groups of cells which have migrated from the part of the neural crest which gives rise to the semilunar ganglion. Some of the cells of the ciliary ganglion are said to migrate from the neural tube along the oculomotor nerve. *27*

Note 138. Schäfer. Textbook of Physiology, 1900. [back]

Note 139. Gaskell, W. H., The Involuntary Nervous System, London, 1916. [back]

Note 140. Die Experimentelle Pharmakologie, 1910. [back]

7a. The Cephalic Portion of the Sympathetic System

(Pars Cephalica S. Sympathici) *1*

The **cephalic portion** of the sympathetic system begins as the **internal carotid nerve,**which appears to be a direct prolongation of the superior cervical ganglion. It is soft in texture, and of a reddish color. It ascends by the side of the internal carotid artery, and, entering the carotid canal in the temporal bone, divides into two branches, which lie one on the lateral and the other on the medial side of that vessel.

The **lateral branch,** the larger of the two, distributes filaments to the internal carotid artery, and forms the **internal carotid plexus.** *2*

The **medial branch** also distributes filaments to the internal carotid artery, and, continuing onward, forms the **cavernous plexus.** *3*

The **internal carotid plexus** (*plexus caroticus internus; carotid plexus*) is situated on the lateral side of the internal carotid artery, and in the *4* plexus there occasionally exists a small gangliform swelling, the **carotid ganglion,** on the under surface of the artery. The internal carotid plexus communicates with the semilunar ganglion, the abducent nerve, and the sphenopalatine ganglion; it distributes filaments to the wall of the carotid artery, and also communicates with the tympanic branch of the glossopharyngeal nerve.

The communicating branches with the abducent nerve consist of one or two filaments which join that nerve as it lies upon the lateral side of the 5
internal carotid artery. The communication with the sphenopalatine ganglion is effected by a branch, the **deep petrosal,**given off from the plexus on the lateral side of the artery; this branch passes through the cartilage filling up the foramen lacerum, and joins the greater superficial petrosal to form the nerve of the pterygoid canal (*Vidian nerve*), which passes through the pterygoid canal to the sphenopalatine ganglion. The communication with the tympanic branch of the glossopharyngeal nerve is effected by the **caroticotympanic,** which may consist of two or three delicate filaments.

The **cavernous plexus** (*plexus cavernosus*) is situated below and medial to that part of the internal carotid artery which is placed by the side of 6
the sella turcica in the cavernous sinus, and is formed chiefly by the medial division of the internal carotid nerve. It communicates with the oculomotor, the trochlear, the ophthalmic and the abducent nerves, and with the ciliary ganglion, and distributes filaments to the wall of the internal carotid artery. The branch of communication with the oculomotor nerve joins that nerve at its point of division; the branch to the trochlear nerve joins it as it lies on the lateral wall of the cavernous sinus; other filaments are connected with the under surface of the ophthalmic nerve; and a second filament joins the abducent nerve.

The **filaments of connection** with the ciliary ganglion *arise* from the anterior part of the cavernous plexus and enter the orbit through the 7
superior orbital fissure; they may join the nasociliary branch of the ophthalmic nerve, or be continued forward as a separate branch.

The **terminal filaments** from the internal carotid and cavernous plexuses are prolonged as plexuses around the anterior and middle cerebral arteries and the ophthalmic artery; along the former vessels, they may be traced to the pia mater; along the latter, into the orbit, where they accompany each of the branches of the vessel. The filaments prolonged on to the anterior communicating artery connect the sympathetic nerves of the right and left sides.

7b. The Cervical Portion of the Sympathetic System

(Pars Cervicalis S. Sympathici) 1

The **cervical portion** of the sympathetic trunk consists of three ganglia, distinguished, according to their positions, as the **superior, middle,** and **inferior ganglia,** connected by intervening cords. This portion receives no white rami communicantes from the cervical spinal nerves; its spinal fibers are derived from the white rami of the upper thoracic nerves, and enter the corresponding thoracic ganglia of the sympathetic trunk, through which they ascend into the neck.

The **superior cervical ganglion** (*ganglion cervicale superius*), the largest of the three, is placed opposite the second and third cervical 2
vertebræ. It is of a reddishgray color, and usually fusiform in shape; sometimes broad and flattened, and occasionally constricted at intervals; it is believed to be formed by the coalescence of four ganglia, corresponding to the upper four cervical nerves. It is in relation, in *front,* with the

sheath of the internal carotid artery and internal jugular vein; *behind,* with the Longus capitis muscle.

