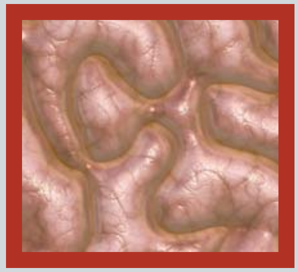
UNIT 2



Nervous Tissue, Central Nervous System, Special Senses, and Endocrine System

PART 1

This unit will be covering the systems that allow communication in the body—the nervous system and the endocrine system. We will begin with the nervous system, then explore the ear and eye, and end this unit with the endocrine system.

Nervous Tissue and the Neuron

Nervous tissue is one of the four types of tissues found in the human body. The primary characteristic of nervous tissue is conductivity. This tissue is capable of transmitting an impulse. This tissue is also described as irritable which means it can be stimulated. When it is stimulated it then conducts the impulse.

The fundamental unit of the nervous system is the **neuron**. This is the cell that is stimulated and responsible for transmitting nervous impulses. There are about 20 billion neurons in the cerebrum and a total of 100 billion neurons in the brain. In the spinal cord there are about 1 billion neurons. The other type of cell found in nervous tissue is the **neuroglia** or glial cells. For every neuron there are 10 to 50 glial cells. These cells serve many functions in the nervous system including support, nourishment, and protection. In the lab the only glial cell studied is the **Schwann cell** (SHWAHN) also known as a **neurolemmocyte** (NU-rah-LEM-mah-site) which is the glial cell found in the peripheral nervous system.

There are three important parts to every neuron: the **cell body**; the **dendrites** (DEN-drytes); and the **axon**. First, let's look at the cell body. This is the control center for the neuron. If the cell body dies, the neuron will die. The cell body may be called the **soma** (so-MAH) or the **perikaryon** (PER-IKER-ee-on). In the neuron you will find the same organelles as in most other cells. Neurons have a nucleus, ribosomes, Golgi bodies, mitochondria, and all the other organelles necessary for cellular function.

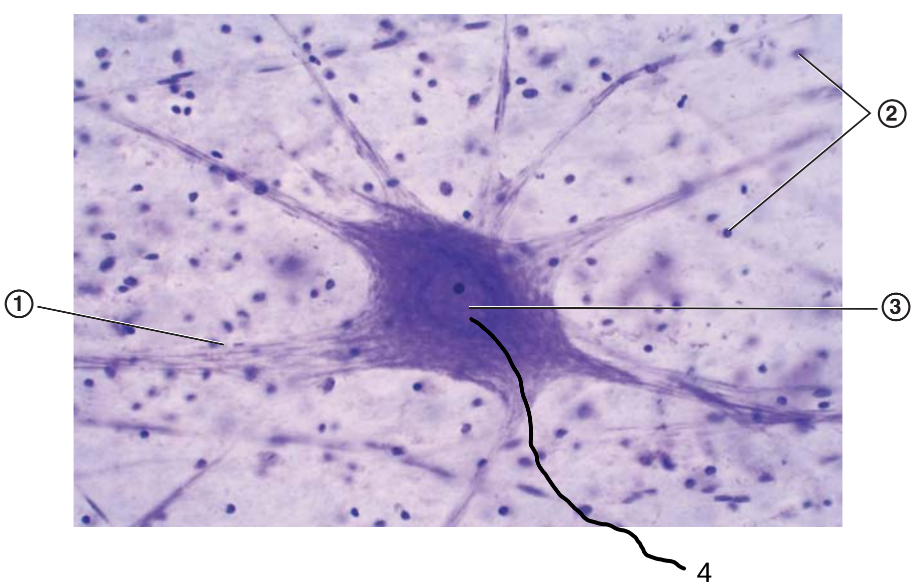
There are a few unique features in the cell body of a neuron that need to be addressed. Scattered throughout the cytoplasm of the neuron there are dark structures called **Nissl bodies** (NIS-ahl). These structures are mainly rough endoplasmic reticulum that are responsible for protein synthesis. The neuron has a well developed cytoskeleton that functions in support and intracellular transport. The microtubules are important in intracellular transport. There are **neurofibrils** (NU-rah-FYE-brils); very thin threads that extend into the axon to support it.

The dendrites are processes of the neuron that receive information from other cells or stimuli and transmit the message to the cell body. Depending on the neuron, the dendrites can take on several different appearances. These processes allow neurons to receive communications from other cells as well as monitoring the environment, internal and external.

