A HANDBOOK OF NERVOUS ANATOMY FOR STUDENTS OF EDUCATION AND PSYCHOLOGY

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Committee on Thesis:

[Signatures]

Date of acceptance August 13, 1940
To Dr. David F. Johnson, chairman of my committee, I wish to express my sincere thanks for his help in putting this material in its present form. Also thanks is due to Dr. P. D. Wilkinson and Dr. R. A. Acher for their suggestions and encouragement toward attempting this type of thesis.

I would like to pay tribute here to the late Dr. Fred Donaghy who gave me my first lessons in neurology, and to Dr. Elizabeth Crosby of the department of anatomy of the University of Michigan from whose lecture notes much of this material was taken.

F.B.

Terre Haute
August, 1940
As we go up the scale of animal life from ineffectual crawling things toward the higher and more enterprising citizens of the animal kingdom the increase in size and complexity of brain gives a rough indicator of improvement in the range and efficiency of their behavior, their competence in adjusting their lives to the hazards of an unfriendly world.

---C. Judson Herrick
The Thinking Machine
1929
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Chapter I

INTRODUCTION

There seems to be a definite need in the field of educational psychology for some accurate material on human nervous anatomy which may be used by beginning students in that work. The literature in neurology and nervous anatomy is voluminous and scattered. Much of the more recent material is still in unpublished or periodical form. It is therefore unreasonable to expect that it can be readily understood by students on the undergraduate level.

It will be the purpose of this collection to bring together and make available such essentials as are now deemed necessary to the formation of a sound psychological background for modern education.

There has been no conscious attempt toward over-simplification, although, naturally, the work is limited in its scope. Only such essentials have been included as seem to have a direct bearing on the study of human behavior. This has, of course, at times involved laying of an almost tedious background of fundamentals.

Behavior is generally used by biologists to call attention to a class of characteristics which conspicuously distinguish animals from plants and non-living things.¹

¹Hogben, Lancelot, Science For The Citizen, 1938
One obvious characteristic of an animal as such is its great reactivity. It is changing its shape, its position, its hue, its texture continually and reversibly. Often these changes can be traced to relatively insignificant events in its surroundings, and its great receptivity to slight changes in its neighborhood is another characteristic which distinguishes it from a relatively complicated man-made machine. A flash of light, a draught of cold air, a soft sound, or a slight jerk which would have no effect on the motion or appearance of a motorcycle may have drastic effects on a racehorse. Knowing how to control an animal is therefore vastly more complicated than knowing how to control a single machine. The problem of animal behavior is to find out where the switches and self-starting devices are placed, where the fuse boxes are located, how the wires are connected, and what sort of work each part carries out.

Examples of simple reflexes which can be easily studied in our own bodies are:

<table>
<thead>
<tr>
<th>Action</th>
<th>Receptor</th>
<th>Effector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quickening of the heart when its blood supply increases</td>
<td>Nerve-endings in right atrium</td>
<td>Heart muscle</td>
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<tr>
<td>Contraction of pupil in strong light</td>
<td>Retina</td>
<td>Plain muscle of iris</td>
</tr>
<tr>
<td>Secretion of saliva on smelling food</td>
<td>Olfactory nerve</td>
<td>Salivary glands</td>
</tr>
<tr>
<td>Knee jerk</td>
<td>&quot;End organs&quot; in tendon</td>
<td>Extensor muscles of thigh</td>
</tr>
</tbody>
</table>
The chief means of transmission of disturbances set up in the receptor organ to the effector organs that carry out the ensuing responses is the nervous system.

That the nerves are the pathway of communication involved in the co-ordination of the reflex stimulus with its appropriate response was recognized by some of the earlier Alexandrian surgeons such as Herophilus (300 B.C.). It was established by the experimental work of Vesalius, who observed that cutting nerves sufficed to paralyse all movements. In the succeeding century of medical research the essential part played by the central nervous system (spinal cord and brain), as opposed to the peripheral nerves which carry impulses from the receptor organs to it and impulses from it to the effector organs, was discovered.

Little more than this was known before the closing years of the eighteenth century. All authentic knowledge about nervous co-ordination available at that time could be demonstrated by consecutive experiments lasting less than half an hour. These agencies especially contributed to the knowledge which has accumulated since then. The first was the discovery of current electricity. The second was the revival of microscopic inquiry which accompanied the introduction of achromatic lenses. The third was the impact of evolutionary speculation.
Chapter II

THE NEURON

The structural unit of the nervous system is the neuron. A neuron may be defined as a nerve cell body or perikaryon with all of its processes including their terminations. The processes of the nerve cell are of two kinds: (1) axons (2) dendrites.

The dendrite is a process which conducts impulses toward the cell body. The axon conducts impulses away from the cell body. In general, nerve cells have one and only one axon or neuraxis. Several dendrites usually arise from a single cell, (see figure).

A cell such as shown in the figure is a unipolar cell. Ganglion cells are of this kind. There are a few bipolar cells; for example, the neurons of the olfactory nerve. Some of the cells of the cerebellum have two processes; one a neuraxis, the other a dendrite.

Others are multipolar cells with two or more dendrites; for example those found in the ventral horn of the spinal cord.

Histological Structure of Nerve Tissue. The nerve cell has all the parts which are characteristic of other animal cells except the centrosome. The nerve cell bodies have no definite pattern, but they are variously shaped. Certain elements are, however, characteristic of the cells of nerve tissue: (1) fibrillar substance which runs to all parts of the neuron, also called neuro-fibrils, (2) neuro-plasm, (3) Nissl granules or
trigoid substance which is believed by some observers not to be present in the living cell as such. In certain pathological conditions this substance is broken down in a process known as chromatolysis.

The nucleus of the nerve cell takes a pale stain in prepared material. This can be attributed to the lack of any great amount of chromatin material. Since there is no reproduction of nerve cells (no cell division) there is no need for any large amount of chromatin.

Nerve cells of course vary in size, but for basis of comparison a cell body in the ventral horn gray of the cord would measure roughly 50 microns in diameter. This, quite naturally, does not take into consideration the axon or dendrites of a complete neuron.

The axon or neuraxis as has been mentioned before is that process of the nerve cell which conducts impulses away from the cell body. The neuraxis is a part of the anatomic nerve. By the anatomic nerve we mean that white cord-like structure which can be seen in gross dissections. The anatomic nerve is made up of many axons and dendrites bound together in a manner which will be described later.

**Kinds of Nerve Cells**

Nerve cells vary in size from 4-6 microns to 100-150 microns. The larger of these cells are found in the lower region in the
Section through a spinal nerve and the spinal cord to illustrate the chief functional types of peripheral nerve-fibers.

**Fig. 1**

Primary motor neuron

**Fig. 2**

Somatic afferent fiber
Visceral afferent fiber
Dorsal root
Spinal ganglion
Dorsal ramus
Ventral ramus
Ramus communicans
Sympathetic ganglion
Visceral efferent fiber
Somatic efferent fiber
Ventral root
Postganglionic fiber
Viscus
spinal cord. The length of the process leading to or from a cell body varies greatly. For instance it may extend for only a fraction of a millimeter within the cord or it may extend from the gray matter of the cord to the sole of the foot.

**Cells of the cerebrum.** The cells of the cerebrum are relatively large and more or less pyramidal in shape. This type of cell is characteristic of the cerebellar cortex.

**Cells of the cerebellum.** The nervous tissue of the cerebellum is characterized by large, branching, flask-shaped Perkinje cells. These cells have all the characteristics of other nerve cells except that there is extensive branching over a large area. The dendrites of the Perkinje cell branch out flat in one plane. In microscopic examination of material from the cerebellum it is possible to see synaptic connections.

**Sympathetic cells.** These cells are located outside of the central nervous system in the sympathetic ganglia and must receive an impulse from the C.N.S. by way of pre-ganglionic fibers. They are small, stellate or star-shaped cells containing fine Nissl granules and having a non-medulated neuraxis.

**Sensory cells of the dorsal root ganglia.** The cell bodies of these neurons are round and flat. These are unipolar units which are arranged compactly in the dorsal root ganglia. The dendrite comes from the periphery carrying sensory impulses, and the axon comes out of the cell going into the dorsal horn gray to make synaptic connections for simple reflexes or impulses to
the higher centers. Each of these cell bodies is encased in a thin capsule and the glomerulus is encased in an neuralemma sheath.

The peripheral nerve. This is the anatomical structure seen in gross dissection made up of both sensory and motor fibers bound together in close unity. Starting with the smallest structural unit within the peripheral nerve we have the axons and dendrites of many nerve cells closely bound together in a bundle or funiculus. Around and between each of these axons and dendrites is a delicate connective tissue called endoneurium. Around each of the funiculi is a covering of dense perineurium.

Several of these funiculi are bound together by a covering of epineurium to make up the peripheral nerve. In addition to carrying motor and sensory fibers the peripheral nerve also carries sympathetic fibers.

Nerve fibers may be classified on one basis according to whether they are medulated or non-medulated. A medullary sheath is a lipoid (fat-like) covering over the neuraxis of certain neurones. The following outline will indicate which fibers are medulated and which are not.

Sensory

1. Exteroceptive
   a. Pain—non-medullated
   b. Temperature—light medullation
   c. Tactile—heavy medullation

2. Proprioceptive (fibers which carry back impulses of pressure, tension and position in space of muscles and tendons)—heavily medullated
3. Interoceptive (impulses from the viscera)--lightly medullated.

Motor

1. Fibers to voluntary muscle--medullated

2. Fibers to involuntary muscle in blood vessels, muscles at the base of the hair, and glands (post-ganglionic sympathetic)--lightly or non-medullated

Nerve Terminations

Sensory endings (receptors) The terminations or what might be more properly called the beginnings of sensory fibers are of two kinds (a) free, and (b) capsulated. The "free" sensory endings may be on a medullated or non-medullated fiber. There are a number of branchings of the fiber without losing the characteristic sheaths. The medullary sheath is lost first and the neurilemma is retained. At the point of termination the neurilemma is also lost and the naked axis cylinder terminates. This type of ending spreads over a relatively wide area and may terminate in connective tissue, between epithelial cells, or on a cell.