Its **branches** may be divided into **inferior, lateral, medial,** and **anterior.** 3

The **Inferior Branch** communicates with the middle cervical ganglion. 4

The **Lateral Branches** (*external branches*) consist of gray rami communicantes to the upper four cervical nerves and to certain of the cranial nerves. Sometimes the branch to the fourth cervical nerve may come from the trunk connecting the upper and middle cervical ganglia. The branches to the cranial nerves consist of delicate filaments, which run to the ganglion nodosum of the vagus, and to the hypoglossal nerve. A filament, the **jugular nerve,** passes upward to the base of the skull, and divides to join the petrous ganglion of the glossopharyngeal, and the jugular ganglion of the vagus. 5

The **Medial Branches** (*internal branches*) are peripheral, and are the**larnygopharyngeal branches** and the **superior cardiac nerve.** 6

The **laryngopharyngeal branches** (*rami laryngopharyngei*) pass to the side of thepharynx, where they join with branches from the glossopharyngeal, vagus, and external laryngeal nerves to form the **pharyngeal plexus.** 7

The **superior cardiac nerve** (*n. cardiacus superior*) *arises* by two or more branches from the superior cervical ganglion, and occasionally receives a filament from the trunk between the first and second cervical ganglia. It runs down the neck behind the common carotid artery, and in front of the Longus colli muscle; and crosses in front of the inferior thyroid artery, and recurrent nerve. The course of the nerves on the two sides then differ. The **right nerve,** at the root of the neck, passes either in front of or behind the subclavian artery, and along the innominate artery to the back of the arch of the aorta, where it joins the deep part of the cardiac plexus. It is connected with other branches of the sympathetic; about the middle of the neck it receives filaments from the external laryngeal nerve; lower down, one or two twigs from the vagus; and as it enters the thorax it is joined by a filament from the recurrent nerve. Filaments from the nerve communicate with the thyroid branches from the middle cervical ganglion. The **left nerve,** in the thorax, runs in front of the left common carotid artery and across the left side of the arch of the aorta, to the superficial part of the cardiac plexus. 8

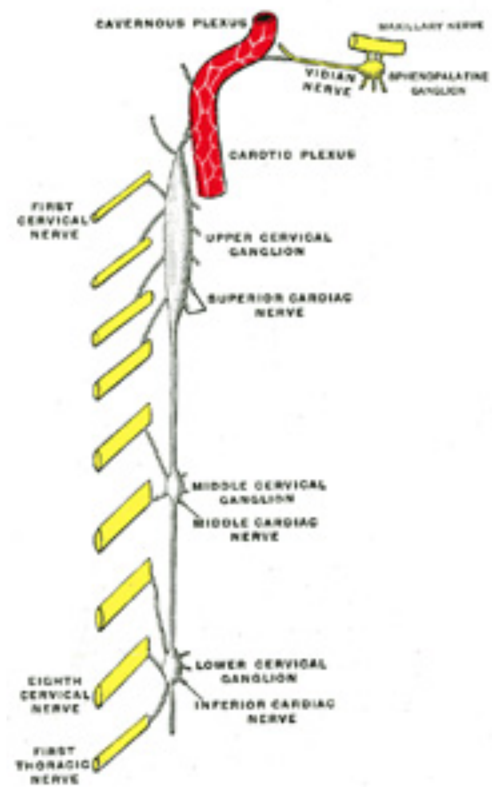


FIG. 844– Diagram of the cervical sympathetic. (Testut.) (See enlarged image)

The **Anterior Branches** (*nn. carotici externi*) ramify upon the common carotid artery and upon the external carotid artery and its branches, forming around each a delicate plexus, on the nerves composing which small ganglia are occasionally found. The plexuses accompanying some of these arteries have important communications with other nerves. That surrounding the external maxillary artery communicates with the submaxillary ganglion by a filament; and that accompanying the middle meningeal artery sends an offset to the otic ganglion, and a second, the **external petrosal nerve,** to the genicular ganglion of the facial nerve. 9

The **middle cervical ganglion** (*ganglion cervicale medium*) is the smallest of the three cervical ganglia, and is occasionally wanting. It is placed opposite the sixth cervical vertebra, usually in front of, or close to, the inferior thyroid artery. It is probably formed by the coalescence of 10 two ganglia corresponding to the fifth and sixth cervical nerves.

It sends gray rami communicantes to the fifth and sixth cervical nerves, and gives off the middle cardiac nerve. 11

The **Middle Cardiac Nerve** (*n. cardiacus medius; great cardiac nerve*), the largest of the three cardiac nerves, *arises* from the middle cervical 12
ganglion, or from the trunk between the middle and inferior ganglia. On the right side it descends behind the common carotid artery, and at the root of the neck runs either in front of or behind the subclavian artery; it then descends on the trachea, receives a few filaments from the recurrent nerve, and joins the right half of the deep part of the cardiac plexus. In the neck, it communicates with the superior cardiac and recurrent nerves. On the left side, the middle cardiac nerve enters the chest between the left carotid and subclavian arteries, and joins the left half of the deep part of the cardiac plexus.