The axon is a process that conducts the message away from the cell body toward other cells. A bundle of axons is known as a **nerve** in the peripheral nervous system, and a **tract** in the central nervous system. There is only one axon leaving a cell body, however, that axon can then branch into collaterals. At the end of the axon there are many small branches that each have a specialized **axon terminal** that ends in the **synaptic knob** (SINAP-tik). The synaptic knob contains the chemical neurotransmitter that will be released to carry the electrical message from the neuron to the next cell. The synaptic knob does not actually touch the next cell, there is a very small gap known as the **synaptic cleft**. A **synapse** is the area that encompasses the synaptic knob, synaptic cleft, and the postsynaptic membrane. Each "typical" neuron is part of a thousand to ten thousand synapses. As a result, there are about a quadrillion synapses in the brain and 60 trillion of those are just in the cerebral cortex.

Axons in the peripheral nervous system may be covered by a **myelin sheath** (MY-ah-lin) formed by neurolemmocytes (Schwann cells). Myelin is a fatty material that serves as insulation on the axon. It is also responsible for the white color of white matter in the nervous system. The neurolemmocytes are wrapped around the axon and the myelin is found between this cell and the axon of the neuron. The nucleus and organelles of the neurolemmocyte are found just beneath the neurilemma. The membranous sheath of the neurolemmocyte around the axon is the **neurilemma** (alternate spelling: neurolemma). There are several neurolemmocytes (Schwann cells) covering each axon and the gaps between these cells are the **nodes of Ranvier** (RON-vee-ay), or **neurofibril nodes**.

Neurons can be classified according to their functions. **Sensory** or **afferent neurons** transmit impulses from sensory receptors to the central nervous system. **Motor** or **efferent neurons** transmit impulses from the central nervous system to the muscles or glands. **Interneurons** are found only in the central nervous system where they connect neuron to neuron.