The capsulated receptors are of three kinds. Those with (1) thin capsules, (2) thick capsules, and (3) capsules with other tissue included.

Characteristic of the thinly capsulated ending is Meisner's tactile capsule which is located just below the epithelium in areas where there is no hair. Another ending with a thin capsule is the circular end-bulb of Krause located in the conjunctiva of the eye. (Figure 3)
ENCAPSULATED SENSORY ENDINGS

(OOGLI, SALA, BÖHM-DAVIOFF, HUBER)

ORIGIN, COURSE, AND TERMINATION OF THE MEDIAL LEMNISCUS

FIG. 3

FIG. 4
An example of the thickly capsulated ending is the Pacinian corpuscle. These endings register deep pressure and are located around joints, deep in dermis, and in the mesenteries, (see figure).

Neuromuscular and neurotendinous spindles are examples of the third type of capsulated endings. These terminations are located in muscle fasciculi on proprioceptive fibers which carry impulses indicating a state of tension and tone of the muscle or tendon.

Motor endings (effectors). Four types of effector endings are known. (1) Termination on voluntary muscle, (2) termination on involuntary muscle, (3) on cardiac muscle, and (4) on glandular cells.

In the case of voluntary muscle there is a branching termination on the individual muscle fibers. Huber believed that terminal branches did not contact the muscle fibrils. His investigations did lead him to believe, however, that each muscle fiber had a nerve termination on it.

The terminations on involuntary fibers is much the same as that for voluntary muscle, but it is greatly simplified.

The nerve endings in cardiac muscle are best distinguished by their branching over a wider area in the muscle fibers.

Motor terminations in glandular structure takes the form of a network on glandular cells.

Physiology of the Neuron

Following are some of the phenomenon characteristic of the nerve cell and its processes:
(1) The nerve impulse is a chemical process; four phases of a chemical reaction characteristic of nerve impulses:
   a. Consumption of oxygen
   b. Production of carbon dioxide
   c. Liberation of heat
   d. A refractory period which is a lapse during the process of recovery

(2) The chromophil substance of Nissl bodies are probably oxidized and the energy used in promoting the nerve impulse.

(3) Nerve tissue obeys the "all or none" rule which means that if a stimulation is sufficient to produce any response, that response will be the maximum possible.

(4) A repeated sub-minimal stimulus will result in a disturbance of nervous tension and eventually a response will result. This is known as summation.

(5) Nerve tissue has the property of independent irritability. All fibres transmit exactly the same type of impulse. A response will occur regardless of the type of stimulus applied.

(6) The "action current" or wave of negativity which travels along the surface of a nerve fibre is not the nerve impulse.

**Fatigue in Nerve Cells.** Two types of fatigue may be distinguished in nerve cells. (1) Fatigue of excitation which results from the utilization of the reserve supply in nerve cells, and (2) fatigue of depression which results from an accumulation of wastes. Some of these waste products are carbonic, lactic and phosphoric acids.
Degeneration and Regeneration of Nerve Fibers. If a nerve fiber is severed, the distal portion will degenerate completely. The axone breaks into granular fragments and the myelin breaks into fatty droplets. Both are absorbed by the blood. Neurilemma cells begin mitotic division and increase in number. A multinucleated mass of protoplasm results when the cell boundaries are destroyed and cytoplasm of the cells fuse. The protoplasm resolves into bands in the place of the fiber. The proximal end of the nerve begins to regenerate along the original path of the fiber which has been preserved by the neurilemma cells. Myelinated nerve fibers of the brain and cord do not have neurilemma and hence cannot regenerate. Fibers lacking neurilemma cannot regenerate.
Chapter III

THE SPINAL CORD

The spinal cord begins where it passes through the foramen magnum of the skull and extends down through the vertebral column into the lumbar vertebrae. It is interesting to note that the bony column grew faster than the cord and therefore through the lower vertebrae the cord is broken up into several strands known as the cauda equina (horse's tail) and the lower spinal nerves branch off the cauda at appropriate levels.

Given off laterally from the cord are 31 pairs of spinal nerves. These anatomical nerves are classified in the following way:

- 8 pairs cervical spinal nerves
- 12 pairs thoracic spinal nerves
- 5 pairs lumbar spinal nerves
- 5 pairs sacral spinal nerves
- 1 pair coccygeal spinal nerves

Examination of a cross section of a spinal cord at any level will reveal that it is made up to two kinds of matter, white and gray. In the central portion of the cord one will observe a butterfly or H-shaped structure which is the gray matter. This gray matter is made up mainly of cell bodies for fiber tracts which have their cells of origin within the cord. The white matter is made up of nerve paths running to and from the brain, (see figure 5)
CROSS-SECTION THROUGH ONE-HALF OF THE SPINAL CORD TO ILLUSTRATE THE ARRANGEMENT OF THE FUNICULI OF WHITE MATTER AND THE COLUMNS OF GRAY MATTER

FIG. 5

SECTION THROUGH THE SPINAL NERVE TO ILLUSTRATE A SIMPLE REFLEX ARC

FIG. 6
Variations in the cross-sectional area of the cord will be noted upon gross examination. Two enlargements are especially noticeable. These are located between the fourth cervical and first thoracic spinal nerves (the cervical enlargement), and between the second lumbar and third sacral (lumbo-sacral enlargement). These positions will of course be recognized as those areas where there are the most muscles to be supplied, namely those of the arms and legs. The nerves in these regions anastomose to form the brachial and lumbar plexuses respectively.

The following chart which indicates some of the principal ascending tracts of the cord may need some explanation. Column 2 indicates graphically the position which that tract occupies within the cord. A given fibre tract occupies the same relative position in the cord at every level at which it appears. It must be remembered, however, that all tracts do not run the entire length of the cord. This will be more clearly indicated when a knowledge of their cells of origin is gained.

Column 3 indicates the cells of origin of the ascending and some of the closely associated descending tracts of the cord. For instance the tract Fasciculus Gracilis has its nucleus of origin in the dorsal root ganglia of the lumbar and sacral regions, therefore, that tract will be found in the position indicated in Column 1 at all levels above the sacral region. Column 4 indicates whether the tract is ascending or descending. Column 5 indicates whether the fibres of that tract are crossed or uncrossed, that is,
## ASCENDING (with certain closely associated descending) TRACTS OF CORD

<table>
<thead>
<tr>
<th>NAME</th>
<th>POSITION</th>
<th>NUCLEUS OF ORIGIN</th>
<th>ASCENDING DESCENDING</th>
<th>CROSSED UNCROSSED</th>
<th>EXTENT IN CORD</th>
<th>NUCLEUS OF TERMINATION</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasciculus gracilis</td>
<td><img src="image1" alt="Image" /></td>
<td>dorsal root ganglia in lumbar and sacral sp. ganglion</td>
<td><img src="image2" alt="Image" /></td>
<td>—</td>
<td>entire</td>
<td>nucleus gracilis (medulla)</td>
<td>proprioceptive tactile (2 point discrimination)</td>
</tr>
<tr>
<td>Fasciculus cuneatus</td>
<td><img src="image3" alt="Image" /></td>
<td>ganglia above vaste cerv. and thoracic</td>
<td><img src="image4" alt="Image" /></td>
<td>—</td>
<td>lower thoracic up</td>
<td>nucleus cuneatus (medulla)</td>
<td>&quot;</td>
</tr>
<tr>
<td>Triangular field</td>
<td><img src="image5" alt="Image" /></td>
<td>dorsal root ganglia of lower 1/3-1/3 cord</td>
<td><img src="image6" alt="Image" /></td>
<td>—</td>
<td>lower 1/4 1/3 cord</td>
<td>vent. horn sp. cord gray</td>
<td>proprioceptive for inter-segmented reflexes</td>
</tr>
<tr>
<td>Oval field</td>
<td><img src="image7" alt="Image" /></td>
<td>dorsal root ganglia middle 1/3-1/2</td>
<td><img src="image8" alt="Image" /></td>
<td>—</td>
<td>middle 1/3-1/2 cord</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Fasciculus inter-fascicularis</td>
<td><img src="image9" alt="Image" /></td>
<td>dorsal root ganglia upper 1/3</td>
<td><img src="image10" alt="Image" /></td>
<td>—</td>
<td>upper 1/3</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Dorsal spino-cerebellar</td>
<td><img src="image11" alt="Image" /></td>
<td>dorsal nucleus of Clarke</td>
<td><img src="image12" alt="Image" /></td>
<td>largely</td>
<td>second lumbar up</td>
<td>cerebellum</td>
<td>proprioceptive</td>
</tr>
</tbody>
</table>