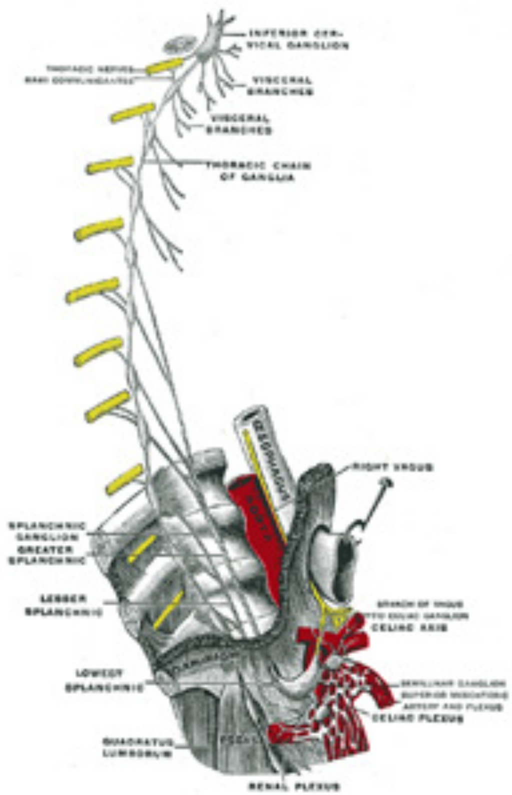


FIG. 845– Plan of right sympathetic cord and splanchnic nerves. (Testut.) (See enlarged image)

The **inferior cervical ganglion** (*ganglion cervicale inferius*) is situated between the base of the transverse process of the last cervical vertebra 13
and the neck of the first rib, on the medial side of the costocervical artery. Its form is irregular; it is larger in size than the preceding, and is frequently fused with the first thoracic ganglion. It is probably formed by the coalescence of two ganglia which correspond to the seventh and eighth cervical nerves. It is connected to the middle cervical ganglion by two or more cords, one of which forms a loop around the subclavian artery and supplies offsets to it. This loop is named the **ansa subclavia** (*Vieussenii*).

The ganglion sends gray rami communicantes to the seventh and eighth cervical nerves. 14

It gives off the inferior cardiac nerve, and offsets to bloodvessels. 15

The **inferior cardiac nerve** (*n. cardiacus inferior*) *arises* from either the inferior cervical or the first thoracic ganglion. It descends behind the 16
subclavian artery and along the front of the trachea, to join the deep part of the cardiac plexus. It communicates freely behind the subclavian artery with the recurrent nerve and the middle cardiac nerve.

The **offsets to bloodvessels** form plexuses on the subclavian artery and its branches. The plexus on the vertebral artery is continued on to the basilar, posterior cerebral, and cerebellar arteries. The plexus on the inferior thyroid artery accompanies the artery to the thyroid gland, and communicates with the recurrent and external laryngeal nerves, with the superior cardiac nerve, and with the plexus on the common carotid artery.

7c. The Thoracic Portion of the Sympathetic System

(Pars Thoracalis S. Smypathici) 1

The thoracic portion of the sympathetic trunk (Fig. 846). consists of a series of ganglia, which usually correspond in number to that of the vertebræ; but, on account of the occasional coalescence of two ganglia, their number is uncertain. The thoracic ganglia rest against the heads of the ribs, and are covered by the costal pleura; the last two, however, are more anterior than the rest, and are placed on the sides of the bodies of the eleventh and twelfth thoracic vertebræ. The ganglia are small in size, and of a grayish color. The first, larger than the others, is of an elongated form, and frequently blended with the inferior cervical ganglion. They are connected together by the intervening portions of the trunk.

Two rami communicantes, a white and a gray, connect each ganglion with its corresponding spinal nerve. 2

The *branches from the upper five ganglia* are very small; they supply filaments to the thoracic aorta and its branches. Twigs from the second, 3
third, and fourth ganglia enter the posterior pulmonary plexus.

The *branches from the lower seven ganglia* are large, and white in color; they distribute filaments to the aorta, and unite to form the greater, the 4
lesser, and the lowest splanchnic nerves.

The **greater splanchnic nerve** (*n. splanchnicus major; great splanchnic nerve*) is white in color, firm in texture, and of a considerable size; it is 5
formed by branches from the fifth to the ninth or tenth thoracic ganglia, but the fibers in the higher roots may be traced upward in the sympathetic

trunk as far as the first or second thoracic ganglion. It descends obliquely on the bodies of the vertebræ, perforates the crus of the diaphragm, and ends in the celiac ganglion. A ganglion (**ganglion splanchnicum**) exists on this nerve opposite the eleventh or twelfth thoracic vertebra.