1. Process
2. Glia
3. Cell body

1. Processes of neuronal cell body
2. Neuroglia
3. Cell body of neuron
4. Nucleus of neuron

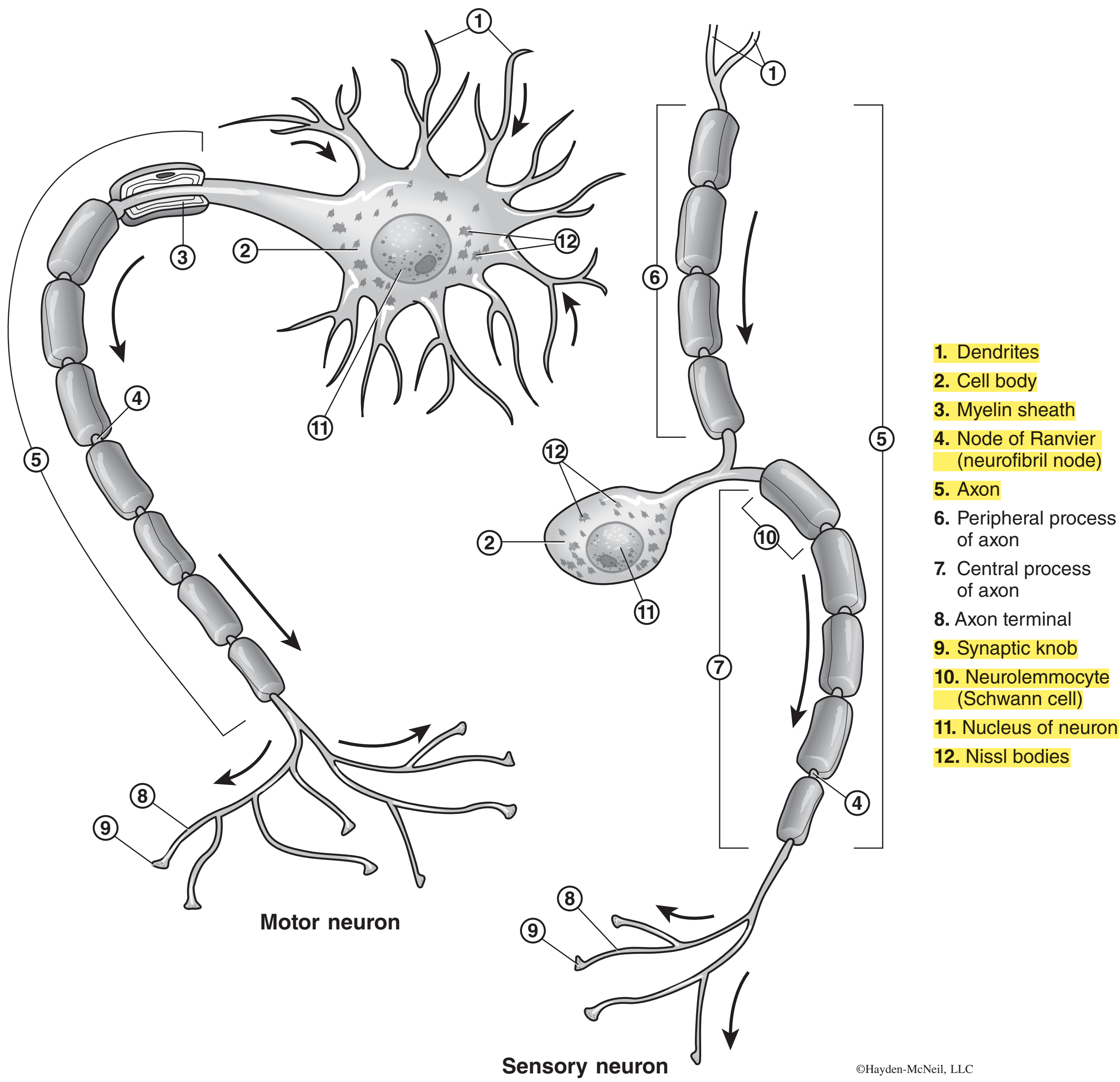
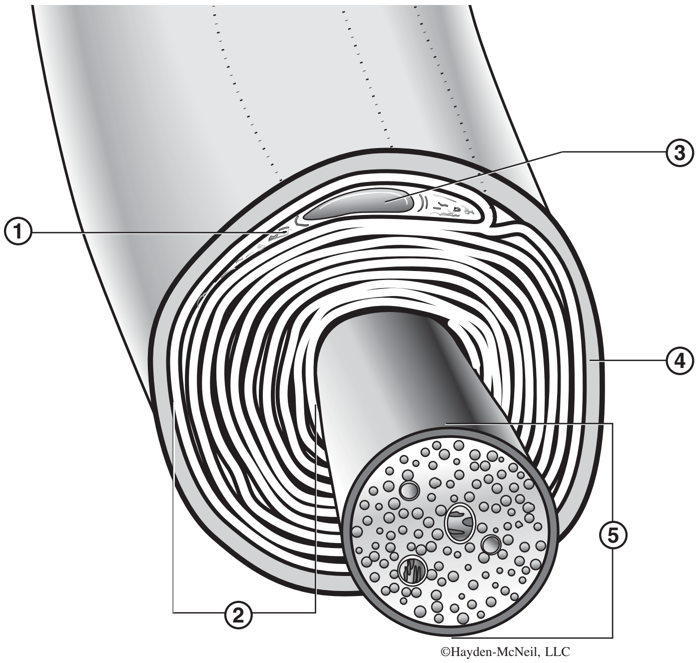


Figure 2.1. Motor and Sensory Neuron



1. Cell body of neurolemmocyte (Schwann cell)
2. Myelin sheath
3. Nucleus of neurolemmocyte (Schwann cell)
4. Neurilemma Neurolemma
5. Axon