1. ASCENDING (with certain closely associated descending) TRACTS OF CORD
2. Fasciculus gracilis: dorsal root ganglia in lumbar and sacral sp. ganglion, crossed, entire, nucleus gracilis (medulla), proprioceptive tactile (2 point discrimination).
3. Fasciculus cuneatus: ganglia above vaste cerv. and thoracic, crossed, lower thoracic up, nucleus cuneatus (medulla).
4. Triangular field: dorsal root ganglia of lower 1/3-1/3 cord, uncrossed, lower 1/4 1/3 cord, vent. horn sp. cord gray, proprioceptive for inter-segmented reflexes.
5. Oval field: dorsal root ganglia middle 1/3-1/2, uncrossed, middle 1/3-1/2 cord, ".
6. Fasciculus inter-fascicularis: dorsal root ganglia upper 1/3, uncrossed, upper 1/3, ".
7. Dorsal spino-cerebellar: dorsal nucleus of Clarke, largely, second lumbar up, cerebellum, proprioceptive.
### Ascending (with certain closely associated descending) Tracts of Cord (Continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Nucleus of origin</th>
<th>Ascending Descending</th>
<th>Crossed Uncrossed</th>
<th>Extent in cord</th>
<th>Nucleus of termination</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsal spinocerebellar</td>
<td><img src="image.png" alt="Image" /></td>
<td>dorsal nucleus of Clarke</td>
<td>↑</td>
<td>largely</td>
<td>2nd lumbar up</td>
<td>cerebellum</td>
<td>proprioceptive</td>
</tr>
<tr>
<td>Ventral spinocerebellar</td>
<td><img src="image.png" alt="Image" /></td>
<td>dorsal funiculär (both sides)</td>
<td>↑</td>
<td></td>
<td>entire-(greatest number in region of extremities)</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Spino-olivary</td>
<td><img src="image.png" alt="Image" /></td>
<td>&quot;</td>
<td>↑</td>
<td>+</td>
<td>cervical cord</td>
<td>inferior olivary nucleus (medulla)</td>
<td>&quot;</td>
</tr>
<tr>
<td>Spino-vestibular</td>
<td><img src="image.png" alt="Image" /></td>
<td>&quot;</td>
<td>↑</td>
<td>+</td>
<td>entire</td>
<td>inferior vestibular nucleus (medulla)</td>
<td>proprioceptive</td>
</tr>
<tr>
<td>Exteroceptive</td>
<td><img src="image.png" alt="Image" /></td>
<td>&quot;</td>
<td>+</td>
<td></td>
<td>entire</td>
<td>&quot;</td>
<td>Exteroceptive</td>
</tr>
<tr>
<td>Dorso-lateral fasciculus (Lissauer's)</td>
<td><img src="image.png" alt="Image" /></td>
<td>all dorsal foot ganglia</td>
<td>↑</td>
<td></td>
<td>one segment above and below entrance; tract thin cord</td>
<td>stellate cells in dorsal gray</td>
<td>pain temperature</td>
</tr>
<tr>
<td>Lateral spino-thalamic</td>
<td><img src="image.png" alt="Image" /></td>
<td>dorsal funiculär and stellate cells</td>
<td>↑ (mixed primitive uncrossed)</td>
<td></td>
<td>entire</td>
<td>Thalamus</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
## Ascending (with certain closely associated descending) Tracts of Cord

(Continued)

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Nucleus of origin</th>
<th>Ascending</th>
<th>Descending</th>
<th>Crossed</th>
<th>Uncrossed</th>
<th>Extent in cord</th>
<th>Nucleus of termination</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventral spino-Thalamic</td>
<td><img src="image1" alt="Diagram" /></td>
<td>dorsal funicular cells</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td>entire</td>
<td>Thalamus</td>
<td>Tactile (Light pressure)</td>
</tr>
<tr>
<td>Spino-tectal</td>
<td><img src="image2" alt="Diagram" /></td>
<td>&quot;</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
<td>entire</td>
<td>Optic-tectum</td>
<td>general sensibility</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>pain, temp.</td>
</tr>
<tr>
<td>Secondary ascending visceral tract</td>
<td><img src="image3" alt="Diagram" /></td>
<td>visceral grey</td>
<td><img src="image4" alt="Diagram" /></td>
<td></td>
<td></td>
<td></td>
<td>entire</td>
<td></td>
<td>visceous sensations</td>
</tr>
<tr>
<td>NAME</td>
<td>POSITION</td>
<td>NUCLEUS OF ORIGIN</td>
<td>ASCENDING DESCENDING</td>
<td>CROSSED UNCROSSED</td>
<td>NUCLEUS OF TERMINATION</td>
<td>EXTENT IN CORD</td>
<td>FUNCTION</td>
<td></td>
<td></td>
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<td>-----------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral cortico-spino</td>
<td><img src="image1.png" alt="Image" /></td>
<td>Motor cortex</td>
<td>↓</td>
<td>Motor decussation</td>
<td>Ventral horn neuron</td>
<td>Entire</td>
<td>Voluntary motor control particularly extremities</td>
<td></td>
<td></td>
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<td>Ventral Cortico-spinal</td>
<td><img src="image2.png" alt="Image" /></td>
<td>Motor cortex</td>
<td>↓</td>
<td>+</td>
<td>Ventral horn motor neuron</td>
<td>To or into cord</td>
<td>Lost to neurons of trunk muscles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubro-spinal</td>
<td><img src="image3.png" alt="Image" /></td>
<td>Red nucleus (cerebellum)</td>
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<td>Ventral horn neuron</td>
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<td>Major efferent path from higher center</td>
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<td>Lateral tectal</td>
<td><img src="image4.png" alt="Image" /></td>
<td>Optic tectum (sup. colliculus of cerebrum)</td>
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<td>Ventral horn neuron</td>
<td>Entire</td>
<td>Visual, exteroceptive reflexes</td>
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<td>Medio-Tecto-spinal</td>
<td><img src="image5.png" alt="Image" /></td>
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<td>Interm. Cervical</td>
<td>Interm. lateral thoracic</td>
<td>Re-ulatory--dialation of pupils Neck reflexes</td>
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<td>Vestibulo-spinal lateral</td>
<td><img src="image6.png" alt="Image" /></td>
<td>Lat. &amp; med. nuclei</td>
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<td>Cervical cord</td>
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**DESCENDING TRACTS**
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<th>Nucleus of origin</th>
<th>Ascending Descending</th>
<th>Crossed Uncrossed</th>
<th>Nucleus of Termination</th>
<th>Extent in cord</th>
<th>Function</th>
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<tr>
<td>Medio-vestibular spinal</td>
<td>![Diagram]</td>
<td>Lat. &amp; med. nuclei</td>
<td>↓</td>
<td>+</td>
<td>Cervical cord</td>
<td>Cervical cord</td>
<td>Maintenance of equilibrium</td>
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<tr>
<td>Olivo-spinal</td>
<td>![Diagram]</td>
<td>Inferior olivary nucleus</td>
<td>↓</td>
<td>+</td>
<td>Ventral horn neurons cervical</td>
<td>Cervical cord</td>
<td>Supplies neck muscles</td>
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</table>
whether it has its nucleus of termination in the brain on the same or opposite side of that of the nucleus of origin in the cord.

Column 6 indicates the extent of the given tract through the cord. This, of course, could be judged from the location of the nucleus of origin since all the ascending tracts run from the origin to the brain. Column 7 indicates where in the brain the given tract has its termination. For instance, the medulla, cerebellum, or thalamus. Column 8 is self-explanatory.

Anatomy of the Cord

In order to understand the functions of the cord and be able to locate the nuclei of origin and termination for the fiber tracts of the cord it is necessary to know some of the simpler anatomical landmarks of the spinal cord.

Throughout its entire length the spinal cord has the same three meninges or coverings which are also found over the brain from the outside toward the inside; these are dura mater, arachnoid, pia mater.

The white matter which surrounds the gray matter of the cord is divided, for purposes of fiber tract location, into four columns or funiculi; the dorsal or posterior funiculus, two lateral funiculi and ventral or anterior funiculus, (see figure).

The gray matter of the cord consists of cell bodies of neurons, dendritic processes, and neuraxons in synaptic relations. Six regions or "horns" are used in locating cell bodies within the
gray matter. These are two dorsal horns or columns, two lateral horns, and two ventral, (see figure).

Nuclear Groups Within the Gray Matter of the Cord

**Dorsal gray column**

1. **Stellate cells**—these are small multipolar cells located at the apex of the dorsal horn and found at all levels of the cord. They have a very short thinly medullated neuraxis. They receive pain and temperature impulses brought in by peripheral nerves. The greatest number of these cells are found in the region of the cervical and lumbo sacral enlargements.

2. **Dorsal funicular cells**—these multipolar cells which have dendrites branching in many directions are also found at all levels of the cord. Some of the dendrites pass through the gray commissure to the dorsal horn on the opposite side. The neuraxes are medullated and give rise to long ascending and descending tracts. These cells can be subdivided into groups, one being known as Clarke's nucleus or the dorsal nucleus of Clarke which begins at the eighth cervical level and runs down to the level of the second or third lumbar vertebrae. This gives rise to the dorso-spino cerebellar tract which will be heard of later. This tract receives proprioceptive impulses.

3. **Visceral gray cells**—this is a patch of gray cells which receive visceral impulses coming in over the spinal nerves. They are found only in the thoracic region and they lie at the base of the dorsal horn.
Lateral gray column

1. Intermedio-lateral column—located in the position indicated by the name (also see figure) between the level of the first thoracic and the third lumbar segments is a group of cells which gives rise to the pre-ganglionic neurons from the thoracolumbar sympathetic nervous system. At a corresponding position between the second and fourth sacral levels is another group of cranio-sacral sympathetic (parasympathetic) system.

Ventral gray column

1. Medial division--

   Dorso-medial
   Ventro-medial

   The ventro-medial column extends through the whole length of the cord except at the fifth lumbar and first sacral levels. This nuclear group supplies the trunk muscles. It is supplemented by the dorso-medial group which has a similar function essentially in the thoracic and upper cervical regions.

2. The lateral division--these groups are present in the enlargements.

   a. Ventro-lateral group supplies the shoulder girdle and extends from the fourth to the eighth cervical. In the lumbo-sacral enlargement it supplies the hip and the thigh and extends from the second lumbar to the second sacral.

   b. The dorso-lateral group supplies the fore-arm and hand and extends from the fourth cervical to the first thoracic. In the lower enlargement it extends from the third lumbar to the third sacral and supplies the leg, ankle and foot.
c. The retro-dorso-lateral group supplies the fingers and extends from the eighth cervical to the first thoracic in the upper enlargement and extends over the first, second and third sacral levels in the lower enlargement and supplies the toes.

3. Central (phrenic) group--this group extends from about the third to the sixth cervical levels and contains the cells of origin for the diaphragm. There is a corresponding group in the lower lumbar and sacral regions for which the function is unknown.

4. Accessory group--in the cervical region between the levels of the first and seventh spinal nerves there are cells of origin which give rise to the spinal accessory nerve (XI cranial nerve) which supplies the trapezius and sterno-cleido-mastoid muscles.