The **lesser splanchnic nerve** (*n. splanchnicus minor*) is formed by filaments from the ninth and tenth, and sometimes the eleventh thoracic ganglia, and from the cord between them. It pierces the diaphragm with the preceding nerve, and joins the aorticorenal ganglion. *6*

The **lowest splanchnic nerve** (*n. splanchnicus imus; least splanchnic nerve*) *arises* from the last thoracic ganglion, and, piercing the diaphragm, ends in the renal plexus. *7*

A striking analogy exists between the splanchnic and the cardiac nerves. The cardiac nerves are three in number; they *arise* from all three cervical ganglia, and are distributed to a large and important organ in the thoracic cavity. The splanchnic nerves, also three in number, are connected probably with all the thoracic ganglia, and are distributed to important organs in the abdominal cavity. *8*

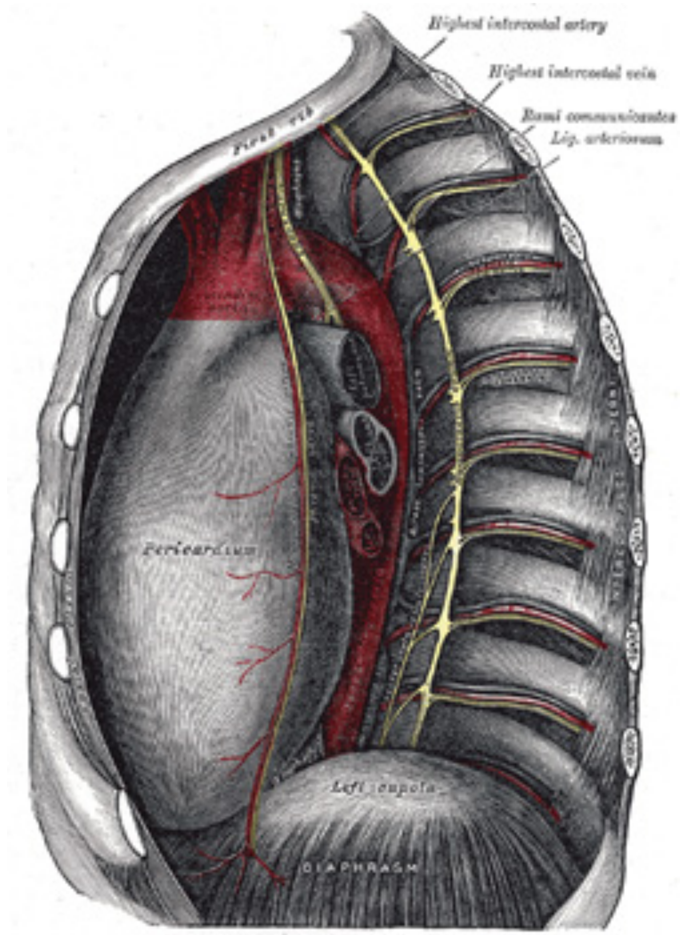


FIG. 846– Thoracic portion of the sympathetic trunk. (See enlarged image)

7d. The Abdominal Portion of the Sympathetic System

(Pars Abdominalis S. Sympathici; Lumbar Portion of Gangliated Cord) 1

The abdominal portion of the sympathetic trunk (Fig. 847). is situated in front of the vertebral column, along the medial margin of the Psoas major. It consists usually of four lumbar ganglia, connected together by interganglionic cords. It is continuous above with the thoracic portion beneath the medial lumbocostal arch, and below with the pelvic portion behind the common iliac artery. The ganglia are of small size, and placed much nearer the median line than are the thoracic ganglia.

Gray rami communicantes pass from all the ganglia to the lumbar spinal nerves. The first and second, and sometimes the third, lumbar nerves send white rami communicantes to the corresponding ganglia. The rami communicantes are of considerable length, and accompany the lumbar arteries around the sides of the bodies of the vertebræ, passing beneath the fibrous arches from which some of the fibers of the Psoas major arise. 2