Figure 2.2. Axon with Myelin Sheath

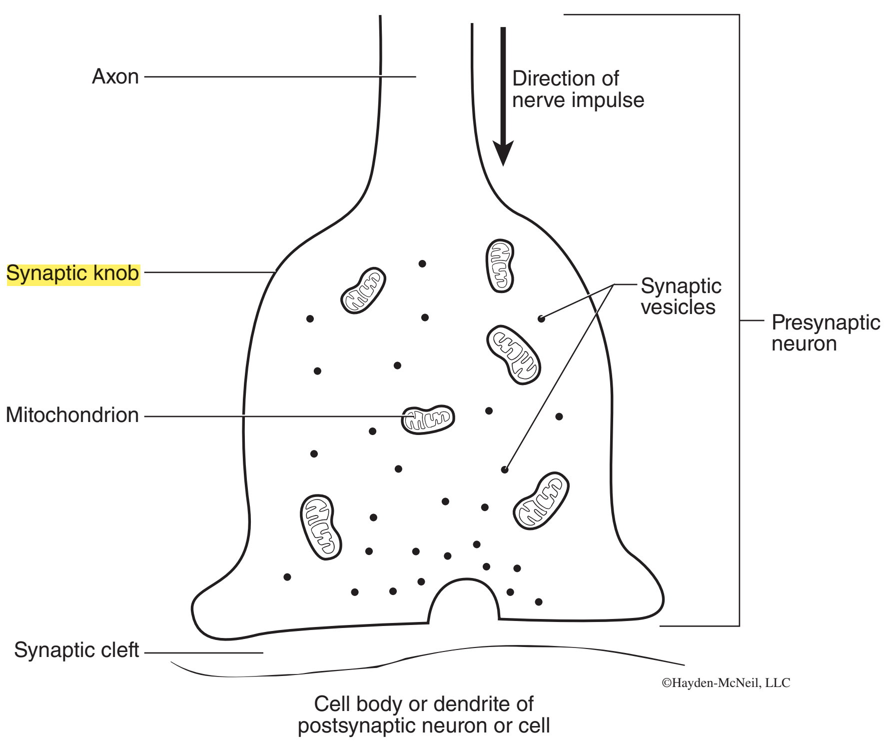


Figure 2.3. Synaptic Knob

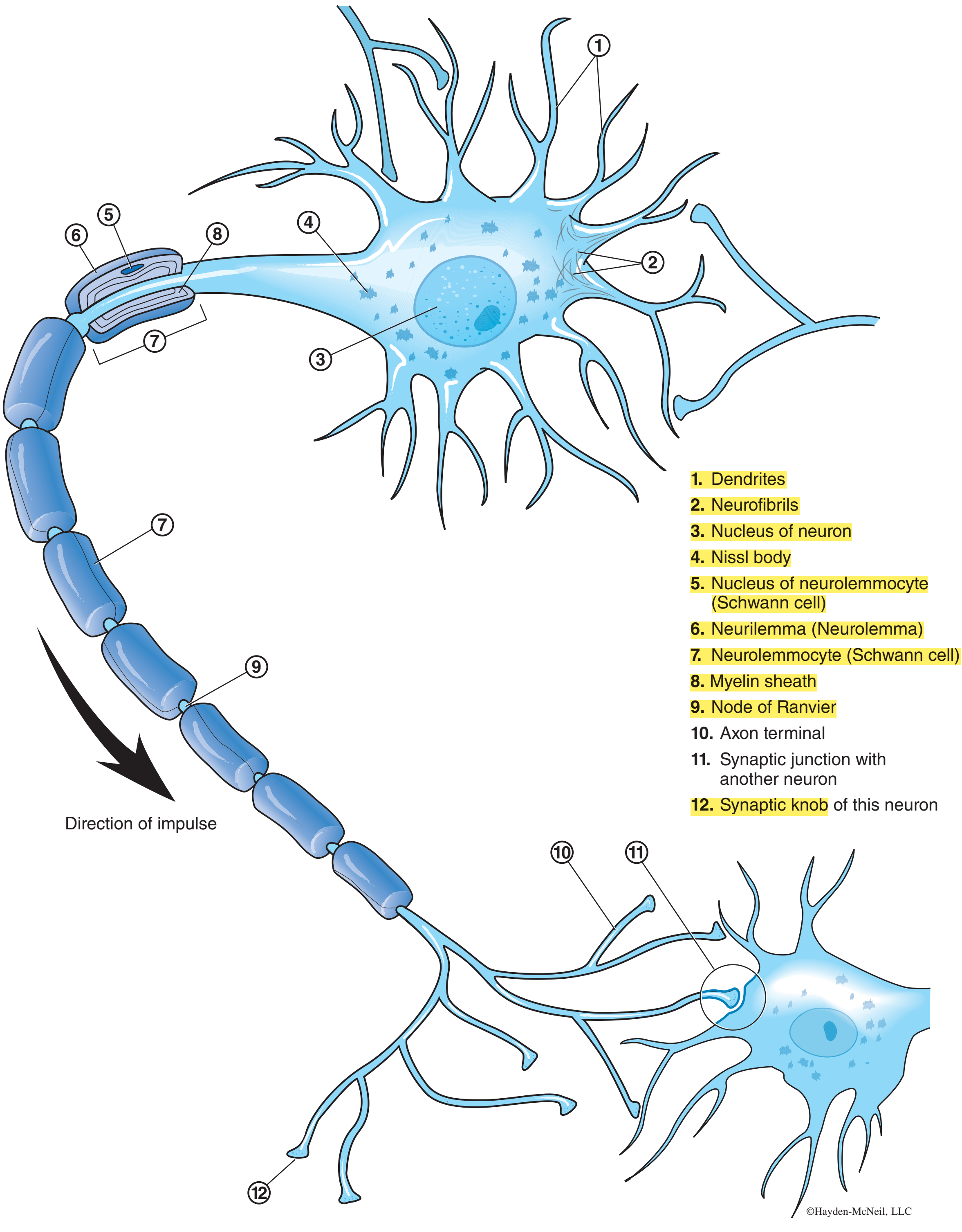


Figure 2.4. Motor Neuron with Synapse

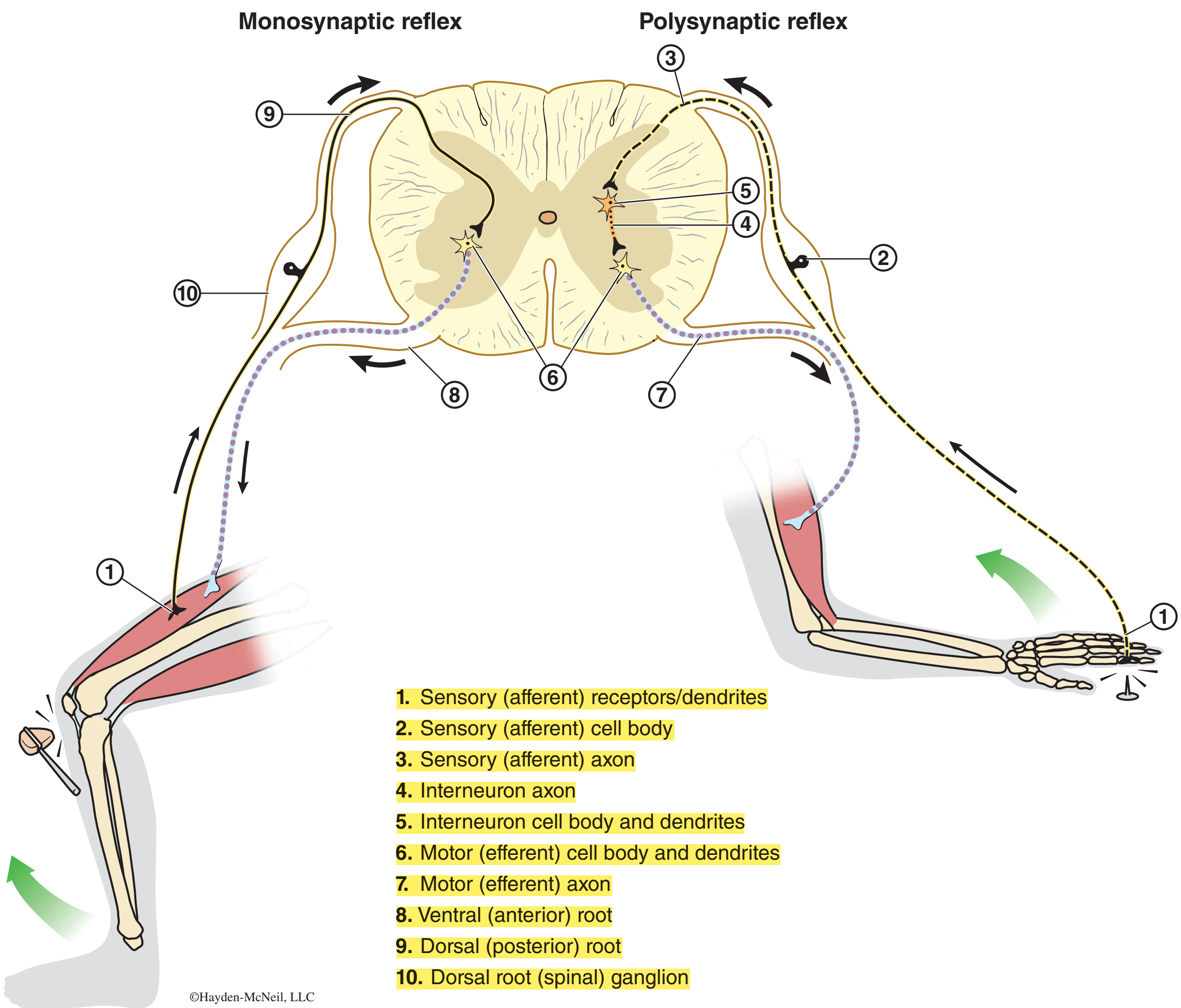


Figure 2.5. Spinal Cross Section with Neurons

PART 2

THE BRAIN

The central nervous system consists of the brain and the spinal cord. You will first examine the brain and then in the next part you will examine the spinal cord.