All sensory impulses brought in over the spinal nerves have their cells of origin in the spinal ganglia. Tactile fibers are those fibers which provide for two-point tactile (touch) discrimination. It will be noted on the chart that the pain fibers (Lissauer's tract) are indicated as going both up and down. This is due to the fact that the short fibers of this tract do not extend over more than one segment but a series of synaptic connections provide for a continuous chain of impulses over the entire length of the cord.

For the purposes of definition we will indicate the following use of the terms:

Proprioceptive--impulses coming from muscles and tendons which indicate orientation in space.
Exteroceptive--impulses carrying pain, temperature and tactile sensations.

Interoceptive--visceral sensibility

Functions of the Spinal Cord

I. In the first place the cord with its associated nerves constitutes the mechanism for the simpler reflexes of the neck, extremities and trunk regions. Such reflexes may be divided into (1) those involving somatic musculature, termed somatic reflexes, and (2) those involving visceral musculature and glands which may be called visceral reflexes.

II. In the second place the spinal cord, largely through its white matter, serves as a pathway for the projection of sensory impulses from the body on to the higher centers of the nervous system and as a pathway through which impulses from higher centers, including the cerebral cortex, reach the various nuclear groups and particularly the efferent nuclei of the cord and so control various body activities. In this sense it becomes a part of the correlating mechanism.

The components of a typical peripheral nerve

(See figure 2)

A component is the sum of all the neurons which have such anatomic and physiological relations in common that they can act in a common mode.

I. Sensory fibers

1. Tactile
2. Proprioceptive Medullated--medial division of the dorsal root
| 3. Pain | Thinly or non-medullated—lateral division of the dorsal root. |
| 4. Temperature | |
| 5. Visceral sensations | |

II. Motor fibers to striated muscle, medullated.

III. Post-ganglionic fibers from the chain ganglia, medullated or non-medullated.

The components of a deep nerve have either or both pre and post-ganglionic fibers and also visceral sensory fibers.
Chapter IV

THE MEDULLA

The medulla oblongata is that part of the brain which is a continuation of the spinal cord and which contains the ascending and descending fiber tracts which unite the cord with higher centers. The medulla is bounded caudally by the motor decussation or a plane through the foramen magnum. The upper limit of the medulla is marked by a plane through the striae medullaris acustica, and ventrally its limits are the lower border of the pons fiber.

A study of the medulla involves the consideration of those cranial nerves which come off at that level. There are four nerves which are given off in the ascending order: XII, or Hypoglossal; XI, Accessory; X, Vagus; and IX, Glossopharyngeal.

All four of these nerves were embryologically related to the gill arches and are therefore sometimes known as the branchiomeric nerves.

The Hypoglossal Nerve (XII). This nerve is purely somatic and has its nucleus of origin in the nucleus of the XII nerve and is the motor innervation to the intrinsic muscles of the tongue. The other probable component is the general somatic afferent which has proprioceptive fibers from the tongue muscles, but the nuclei of origin and termination are not known.

The Accessory Nerve (XI). It must be remembered that some of the motor fibers of the accessory nerve have the function of a
spinal nerve and were discussed with the accessory group of nuclei of the ventral gray column of the cord. The cranial components, of which there are two, are closely associated in function with the efferent components of the Vagus (X) nerve. The special visceral efferent component originates in the nucleus ambiguus and furnishes motor fibers to the branchiomeric muscles of the larynx and oesophagus. The general visceral efferent component originates in dorsal efferent nucleus of XI and terminates in sympathetic ganglia. Its function is motor and secretory. There are said to be proprioceptive fibers from XI scattered along the root.

The Vagus (X). Because of its wide distribution and variety of function the vagus nerve is very interesting. Five distinct components make up the nerve. The functions only of these components will be given here. The nuclei of origin and termination may be noted on the accompanying chart. The special visceral efferent part furnishes the motor innervation to the branchiomeric muscles of the larynx and oesophagus. The general visceral efferent part is motor to the smooth muscle and glands of the thoracic and abdominal organs. This component gives the clue to why the respiratory centers are said to be located in the medulla. It is the general visceral component which largely governs respiration.

The special visceral afferent fibers carry taste sensations from the epiglottis. General visceral sensibility from the neck to the descending colon is carried by the general visceral afferent

1Huber
component. The cutaneous sensations of the ear are carried over the general somatic afferent part of X.

The Glossopharyngeal Nerve (IX). This nerve is almost as varied in function as the vagus and has the same components. The special visceral efferent part furnishes the motor innervation to the stylo-pharyngeus muscle in the neck. The general visceral efferent component furnishes the motor innervation for the secretion of the parotid gland. The special visceral afferent fibers carry gustatory (taste) sensations from the posterior one-third of the tongue. The general visceral afferent part receives sensory impulses from the entodermal surface of the back of the throat. The general somatic afferent component is frequently absent but when present it carries sensory impulses from the outer ear.

Motor Decussation

The motor decussation or crossing is that area of the medulla where the lateral cortico-spinal tract crosses from the lateral to the ventral funiculus. This crossing is between the ventral cortico-spinal, medial vestibulo-spinal, medial tecto-spinal, and the ventral spino-thalamic tracts.
<table>
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<tr>
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<th>NUCLEUS OF ORIGIN</th>
<th>NUCLEUS OF TERMINATION</th>
<th>FUNCTIONS</th>
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<td>Stylo-pharyngeus muscle</td>
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<td>Otic ganglion</td>
<td>Secretory (parotid gland)</td>
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<td>Nucleus of fasciculus solitarius</td>
<td>Gustatory (posterior one-third of tongue)</td>
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<td>&quot; &quot;</td>
<td>&quot;</td>
<td>Entodermal surface of back of the throat</td>
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<td>Branchiomeric muscle of larynx and oesophagus</td>
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<td>Terminal sympathetic ganglia</td>
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<td>Ciliary ganglion</td>
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<td>Spiral ganglion</td>
<td>Spiral organ of corti</td>
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Chapter V

THE PONS

The pons or bridge is that portion of the brain between the medulla and the midbrain. Ventrally it is bounded by the bordering fibers of the pons; dorsally it extends from the striae acustici to the decussation of the IV nerve in the anterior medullary velum; laterally the pons is cut off from the cerebellum by the emerging roots of cranial nerve V.

For purposes of description the pons may be said to have two divisions.

I. Dorsal or tegmental portion.

II. Ventral fibrous or basilar portion.

   a. Pontine gray
   b. Certain fiber bundles including:
      cortico-spinal
      cortico-pontine
      cortico-bulbar
      ponto-cerebellar fibers, which make up more than one half the area of the pons.

The tegmental portion has the nuclei of origin for those cranial nerves arising from the pons. There are three strictly pons nerves; the VII, facial; VI, abducens; and V, trigeminal. The vestibular nerve (VIII) has its nuclei partly in the pons and partly in the medulla.
The Facial Nerve (VII). The special visceral efferent component of VII originates in the motor nucleus of VII and furnishes the motor innervation to the muscles of facial expression. The general visceral efferent fibers come from the superior salivatory nucleus and the lacrimal nucleus and furnish the motor innervation for secretion from the sublingual, sub-maxillary, and lacrimal glands. The special visceral afferent fibers carry the taste sensations from the anterior two-thirds of the tongue. Sensory fibers from the sub-maxillary and sub-lingual salivary glands make up the general visceral afferent component. Proprioceptive fibers from the face muscles make up the general somatic afferent component.

The Abducens (VI). The components make up the VI nerve. The special somatic efferent fibers innervate the lateral rectus muscle of the eye ball. Proprioceptive fibers from the lateral rectus muscle make up the general somatic afferent component.

The Trigeminal (V). The general somatic afferent fibers of the V nerve are of two kinds: (1) Exteroceptive fibers which carry pain, temperature, and tactile sensations, and (2) Proprioceptive fibers from the muscles of mastication. The special visceral efferent component furnishes the motor innervation to the muscles of mastication.

The Functions of the Pons and Medulla

The medulla and pons have the nuclei of reception for the entering cutaneous sensibility—pain, temperature, and tactile—
and relaying of sensory impulses to the cord.
so far as these senses are served by cranial nerves. In the same way they have the nuclei of reception for incoming visceral sensations.

On the motor side the medulla and pons have the nuclei of origin for all the motor neurons supplying branchiomeric muscles with the exception of the spinal components of the XI nerve. They have the nuclei of origin for nerves supplying the tongue and one of the eye muscles.

The pre-ganglionic fibres supplied through the cranial nerves all lie within the pons or the medulla with the exception of those from the oculomotor (III) nerve to the ciliary ganglion.

The medulla and the pons have many important connections for relatively simple reflexes which involve on the motor side muscles of the head and face or pre- and post-ganglionic innervation through cranial nerves.

The medulla and the pons combined together with their relations to the cord play a part in more complicated reflexes involving respiration, eating, regulation of the heart beat and gustatory reflexes in relation to the salivary glands. They also have relations to the gastro-intestinal tract in general and the endocrine system.

In the medulla and the pons are the first parts of important paths for cochlear and vestibular systems.