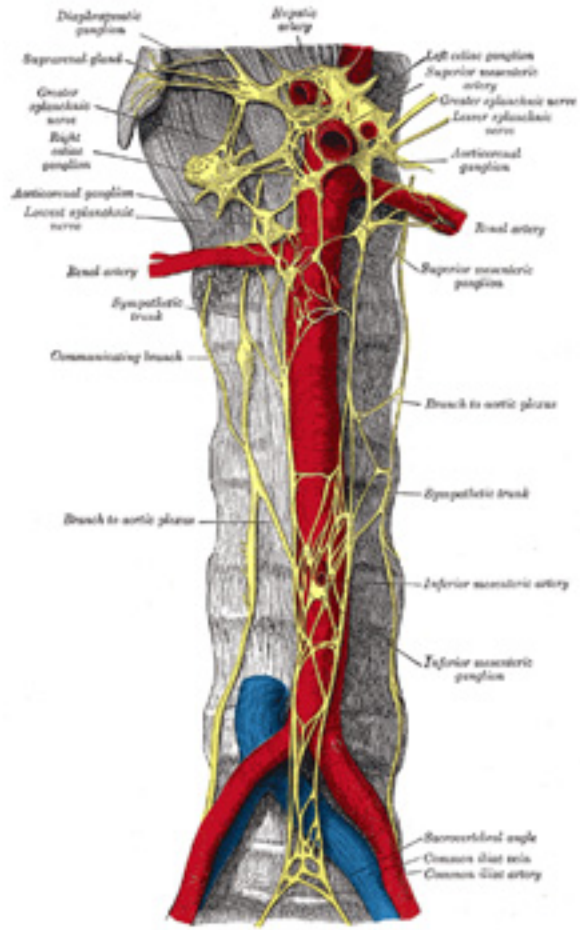


FIG. 847– Abdominal portion of the sympathetic trunk, with the celiac and hypogastric plexuses. (Henle.) (See enlarged image)

Of the **branches of distribution,** some pass in front of the aorta, and join the aortic plexus; others descend in front of the common iliac arteries, 3
and assist in forming the hypogastric plexus.

7e. The Pelvic Portion of the Sympathetic System

(Pars Pelvina S. Sympathici) 1

The pelvic portion of each sympathetic trunk is situated in front of the sacrum, medial to the anterior sacral foramina. It consists of four or five small sacral ganglia, connected together by interganglionic cords, and continuous above with the abdominal portion. Below, the two pelvic sympathetic trunks converge, and end on the front of the coccyx in a small ganglion, the **ganglion impar.**

Gray rami communicantes pass from the ganglia to the sacral and coccygeal nerves. No white rami communicantes are given to this part of the gangliated cord, but the visceral branches which arise from the third and fourth, and sometimes from the second, sacral, and run directly to the pelvic plexuses, are regarded as white rami communicantes. 2

The **branches of distribution** communicate on the front of the sacrum with the corresponding branches from the opposite side; some, from the first two ganglia, pass to join the pelvic plexus, and others form a plexus, which accompanies the middle sacral artery and sends filaments to the **glomus coccygeum** (*coccygeal body*).

1F. The Great Plexuses of the Sympathetic System

The great plexuses of the sympathetic are aggregations of nerves and ganglia, situated in the thoracic, abdominal, and pelvic cavities, and named the **cardiac, celiac,** and**hypogastric plexuses.** They consist not only of sympathetic fibers derived from the ganglia, but of fibers from the medulla spinalis, which are conveyed through the white rami communicantes. From the plexuses branches are given to the thoracic, abdominal, and pelvic viscera. 1

The Cardiac Plexus (Plexus Cardiacus)(Fig. 838).—The **cardiac plexus** is situated at the base of the heart, and is divided into a **superficial part,** which lies in the concavity of the aortic arch, and a **deep part,** between the aortic arch and the trachea. The two parts are, however, closely connected. 2

The **superficial part of the cardiac plexus** lies beneath the arch of the aorta, in front of the right pulmonary artery. It is formed by the superior cardiac branch of the left sympathetic and the lower superior cervical cardiac branch of the left vagus. A small ganglion, the **cardiac ganglion of Wrisberg,** is occasionally found connected with these nerves at their point of junction. This ganglion, when present, is situated immediately beneath the arch of the aorta, on the right side of the ligamentum arteriosum. The superficial part of the cardiac plexus gives branches (*a*) to the deep part of the plexus; (*b*) to the anterior coronary plexus; and (*c*) to the left anterior pulmonary plexus. 3

The **deep part of the cardiac plexus** is situated in front of the bifurcation of the trachea, above the point of division of the pulmonary artery, and behind the aortic arch. It is formed by the cardiac nerves derived from the cervical ganglia of the sympathetic, and the cardiac branches of the vagus and recurrent nerves. The only cardiac nerves which do not enter into the formation of the deep part of the cardiac plexus are the 4 superior cardiac nerve of the left sympathetic, and the lower of the two superior cervical cardiac branches from the left vagus, which pass to the superficial part of the plexus.

The branches from the **right half** of the deep part of the cardiac plexus pass, some in front of, and others behind, the right pulmonary artery; the 5
former, the more numerous, transmit a few filaments to the anterior pulmonary plexus, and are then continued onward to form part of the anterior coronary plexus; those behind the pulmonary artery distribute a few filaments to the right atrium, and are then continued onward to form part of the posterior coronary plexus.

The **left half** of the deep part of the plexus is connected with the superficial part of the cardiac plexus, and gives filaments to the left atrium, 6
and to the anterior pulmonary plexus, and is then continued to form the greater part of the posterior coronary plexus.

The **Posterior Coronary Plexus** (*plexus coronarius posterior; left coronary plexus*) is larger than the anterior, and accompanies the left 7
coronary artery; it is chiefly formed by filaments prolonged from the left half of the deep part of the cardiac plexus, and by a few from the right half. It gives branches to the left atrium and ventricle.

The **Anterior Coronary Plexus** (*plexus coronarius anterior; right coronary plexus*) is formed partly from the superficial and partly from the 8
deep parts of the cardiac plexus. It accompanies the right coronary artery, and gives branches to the right atrium and ventricle.

The Celiac Plexus (Plexus Cœliacus; Solar Plexus) (Figs. 838, 848)—The **celiac plexus,** the largest of the three sympathetic plexuses, is 9
situated at the level of the upper part of the first lumbar vertebra and is composed of two large ganglia, the **celiac ganglia,**and a dense net-work of nerve fibers uniting them together. It surrounds the celiac artery and the root of the superior mesenteric artery. It lies behind the stomach and the omental bursa, in front of the crura of the diaphragm and the commencement of the abdominal aorta, and between the suprarenal glands. The plexus and the ganglia receive the greater and lesser splanchnic nerves of both sides and some filaments from the right vagus, and give off numerous secondary plexuses along the neighboring arteries.

The **Celiac Ganglia** (*ganglia cœliaca; semilunar ganglia*) are two large irregularlyshaped masses having the appearance of lymph glands and 10
placed one on either side of the middle line in front of the crura of the diaphragm close to the suprarenal glands, that on the right side being placed behind the inferior vena cava. The upper part of each ganglion is joined by the greater splanchnic nerve, while the lower part, which is segmented off and named the **aorticorenal ganglion,** receives the lesser splanchnic nerve and gives off the greater part of the renal plexus.

The secondary plexuses springing from or connected with the celiac plexus are the 11

Phrenic.	Renal.
Hepatic.	Spermatic.
Lienal.	Superior mesenteric.
Superior gastric.	Abdominal aortic.
Suprarenal.	Inferior mesenteric.

The **phrenic plexus** (*plexus phrenicus*) accompanies the inferior phrenic artery to the diaphragm, some filaments passing to the suprarenal 12
gland. It *arises* from the upper part of the celiac ganglion, and is larger on the right than on the left side. It receives one or two branches from the phrenic nerve. At the point of junction of the right phrenic plexus with the phrenic nerve is a small ganglion (**ganglion phrenicum**). This plexus distributes branches to the inferior vena cava, and to the suprarenal and hepatic plexuses.

The **hepatic plexus** (*plexus hepaticus*), the largest offset from the celiac plexus, receives filaments from the left vagus and right phrenic nerves. It accompanies the hepatic artery, ramifying upon its branches, and upon those of the portal vein in the substance of the liver. Branches from this plexus accompany all the divisions of the hepatic artery. A considerable plexus accompanies the gastroduodenal artery and is continued as the **inferior gastric plexus** on the right gastroepiploic artery along the greater curvature of the stomach, where it unites with offshoots from the lienal plexus. *13*