The pons and medulla are regions of passage for ascending systems from the cord and the brain stem regions to higher centers, and regions of passage for descending paths from higher centers to the cord.
### TRACTS OF PONS AND MEDULLA

<table>
<thead>
<tr>
<th>TRACT</th>
<th>POSITION</th>
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<th>➕</th>
<th>➖</th>
<th>EXTENT</th>
<th>TERMINATION</th>
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<td>medulla and pons</td>
<td>nucleus fasc. gracilis and cuneatus</td>
<td>➕</td>
<td>➖</td>
<td>lower medulla to pons</td>
<td>thalamus</td>
<td>proprioceptive and certain tactile discrimination</td>
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<td>chiefly extent of olive</td>
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<td>➕</td>
<td>➖</td>
<td>medulla to cerebellum</td>
<td>cerebellum</td>
<td>proprioceptive to neck</td>
<td></td>
</tr>
<tr>
<td>Cerebello-olivary</td>
<td>cerebellum</td>
<td>➖</td>
<td>➕</td>
<td>chiefly extent of olive</td>
<td>olive</td>
<td>part of discharge path from cerebellum to neck muscles</td>
<td></td>
</tr>
<tr>
<td>Secondary dorsal cochlear fibers</td>
<td>on floor of medulla under stirate acustici</td>
<td>➖</td>
<td>➕</td>
<td>trans. in plane given</td>
<td>to inf. callliculus med. semil. culate nucleus</td>
<td>part of cochlear path</td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**
- Medial lemniscus (Figure 4)
- Dorsal superficial arcuates
- Venteral superficial arcuates
- Olivo-cerebellar
- Reticulo-cerebellar
- Cerebello-olivary
- Secondary dorsal cochlear fibers
<table>
<thead>
<tr>
<th>Tract</th>
<th>Position</th>
<th>Origin</th>
<th>Extent</th>
<th>Termination</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezoid fibers</td>
<td>At pons level with medial lemniscus</td>
<td>Ventral cochlear nucleus</td>
<td>↑</td>
<td>transversely</td>
<td>joins lateral lemniscus</td>
</tr>
</tbody>
</table>
Chapter VI

THE MIDBRAIN

The midbrain or mesencephalon extends from a caudal plane which passes dorsally from the decussation of nerve IV to the front end of the pons fibers, and ventrally it extends forward to a plane which cuts posterior commissure and the mammillary body.

The mesencephalon is divided into: (Figure 7)

1. Tectum (roof of the midbrain)
2. Tegmentum
3. Basis pedunculi

The tectum has four major masses:

1. Superior colliculi (two) } anterior and posterior
2. Inferior colliculi (two) } corpora quadrigemina

The inferior colliculi are the auditory reflex centers.

The superior colliculi, with their included pre-tectal centers, are the light, and indirectly, the visual reflex centers.

The inferior colliculi consist of oval-shaped masses made up of small cells bounded by a capsule of fibers which shuts it off from the surrounding structures. The inferior colliculus of one side is connected to the colliculus of the other by scattered cells. The fibers bundles around it are terminal fibers of the lateral lemniscus. The connections of the inferior colliculi are:

1) Lateral lemniscus--the primary connection to inferior colliculus. This makes the inferior colliculus an auditory reflex center.
(2) Peduncle of inferior colliculus

(3) Acustico-optic connections from the superior to inferior colliculi.

(4) Gudden's commissure—a commissural connection to median geniculate nucleus of the other side.

(5) Commissure of inferior colliculi

The superior colliculi are more highly differentiated than the inferior. The fibers are arranged in layers or strata. There is a sensory correlation on a high plane.

From the exterior inward the strata and their functions are:

(1) Stratum zonale which contains fibers of the corticotectal tract.

(2) Superficial gray layer which receives terminal fibers of optic tract, peduncle of superior colliculus, and cortico-tectal (visual).

(3) Stratum opticum which carries the peduncle of superior colliculus plus a few optic fibers.

(4) Stratum griseum mediale receives terminal optic, the peduncle of superior colliculus, many cortico-tectal, and some spino-tectal fibers.

(5) Stratum album mediale is made up of fiber bundles of cortico-tectal and some spino-tectal paths.

(6) Stratum griseum profundum (deep gray) receives some terminating spino-tectal and cortico-tectal fibers and has the cells of origin for major efferent paths.

(7) Stratum album or medullare profundum contains efferent fibers to the tectum.
(8) Paraventricular layer receives acustico-optic tracts from the inferior colliculus and fibers from hypothalamus; it is an olfactory visceral correlation center.

The connections of the superior colliculus are:

(1) Optic tract to pretectal area for light reflexes; the neurons of the first order are in the rods and cones of the retina

(2) The tecto-oculomotor tract

(3) Commissure of the superior colliculi

(4) Spino-tectal tract

(5) Peduncle of superior colliculus

(6) Acustico-optic fibers

(7) Lateral and medial tecto-spinal tract

(8) Cortico-tectal tract

(9) Also connections from tectum to the red nucleus (crossed and uncrossed), substantia nigra, other tegmental regions of midbrain, and interconnections between superior colliculi of the two sides.

The Cranial Nerves of the Midbrain

Two cranial nerves arise from the second part of the midbrain, the tegmentum. These nerves are the trochlear (IV) and the oculomotor (III).

The Trochlear Nerve (IV). The special somatic efferent component of IV arises from several nuclei in the tegmentum which are usually called collectively the motor nucleus of IV. These fibers supply the motor innervation to the superior oblique muscle of the
eye ball. The other component of this nerve is the general somatic afferent which brings in the proprioceptive fibers from the same muscle.

The Oculomotor Nerve (III). The special somatic efferent part of III innervates the superior, inferior, and medial recti, and the inferior oblique muscles of the eye ball. The general visceral efferent fibers go to the circular muscle in the iris of the eye. The proprioceptive fibers are carried by the general somatic afferent part.

Another important structure of the tegmental portion of the mesencephalon is the red nucleus or nucleus ruber which is seen at the level of the superior colliculus. This nucleus is in two parts: (1) One is seen in the midbrain and is known as the magnocellular part. It is made up of large cells which are relatively reduced in man as compared with lower animals. (2) the parvocellular portion which extends in front of the midbrain into the diencephalon. This is the largest portion of the red nucleus. It receives fibers from the cerebellum from the dentate nucleus. This is the dento-rubral tract which crosses at the level of the inferior colliculus and terminates to form a capsule around the red nucleus. Some fibers pass along the side of the red nucleus and go to the thalamus; the dento-thalamic tract.

The cerebellum can discharge forward to the thalamus with or without a synapse in the red nucleus.

The crossing of the rubro-spinal tract is known as the ventral tegmental decussation. The crossing of the dento-rubral tract is
the crossing of the superior cerebellar peduncle (brachium conjunctiva).

The Functions of the Nucleus Ruber

1. It is a discharge path for the cerebellum. The center for tonic control of muscle fibers is nearby.

2. It provides a discharge forward for impulses from the cerebellum to the thalamus. There are probably fibers from the cortex to the red nucleus (cortico-rubral) which with the rubrospinal fibers is concerned with orientation in space.

3. It is a discharge path from striatum by way of strio-rubral fibers.

The connections of the red nucleus may be summarized in the following way:

**Incoming**
1. dento-rubral
2. tecto-rubral
3. strio-rubral
4. cortico-rubral (uncrossed)

**Outgoing**
1. rubro-thalamic
2. rubro-bulbar
3. rubro-spinal (crossed)

(The cortico-rubral and the rubro-spinal tracts make up what is known as the extra-pyramidal system.)

The peduncular portion of the midbrain is composed of the following fiber tracts: occipito-temporo-cortico-pontine, cortico-spinal, fronto-cortico-pontine, medial cortico-bulbar, lateral cortico-bulbar, and medial lemniscus.

Although not particularly peculiar to the mesencephalon, the medial longitudinal fasciculus should be mentioned here since it is more conspicuous in the midbrain than in other parts of the brain.
brain stem. This bundle is composed of three components. (1) the vestibular components, which connect the nuclei of nerves XI, VI, IV, III with the vestibular nuclei and higher centers (2) the interrelating motor components which connect the motor nuclei of nerves III, IV, VI, XII, XI, VII, (3) the conditioning components which modify the reflex.

From the connections given it may be seen that these factors are a major factor in the reflex control of movements of the eyes, and especially in the coordination of these movements with those of the head and neck.

The Functions of the Midbrain

The midbrain contains the cells of origin for two of the eye muscle nerves, III and IV.

It has the important auditor reflex center in the inferior colliculus, and a center for accommodation in the superior colliculus and its associated pretectal area. There is also in the superior colliculus (largely and indirectly by way of a synapse in the lateral geniculate body) a visual reflex center.

The midbrain region has through the red nucleus a highly important discharge center for impulses concerned with muscular coordination, synergy, and muscle tone. Through the red nucleus, substantia nigra, and other gray masses in the midbrain there are important discharge centers for the striatum in its action over automatic associative movements and tonus.

The midbrain also is a region of passage for the great ascending secondary system to the thalamus and for descending motor pathways to motor neurons of spinal and cranial nerves.
Cross-section through the human mesencephalon

Sagittal sections of the human cerebellum through the vermis in the median plane

Fig. 7

Fig. 8
Chapter VII

THE CEREBELLUM

The cerebellum consists of two large hemispheres and a central portion, the vermis (worm). Phylogenetically the vermis is the older.

In the following diagram anatomical structures have been combined in the manner in which they are believed to function. (Figure 8)

<table>
<thead>
<tr>
<th>Hemisphere</th>
<th>Vermis</th>
<th>Hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>lingula</td>
<td>PRECENTRAL</td>
</tr>
<tr>
<td>ala centralis</td>
<td>lobus centralis</td>
<td>POSTCENTRAL</td>
</tr>
<tr>
<td>anterior semilunar</td>
<td>preculmen</td>
<td>anterior semilunar</td>
</tr>
<tr>
<td>2)</td>
<td>de clivis</td>
<td>POSTCENTRAL</td>
</tr>
<tr>
<td>posterior crescentric</td>
<td>postclivis</td>
<td>posterior crescentric</td>
</tr>
<tr>
<td>post. sup. lobule</td>
<td>folia vermis</td>
<td>post. sup. lobule</td>
</tr>
<tr>
<td>(4)</td>
<td>GREAT HORIZONTAL</td>
<td></td>
</tr>
<tr>
<td>post. inf. lobule</td>
<td>tuber</td>
<td>post. inf. lobule</td>
</tr>
<tr>
<td>biventer</td>
<td>pyramid</td>
<td>biventer</td>
</tr>
<tr>
<td>(5)</td>
<td>uvula</td>
<td>POSTNODULAR</td>
</tr>
<tr>
<td>tonsil</td>
<td>postnodule</td>
<td>tonsil</td>
</tr>
<tr>
<td>6)</td>
<td>flocculus</td>
<td>Postnodule</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lobes</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. anterior lobe</td>
<td>Coordination of head muscles</td>
</tr>
<tr>
<td>2. lobus simples</td>
<td>Coordination of neck muscles</td>
</tr>
<tr>
<td>3. lobus ansiformis</td>
<td>Arm</td>
</tr>
<tr>
<td>4. lobus median medianus</td>
<td>Trunk</td>
</tr>
<tr>
<td>5. lobus paramedianus</td>
<td>Leg</td>
</tr>
<tr>
<td>6. posterior lobe</td>
<td>Trunk (flocculus..equilibrium)</td>
</tr>
</tbody>
</table>
There are three cerebellar peduncles occurring in pairs. The inferior cerebellar peduncle or restiform body; the middle cerebellar peduncle or brachium pontis; and the superior cerebellar peduncle or brachium conjunctiva.