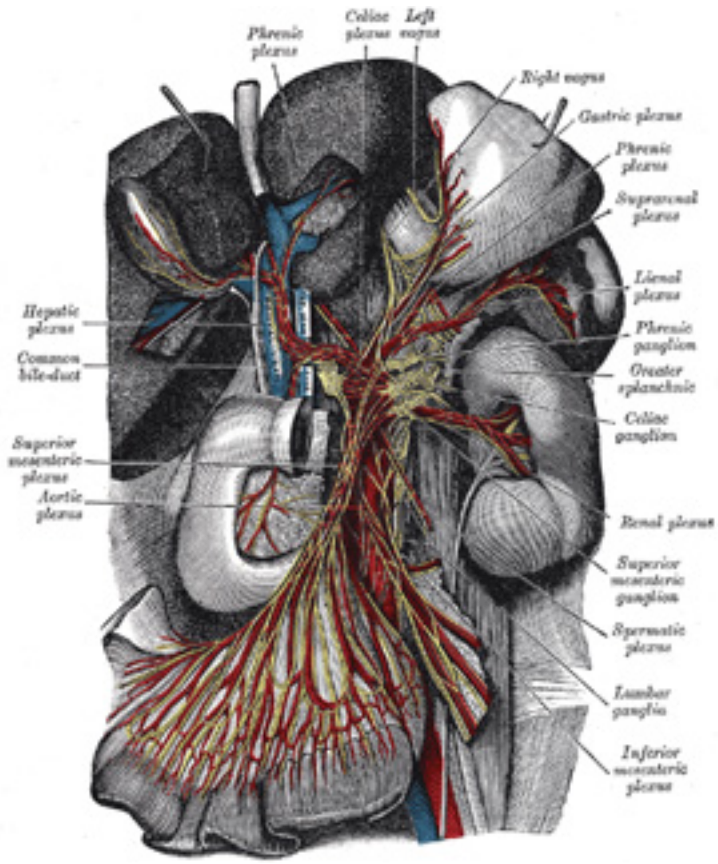


FIG. 848– The celiac ganglia with the sympathetic plexuses of the abdominal viscera radiating from the ganglia. (Toldt.) (See enlarged image)

The **lienal plexus** (*plexus lienalis; splenic plexus*) is formed by branches from the celiac plexus, the left celiac ganglion, and from the right vagus nerve. It accompanies the lienal artery to the spleen, giving off, in its course, subsidiary plexuses along the various branches of the artery. *14*

The **superior gastric plexus** (*plexus gastricus superior; gastric or coronary plexus*) accompanies the left gastric artery along the lesser curvature of the stomach, and joins with branches from the left vagus. *15*

The **suprarenal plexus** (*plexus suprarenalis*) is formed by branches from the celiac plexus, from the celiac ganglion, and from the phrenic and greater splanchnic nerves, a ganglion being formed at the point of junction with the latter nerve. The plexus supplies the suprarenal gland, being distributed chiefly to its medullary portion; its branches are remarkable for their large size in comparison with that of the organ they supply. *16*

The **renal plexus** (*plexus renalis*) is formed by filaments from the celiac plexus, the aorticorenal ganglion, and the aortic plexus. It is joined also by the smallest splanchnic nerve. The nerves from these sources, fifteen or twenty in number, have a few ganglia developed upon them. They accompany the branches of the renal artery into the kidney; some filaments are distributed to the spermatic plexus and, on the right side, to the inferior vena cava. *17*

The **spermatic plexus** (*plexus spermaticus*) is derived from the renal plexus, receiving branches from the aortic plexus. It accompanies the internal spermatic artery to the testis. In the female, the **ovarian plexus** (*plexus arteriæ ovaricæ*) *arises* from the renal plexus, and is distributed to the ovary, and fundus of the uterus. *18*

The **superior mesenteric plexus** (*plexus mesentericus superior*) is a continuation of the lower part of the celiac plexus, receiving a branch from the junction of the right vagus nerve with the plexus. It surrounds the superior mesenteric artery, accompanies it into the mesentery, and divides into a number of secondary plexuses, which are distributed to all the parts supplied by the artery, viz., pancreatic branches to the pancreas; intestinal branches to the small intestine; and ileocolic, right colic, and middle colic branches, which supply the corresponding parts of the great intestine. The nerves composing this plexus are white in color and firm in texture; in the upper part of the plexus close to the origin of the superior mesenteric artery is a ganglion (**ganglion mesentericum superius**). *19*

The **abdominal aortic plexus** (*plexus aorticus abdominalis; aortic plexus*) is formed by branches derived, on either side, from the celiac plexus and ganglia, and receives filaments from some of the lumbar ganglia. It is situated upon the sides and front of the aorta, between the origins of the superior and inferior mesenteric arteries. From this plexus arise part of the spermatic, the inferior mesenteric, and the hypogastric plexuses; it also distributes filaments to the inferior vena cava. *20*

The **inferior mesenteric plexus** (*plexus mesentericus inferior*) is derived chiefly from the aortic plexus. It surrounds the inferior mesenteric artery, and divides into a number of secondary plexuses, which are distributed to all the parts supplied by the artery, viz., the**left colic** and **sigmoid plexuses,** which supply the descending and sigmoid parts of the colon; and the **superior hemorrhoidal plexus,** which supplies the rectum and joins in the pelvis with branches from the pelvic plexuses. *21*

The Hypogastric Plexus (Plexus Hypogastricus)(Fig. 838).—The **hypogastric plexus** is situated in front of the last lumbar vertebra and the promontory of the sacrum, between the two common iliac arteries, and is formed by the union of numerous filaments, which descend on either side from the aortic plexus, and from the lumbar ganglia; it divides, below, into two lateral portions which are named the **pelvic plexuses.** *22*

The Pelvic Plexuses (Fig. 838).—The pelvic plexuses supply the viscera of the pelvic cavity, and are situated at the sides of the rectum in the *23* male, and at the sides of the rectum and vagina in the female. They are formed on either side by a continuation of the hypogastric plexus, by the sacral sympathetic efferent fibers from the second, third, and fourth sacral nerves, and by a few filaments from the first two sacral ganglia. At the points of junction of these nerves small ganglia are found. From these plexuses numerous branches are distributed to the viscera of the pelvis. They accompany the branches of the hypogastric artery.

The **Middle Hemorrhoidal Plexus** (*plexus hæmorrhoidalis medius*) *arises* from the upper part of the pelvic plexus. It supplies the rectum, and 24
joins with branches of the superior hemorrhoidal plexus.

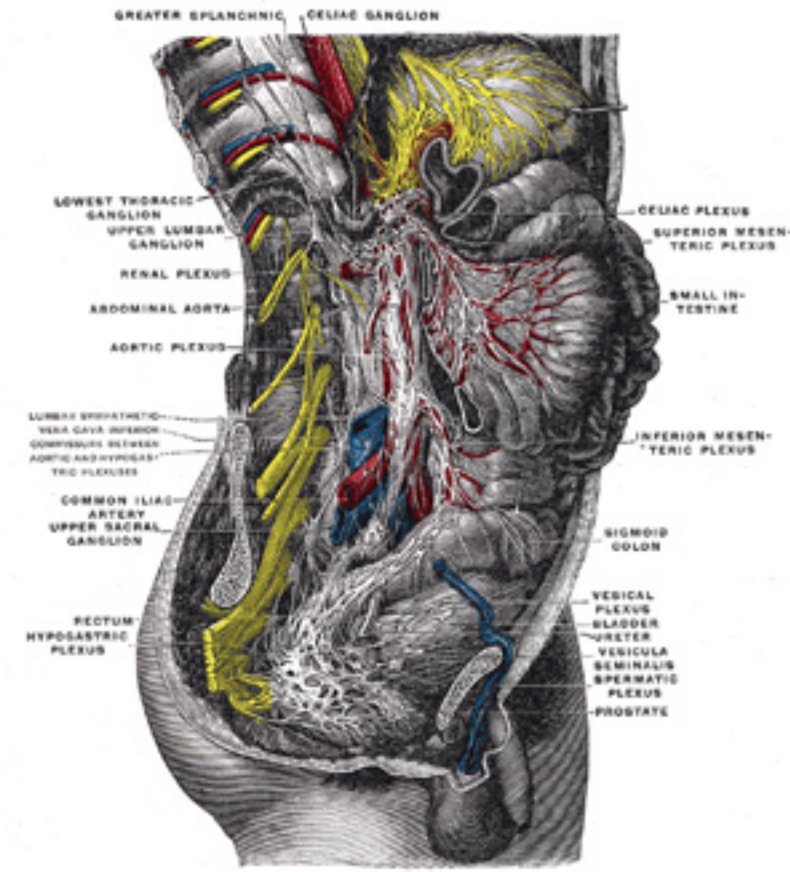


FIG. 849– Lower half of right sympathetic cord. (Testut after Hirschfeld.) (See enlarged image)

The **Vesical Plexus** (*plexus vesicalis*) *arises* from the forepart of the pelvic plexus. The nerves composing it are numerous, and contain a large 25
proportion of spinal nerve fibers. They accompany the vesicle arteries, and are distributed to the sides and fundus of the bladder. Numerous filaments also pass to the vesiculæ seminales and ductus deferentes; those accompanying the ductus deferens join, on the spermatic cord, with branches from the spermatic plexus.

The **Prostatic Plexus** (*plexus prostaticus*) is continued from the lower part of the pelvic plexus. The nerves composing it are of large size. They 26
are distributed to the prostate vesiculæ seminales and the corpora cavernosa of the penis and urethra. The nerves supplying the corpora cavernosa consist of two sets, the lesser and greater cavernous nerves, which arise from the forepart of the prostatic plexus, and, after joining with branches from the pudendal nerve, pass forward beneath the public arch.

The **lesser cavernous nerves** (*nn. cavernosi penis minores; small cavernous nerves*) perforate the fibrous covering of the penis, near its root. 27

The **greater cavernous nerve** (*n. cavernosus penis major; large cavernous plexus*) passes forward along the dorsum of the penis, joins with the 28
dorsal nerve of the penis, and is distributed to the corpora cavernosa.

The **Vaginal Plexus** *arises* from the lower part of the pelvic plexus. It is distributed to the walls of the vagina, to the erectile tissue of the 29
vestibule, and to the clitoris. The nerves composing this plexus contain, like the vesical, a large proportion of spinal nerve fibers.

The **Uterine Plexus** accompanies the uterine artery to the side of the uterus, between the layers of the broad ligament; it communicates with the 30
ovarian plexus.

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