**Peduncular Components**

**Inferior** (incoming)

1. dorsal spino-cerebellar
2. dorsal superficial arcuates
3. ventral superficial arcuates
4. olivo-cerebellar
5. direct root fibers of the vestibular part of VIII and probably V.
6. vestibulo-cerebellar fibers
7. nucleo-cerebellar fibers from the chief sensory nucleus
8. reticulo-cerebellar fibers

**Middle**

More than ninety-five percent of this peduncle is made up of ponto-cerebellar fibers.

**Superior**

This peduncle consists largely of dento-rubral and dento-thalamic fibers. There are also some cerebellum-tegmental and ceregello-motorius fibers. At the side of the peduncle runs the ventral spino-cerebellar tract.

**The Cerebellar Nuclei**

The cerebellum has four important nuclei; (1) nucleus tecti, (n. fastigii or roof nucleus), (2) nucleus globosus, (3) nucleus
embliformis, and (4) nucleus dentatus.

The nucleus tecti discharges through both the superior and inferior cerebellar peduncles. The main efferent paths are the cerebello-spinal, cerebello-vestibulo, cerebello-motorius, and cerebello-tegmentals which all come through the inferior peduncle. All the efferent paths of which we know the origin and which come from the cerebellum through the inferior peduncle, come from the nucleus tecti. The cerebello-motorius through the superior peduncle is also from the nucleus tecti.

Incoming impulses to the tecti are primarily from vestibular paths--vestibulo-cerebellar--ventral spino-cerebellar tract, and vermis of cerebellum.

The dentate nucleus is folded like the inferior olivary nucleus. It develops from a common mass of gray. Primarily, it receives connections from the hemispheres, and discharges through the superior cerebellar peduncle giving rise to dento-rubro-thalamic and cerebello-tegmental fibers.

The Cerebellar Cortex

The cerebellar cortex or what is more commonly known as "arbor vitae" because of the resemblance to a tree when observed grossly in sagittal section may be divided into four strata: (1) stratum moleculare, (2) stratum granulare, (3) stratum Perkinji, and (4) stratum album.

In order to get as complete as possible understanding of the functioning of the cerebellum one would need to study in some detail the histological structure of the cortex and be able to trace
the ponto-cerebellar climbing fibers, basket cells and pericellular synapse. This would then be a basis for an understanding of avalanche conduction of Cajal.
SUMMARY OF CEREBELLAR FUNCTION

1. From its phylogenetic and ontogenetic history and from its fiber connections, the cerebellum is in intimate connection on the afferent side of the arc, (a) with the vestibular system and (b) with various conductors of proprioceptive impulses which have their origin from neuromuscular and neurotendinous nerve endings and the Pacinian corpuscles. Such incoming impulses are discharged to some extent to the cerebellar nuclei but also to the cerebellar cortex.

2. The cerebellum is under the control of the cerebral cortex, the major part of its hemisphere, and particularly the middle lobe, developing hand in hand with the cerebral cortex. The termination of the ponto-cerebellar neurons of the two neuron cortico-ponto-cerebellar chain is as climbing fibers directly on Purkinje cell dendrites.

3. Discharge paths from the cerebellum fall into two major groups. To the first group belong those paths that pass either directly to the motor centers of the brain stem and upper spinal cord or indirectly to such centers by way of the vestibular nuclei, the tegmental gray, or the red nucleus. To the second group are allocated fibers which pass forward to convey impulses to the thalamus, either with or without relay in the red nucleus. The vast majority of these fibers arise from the cerebellar nuclei, though a certain few may arise from the cortex directly.

4. The histological structure indicates that the impulses brought into the cerebellum are built up and strengthened along the
lines of Ramon y Cajal's theory of avalanche conduction. This admission of a mechanism for strengthening the impulses in no way implies that an increased motor response or a complete inhibition of a motor response necessarily results from the discharge of the cerebellum into the centers, but rather that there is regulation of the impulses which pass through the motor nuclei of the brain stem and the spinal cord and over the peripheral fibers arising from their neurons. This action of the cerebellum tends to make the responses of the neuromotor mechanisms of the body adequate to the demands made upon them and finds partial expression at least in the regulation of posture and postural tone. The action of the cerebellum is synergic, then, and is concerned with the maintenance of equilibrium, static, and dynamic, of the body masses. That in carrying out this regulation its action on the lower centers may often be inhibitory is probable. It is certain that the cerebellum acts in correlation with the striatum and cerebral cortex.
Chapter VIII

THE DIENCEPHALON

The diencephalon has as its caudal boundary dorsally the commissure, and ventrally it extends to a line just caudal to the mammillary body. The forward boundary dorsally is the interventricular foramen and it extends down through to the region of the preoptic recess. Laterally the diencephalon is bounded by the internal capsule and caudate nucleus.

The diencephalon is composed of the following parts:

1. Epithalmus
2. Hypothalamus
3. Thalamus

   (a) dorsal
   (b) ventral

Epithalmus

A. Secretory portions

1. Epiphysis (pineal gland) "Seat of the Soul." This ectodermal gland of internal secretion is concerned with the development of secondary sex characteristics. Its connections are relatively small; to habenula and perhaps other regions of diencephalon.

2. Choroid plexus—thin roof covering the top of third ventricle. It is a capillary plexus and ependyma of ventricle.
B. Non-olfactory commissure portion

1. Posterior commissure—between pineal gland and superior colliculus. This commissure connects one superior colliculus with the other and one pretectal nucleus with the other. It contains crossed fibers of medial longitudinal fasciculus.

C. Olfacto-somatic correlation center with its connections

1. Habenula—a small nucleus in front of the posterior commissure. The stria medullaris is the major afferent connection. The habenulo-peduncular, habenulo-thalamic, and habenulo-tegmental are efferent paths from the habenula.

Hypothalamus

A. Secretory portion

1. Hypophysis (pituitary gland)
   (a) Posterior or neural lobe—strictly neural
   (b) Anterior lobe—of ectodermal derivation from the oral cavity
      (1) Anterior oral lobe
      (2) Pars intermedia
      (3) Pars tuberalis

   The fiber connections to pars neuralis are from the hypothalamus.

   Pars oralis is in a large part responsible for body growth. Overactivity of the hormone secreted by this part leads in youth to gigantism, in which the bones greatly increase in length; if the overactivity is confined to the time of maturity or beyond, the bones increase in width. Underactivity of this hormone causes dwarfism in the young. The pars oralis is interlocked in function with the corpus luteum and the thyroid.
B. Non-olfactory commissural systems

1. Optic chiasm

2. Posterior optic commissural system. This is what is known as Meynert's commissure and carries fibers from the lenticulate nucleus of one side to that of the other.

C. Olfacto-visceral correlation centers and discharge centers for visceral impulses.

1. The mammillary bodies—these bodies are a pair of small spheric masses of gray matter situated close together in the interpeduncular space rostral to the optic chiasm. Each body is composed of two nuclear masses. Each of these nuclei receives fibers from the hippocampus. These fibers curve around the thalmus and form a bundle known as the fornix.

2. The tuber cinereum is a slightly elevated gray area back of the mammillary bodies. It is fastened to the hypophysis (pituitary gland) by a stalk known as the infundibulum.
SUMMARY OF HYPOTHALAMIC FUNCTIONS

The following centers have been said to be present in the hypothalamus:

1. Centers affecting glands of internal secretion. Morgan believed the "nuclei of the tuber cinereum are probably secretory centers for certain internally secreting glands (especially the thyroids and suprarenals.)" He thought that such centers might affect "metabolism, body temperature, blood pressure, heart-rate, vasomotor function, motor activity of the intestinal canal, pupillary control, states of consciousness, and other vegetative functions." He regarded the nucleus tuber-mamillaris as being a center affecting the thyroid gland and the substantia grisea as probably related to the functional activity of the suprarenals.

2. Vasomotor centers, located somewhere near the nucleus subthalamicus.

3. Temperature regulating center.

4. Centers concerned with the regulation of the water and salt content of the body.

5. Center, either hypothalamic or subtahalic or both, concerned with the regulation of smooth muscle and hence for regulation the size of the pupil of the eye for contraction of the bladder and for the regulation of sweat and lachrymal glands. There centers appear to lie in the neighborhood, at least, of the nucleus subthalamicus.

6. Centers concerned with the objective manifestations of various emotional states such as the so-called shammage of the diencephalic or decorticate cat. These have been allocated to the more caudal and ventral part of the diencephalon.

Dorsal Thalamus

There are approximately 35 nuclei in the dorsal thalamus. All sensory impulses from secondary centers in the brain stem synapse in the dorsal thalamus on the way to the cortex.

The dorsal thalamus may be divided into four divisions: (1) the metathalamic portion, (2) lateral division, (3) anterior division, and (4) medial division. The work of the first two divisions can perhaps best be shown by the following simple table.

I. METATHALMUS

<table>
<thead>
<tr>
<th>Incoming</th>
<th>Nucleus Involved</th>
<th>Outgoing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optic tract</td>
<td>Lateral geniculate nucleus</td>
<td>(a) geniculo-cortical or visual radiations</td>
</tr>
<tr>
<td>Lateral lemniscus fibers and fibers peduncle of inferior colliculus</td>
<td>Medial geniculate nucleus</td>
<td>(b) geniculo-tectal (branch of superior colliculus) To cortex by auditory radiations</td>
</tr>
</tbody>
</table>

II. LATERAL DIVISION

<table>
<thead>
<tr>
<th>Primary Sensory Tracts</th>
<th>Nucleus Involved</th>
<th>Sensory radiations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial lemniscus, lat. spino-thalamic, vent. spino-thalamic, vent. secondary ascending tract of V, dorsal</td>
<td>Ventral nucleus (Great sensory center of reception)</td>
<td>Sensory radiations to cortex to post central gyrus, some proprioceptive to pre-precentral</td>
</tr>
</tbody>
</table>
secondary asc. tract of V, dento-rubral-thalamic

internuclear connections

cortico-thalamic

III. ANTERIOR DIVISION

Three nuclear groups make up the anterior division of the dorsal thalamus. They are (1) antero-dorsal, (2) antero-ventral, and (3) antero-medial.

The mammillothalamic tract is the major incoming connections to the anterior nucleus. The anterior nucleus connects with the cingulum or the fornicate gyrus in the frontal part of the cerebral cortex. There are also important internuclear connections with the medial nuclear group.

IV. MEDIAL DIVISION

Most important of the nuclei in this group is the principal medial nucleus. This nucleus may be very large. It is separated from the anterior group by the internal medullary lamina. There are internuclear fibers connecting this group with the other nuclei of the dorsal thalamus. There are connections from the tuber cinereum. The medial nucleus is an olfacto-somatic correlation center for all sorts of impulses reaching the thalamus. Unlocalized pain is from thalamic centers. There are no lemnisci connections.
Functions of the Dorsal Thalamus

On the afferent (receptor) side of the arc, being a development of regions above the sulcus limitans, it falls into four major divisions characterized in general by specific types of fiber relations and corresponding differences in function. Of these divisions the following general functional subdivisions may be emphasized.

(a) The metathalamic—contains essentially the thalamic centers for auditory and visual impulses with the corresponding connections to the auditory and visual cortical projection areas, and are therefore essential internodes in the path to consciousness of auditory and visual impulses. The lateral geniculate nucleus is also a part of the visual reflex path.

(b) The lateral division of the dorsal thalamus falls essentially so far as here considered into three major types of nuclear centers on the basis of their functional relation. First as represented by the ventral nucleus which is the essential internode in the ascending pathways for pain, temperature, tactile, and proprioceptive impulses from the body and head into consciousness. Whether or not it receives gustatory impulses is at present uncertain. The second type is represented by the lateral nucleus and the pulvinar which are correlated in development as indicated by their connections and size with the development of the association areas of the cerebral cortex. This is particularly true in the case of the lateral nucleus with the frontal and parietal association areas and the pulvinar with the occipital association area. The third type is represented by the mechanism for intra-
thalamic correlation as shown by the centro-median nucleus.

(c) The anterior division is an olfactory correlation area tied up with the gyrus cinguli of the cortex and with the medial division of the dorsal thalamus.

(d) The medial division of the dorsal thalamus is characterized chiefly by its dominantly incoming internuclear connections with surrounding dorsal thalamic and hypothalamic regions so that it becomes a rich correlation center for the various sensory impulses reaching the dorsal thalamus from the body and head regions. These correlations are sufficiently rich so that no one type of connection is dominant and the result is that the connections to the cortex give the anatomic pathways for the pleasure-pain complex and affective tone. This is sometimes referred to as the anatomic basis of personality.
Striatum

Caudate-lenticular complex. Connections fall into four categories:

1. Thalamo-striate connections

   a. From medial, ventral, and lateral nuclei of the dorsal thalamus to the caudate and putamen.

   b. Internuclear connections-interrelated with nuclei of the complex.

   c. Efferent tracts to lower centers.

   1. Particularly ansa lenticularis

      a. Dorsal division (lenticular fasciculus of Forel) passes across the posterior limb of the internal capsule to the nucleus of the field of Forel and zona incerta, the capsule of the red nucleus and perhaps the nucleus, also the nucleus of the medial longitudinal fasciculus and the nucleus of the posterior commissure.

      b. Medial division (subthalamic fasciculus of Forel) from the globus pallidus and probably also the putamen across the internal capsule to the nucleus subthalamicus and the substantia nigra.

      c. Ventral division from the caudate and putamen to essentially the regions of distribution reached by the medial division. There are some minor differences here which need not be emphasized, but the course of the bundle
is beneath the internal capsule to diencephalic areas, rather than through it.

2. There are various other associated tracts which reach tegmental areas of the midbrain; these need not be discussed here.

d. Cortical connections. Cortical connections to the caudate-lenticular complex have been questioned by many observers. They have been described to the various subdivisions of the caudate-lenticular complex.

**Functions of the caudate-lenticular complex.**

The globus pallidus is concerned with producing automatic associated movements and in their adequate control, particularly through myotomic stabilization, so that there may be an adequate performance of such associated movements. Atrophy of the globus pallidus leads, then, to a disappearance of automatic associated movements; tremor and hypertonicity of the muscles. A condition of progressive lenticular degeneration, which affects the putamen especially but may also involve the globus pallidus, shows a loss of automatic associative movements and usually a somewhat greater hypertonicity of the muscles. Degeneration affecting the caudate nucleus produces a fine tremor, various choreoathetoid movements (such as "twisting and squirming") and an overabundance of automatic associated movements. Such an abundance of automatic associated movements is regarded by some observers as due to the release of inhibitory influences which normally the caudate exerts over the globus pallidus. According to Morgan, "the motor disturbances
attributed to progressive degeneration in the corpus striatum in man are due to irritative stimulation of the corpus striatum rather than to loss of striate function" and "symptoms commonly attributed to the corpus striatum are irritative rather than release symptoms."

Various observers have regarded the corpus striatum as affecting visceral functions, such as smooth muscle action, respiration, temperature regulation, and pupillary contraction.

Exactly what the effect of the cortical connections over the striatum may be is uncertain. It would appear that they had some type of regulatory effect, tending to bring the strength of the striatal response into line with the voluntary motor discharge of the cortex. Cortico-striate and ansa-lenticular paths combined may serve as extra-pyramidal paths in mammals, though the matter needs further consideration.

Clastrum.

Although its morphologic relations are easily seen in gross material, the fiber connections of the clastrum and its development are not as yet sufficiently well-known to give any explanation of its functions. The probability is that it is cortical and not striatal.

Amygdaloid nucleus.

The amygdaloid nucleus is an olfactory and olfacto-somatic correlation center, of more importance in lower mammals than in man.
Chapter IX

THE CEREBRUM

The cerebrum is composed of two kinds of nervous tissue as is the cord, white and gray, but the gray matter has now migrated to the outside whereas in the cord it was on the inside. This gray matter is known as the cerebral cortex and will be discussed in a later part of this chapter.

The white matter or medullated substance of the cerebrum is made up of three types of fibers: (1) projection, (2) association, and (3) commissural.

The projection fibers connect the cerebral cortex with the lower or sub-cortical centers. These connections carry impulses in both directions. Three types of these projection paths will be mentioned. (Figure 10)

(a) The fimbria-fornix system of the hippocampus is the projection system from the hippocampus or olfactory cortex which consists of a bundle called the fimbria and a continuation beyond called posterior pillars, body, and the anterior pillars of fornix. This system carries cortico-mammillary, cortico-hypothalamic, and cortico-habenular fibers.

(b) The cortico-stria paths run from the cortex to caudate and lenticular nuclei. (This will be mentioned again later in the chapter summary.)
(c) The internal capsule is the angular fiber tract area, between the lentiform and caudate nuclei and thalamus. The anterior limb of the internal capsule lies between the two nuclei; the posterior limb between the lentiform nucleus and the thalamus. In the anterior limb run the fronto-cortico-pontine fibers and the anterior thalamic radiations. At the genu (knee), or angle at which anterior and posterior limbs meet, runs the cortico-bulbar tract. In the posterior limb are cortico-spinal (arm), cortico-spinal (leg), and cortico-rubral tracts. In close relation to the posterior limb are sub-lenticular fibers, the cortico-pulvinar portion of the visual radiations, and the geniculo-cortico visual radiations.

A detailed list of the components of the internal capsule will be found in the accompanying table.

**COMPONENTS OF THE INTERNAL CAPSULE**

<table>
<thead>
<tr>
<th>Origin</th>
<th>Tract</th>
<th>Termination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal cortex</td>
<td>Fronto-cortico-pontine</td>
<td>Pontine gray (homolateral)</td>
</tr>
<tr>
<td>Medial nucleus</td>
<td>Anterior thalamic radiations</td>
<td>Frontal cortex</td>
</tr>
<tr>
<td>Anterior nucleus</td>
<td></td>
<td>Cingulate gyrus</td>
</tr>
<tr>
<td>Lateral nucleus</td>
<td></td>
<td>Frontal cortex</td>
</tr>
<tr>
<td>(dorsal thalamus)</td>
<td></td>
<td>Med., 1st. thalamic nuclei</td>
</tr>
<tr>
<td>Frontal cortex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower part of per-</td>
<td>Cortico-bulbar</td>
<td>Motor nucleus of cranial nerves</td>
</tr>
<tr>
<td>central gyrus</td>
<td></td>
<td>(crossed and uncrossed)</td>
</tr>
</tbody>
</table>
Components of the Internal Capsule
(Continued)

<table>
<thead>
<tr>
<th>Origin</th>
<th>Tract</th>
<th>Termination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor cortex pre and paracentral gyri (upper 2/3)</td>
<td>Cortico-spinal</td>
<td>Ventral horn (contralateral)</td>
</tr>
<tr>
<td>Frontal cortex</td>
<td>Cortico-rubral</td>
<td>Homolateral red nucleus</td>
</tr>
<tr>
<td>Ventral nucleus of dorsal thalamus</td>
<td>Sensory radiations</td>
<td>Post and paracentral gyri (proprioceptive in percentral gyrus)</td>
</tr>
<tr>
<td>Medial geniculate nucleus</td>
<td>Auditory radiations</td>
<td>Superior transverse temporal gyrus (Heschl's convolution)</td>
</tr>
<tr>
<td>Cuneus and lingual gyri, exclusive of calcarine area</td>
<td>Cortico-pulvinar portion of visual radiations</td>
<td>Pulvinar</td>
</tr>
<tr>
<td>Lateral geniculate nucleus</td>
<td>Geniculo-cortico portion</td>
<td>Visual projection, cortex-calcarine area</td>
</tr>
<tr>
<td>Cortex</td>
<td>Occipito-temporo-pontine</td>
<td>Gray of pons</td>
</tr>
</tbody>
</table>

The association fibers of the cerebrum connect cortical regions. Functionally and topographically two kinds of association fibers may be recognized: (1) intracortical fibers which are small fibers and run through the cortex to connect fairly closely located areas, and, (2) subcortical fibers which begin and end in the cortex gray and run under the cortex not through it. Of this kind there are two varieties. First the short or intralobular association paths, and
secondly the long or interlobular paths. The number of these longer paths is enormous but only six will be emphasized here.

(a) The cingulum is located above the corpus callosum. It is the olfactory association bundle.

(b) The superior longitudinal fasciculus runs from the frontal to the occipital lobes and lies above the corona radiata.

(c) The fasciculus fronto-occipitalis superior runs over the top of the caudate nucleus just beneath the corpus callosum.

(d) The inferior longitudinal fasciculus may not actually exist except as fibers from the inferior fronto-occipitalis fasciculus.

(e) The uncinate fasciculus connects the orbital gyri of the frontal lobe with the rostral part of the temporal lobe.

(f) The inferior fronto-occipitalis fasciculus passes under the lentiform nucleus and connects the cortex of the frontal and occipital lobes.

The commissural fibers of the cerebral hemispheres connect areas on the two sides. These fibers may be either basal, cortical, or both. Three commissures are recognized.

(a) The hippocampal commissure is an olfacto-cortical path connecting the hippocampi of the two sides. Because of older phylogenetic origin this is sometimes called the archipallial commissure. At one time the olfactory cortex (the hippocampus) was much larger and played a relatively more important role in the earlier animal forms.
(b) The anterior commissure is a basal commissure and has three components (1) the interbulbar fibers (2) the intertemporal component (3) stria terminalis. The anterior commissure is also an olfactory commissure.

(c) The corpus callosum is an non-olfactory and neopallium (new brain) connection. These fibers make up a large bundle in proportion to the development of the non-olfactory regions. All the fibers of the corpus callosum are cortical. Two components are recognized (1) the commissural component and (2) collaterals of projection and association fibers.

The Brain Ventricles

The brain is actually a hollow structure. Below the corpus callosum there is a fluid-filled space, the third ventricle. If one were to cut with a knife down through the middle of this cavity, on the outer wall could be seen a small hole, the interventricular foramen (Monro), which leads into a similar cavity in the left cerebrum hemisphere. A similar chamber lies in the right hemisphere. These two recesses are called the lateral or first and second ventricles. Below and to the rear the third ventricle narrows down into a small tube, the cerebral aqueduct. It runs through the midbrain and connects with a fourth ventricle lying almost vertically between the cerebellum and the medulla. From this cavity a very small central canal runs down to the very end of the cord. Not only the brain therefore, but the whole C.N.S. is hollow. However the fluid filled cavities comprise only a very small percentage of the brain's volume.
In the third and fourth ventricles will be found a delicate vascular network known as the choroid plexuses which are modifications of the pia mater. These plexuses secrete the cerebrospinal fluid.

An increase in ventricular pressure due to hypersecretion of this fluid is the cause of the enlarged head condition known as hydrocephalus.

The Cerebral Cortex

Because of the importance of blood supply in pathological conditions which result from the disturbance of it, a brief outline of the arterial supply of the cerebral cortex will be included here.

The cerebral arteries are larger and thinner-walled in man than other animals. The vertebral arteries come up along side of the vertebrae and fuse at the level of the pons to form the basilar artery. The posterior inferior cerebral branch passes around the medulla over the entrance of the auditory (VIII) nerve. This artery is subject to injury which, when it results in hemorrhage, will cause dizziness by effecting the vestibular component of VIII.

All along the course of the basilar artery are given of small pontine branches which enter the substance of the pons. At the upper border of the pons is given off a branch, the superior cerebellar artery, which runs to the superior surface of the cerebellum.
Cortical projection centers on the lateral aspect of the cerebral hemisphere

Lobes on the lateral aspect of the human cerebral hemisphere

Cortical areas especially concerned with language
The basilar bifurcates to the posterior surface of the cerebral cortex and goes more specifically to the region of the visual cortex. A hemorrhage of this branch results in blindness. This is often caused by a blow on the back of the head. The middle cerebral artery goes to the olfactory area (hippocampus), the auditory area and the motor and sensory areas except to the portions for the lower extremeties (toes, feet, and ankles). This artery gives off branches to the striatum (basal ganglia). The lenticular-striat artery involves the internal capsule. This branch has a very thin wall and is the artery of cerebral hemorrhage.

Structures of the Cortex

Lobes: (Figure 9)

1. Frontal
2. Parietal
3. Temporal
4. Occipital
5. Fornicate gyrus (a lobe)
6. Island (insula)

Interlobar fissures:

1. Central
2. Parieto-occipital
3. Portion of the lateral fissure
4. Circular fissure
5. Calloso-marginal fissure
6. Fissure of the corpus callosum
7. Calcarine fissure
8. Collateral fissure

Total fissures:

Total fissures are those which are deep enough to make a mark on the ventricular floor.
1. Hippocampal fissure
2. Collateral (forms the collateral eminence in the lateral ventricle)
3. Calcarine (makes a mark on the posterior horn like the claw of a bird)
4. Parieto-occipital eminence (rare)
5. Lateral fissure
6. Choroid fissure (this fissure is an embryonic structure and is represented in the adult by the choroid plexus of the lateral ventricle.)

The convolutions in the cerebral cortex are due to an increase in cortical surface.
Chapter X

LABORATORY SUPPLEMENT

Gross Material—Brain Stem: (Sheep or human)

These are considered together because of their intimate interrelations structurally and functionally.

1. Determine the limits of medulla oblongata and of pons on the gross material.

2. Identify the following structures on the dorsal surface of the gross specimen:
   a. sulcus posterior (dorsal) medianis
   b. Sulcus posterior intermedius
   c. sulcus posterior lateralis
   d. rhomboid fosse (floor of fourth ventricle)
   e. obex
   f. calamus scriptorius (inferior portion of fossa)
   g. superior cerebellar peduncle (brachium conjunctivum)
   h. middle cerebellar peduncle (brachium pontis)
   i. inferior cerebellar peduncle (corpus restiforme)
   j. anterior medullary velum
   k. nervus trochlearis (IV)
   l. clava
   m. tuberculum cuneatum
   n. tuberculum cinereum
   o. eminentia medialis (medial eminence)
   p. trigonum hypoglossi
   q. ala cinerea
   r. area acustica
   s. striae medullares acustici
   t. colliculus facialis
   u. sulcus limitans
   v. sulcus medialis
   w. fovea superior
   x. funiculus gracilis
   y. funiculus cuneatus

3. Identify the following structures on the ventrolateral surface of the gross specimen:
   a. sulcus ventralis (anterior) medianis (midline, ventral side)
   b. pyramid
   c. nervus hypoglossi (XII)
d. inferior olivary nucleus  
e. nervus accessorius (XI) (as well as any cervical rootlets present)  
f. nervus vagus (X)  
g. nervus glossopharyngeus (IX)  
h. nervus acusticus (VIII)  
i. nervus facialis (VII)  
j. nervus abducens (VI)  
k. nervus trigeminus (V)  
l. middle cerebellar peduncle (brachium pontis)

Cerebellum.

Identify on the gross material the following:

a. vermis  
b. hemisphere  
c. lobes  
d. fissures  
e. peduncles  
f. nuclei (on some material)

Midsagittal section of the brain.

Take the midsagittal section of the gross material of the human brain and identify, by the aid of texts and atlases, all the visible structures.

Study:

midsagittal view  
lateral  
ventral  
cross section  
horizontal

1. Identify the frontal, occipital, and temporal poles of the hemisphere.

2. Identify the lobes of the hemisphere: frontal, parietal, temporal and occipital lobes and the insula and gyrus fornicatus.

3. Identify the interlobar fissures: central, lateral, parieto-occipital, calcarine, collateral, sulcus cinguli (calloso-marginal), limiting.
4. Identify the following structures in--

A. The frontal lobe
   a. Fissures: superior frontal, inferior frontal, percentral, olfactory sulcus (sulcus rectus).
   b. Gyri: superior frontal, middle frontal, inferior frontal, triangular, orbital opercular, precentral, paracentral.

   What is Broca's convolution?

B. The parietal lobe
   a. Fissures: postcentral, interparietal
   b. Gyri: postcentral, superior parietal, inferior parietal, angular supramarginal, paracentral.

C. The temporal lobe

D. The occipital lobe
   a. Fissures: calcarine, lunate (if visible).

E. The gyrus fornicatus
   a. Fissures: fissura hippocampi, sulcus of corpus callosum.
   b. Gyri: Hippocampi, cinguli isthmus of gyrus fornicatus, uncas

F. The insula
   b. Gyri: brevis, longus

Identify frontal, parietal, and temporal opecula. The entrance to the insula is known as the limen.
The following books should be helpful to the student of nervous anatomy especially for their figures and illustrative material.