The human brain weighs about three pounds and is located inside the skull or cranium which protects it from harm. The brain is made of white and gray matter. White matter refers to the presence of myelin and gray matter refers to the absence of myelin. When observing actual brain tissue it does not actually appear gray and white. All brain tissue appears beige with the gray matter referring to the darker beige tissue and the white matter referring to the lighter beige tissue.

In the cerebrum and cerebellum the gray matter is a thin layer on the exterior surface and is referred to as the cortex. The white matter is located in the interior. The thalamus and hypothalamus are mainly gray matter. In the brainstem gray matter is scattered within the white matter and is associated with the reflex centers.

The brain has four main divisions: the **cerebrum** (SER-e-brum), the **diencephalon** (DYE-en-SEF-ah-lon), the **cerebellum** (ser-e-BELL-um), and the **brainstem**. The brainstem is the most inferior part of the brain and it consists of the **medulla oblongata** (mah-DUL-ah OB-long-GAH-tah), **pons** (PONZ), and **midbrain**. The brainstem is the structure that connects the brain with the spinal cord. Attached posteriorly to the pons and midbrain is the cerebellum. Superior to the brainstem is the diencephalon, and the largest division of the brain is the cerebrum.

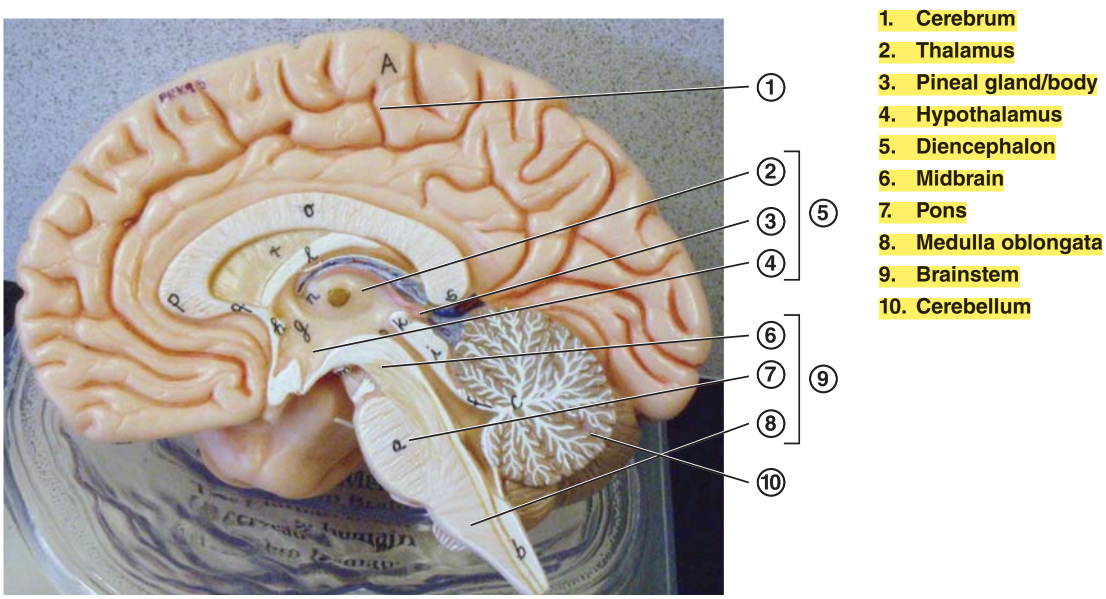


Figure 2.6. Divisions of the Brain

Cerebrum

The **cerebrum** has two hemispheres that superficially appear the same. The surface of the cerebrum has many ridges and grooves. The ridges are the **gyri** (JI-rye) [singular, gyrus (JI-rahs)] and the grooves are the **sulci** (SUL-key) [singular, sulcus (SUL-kus)]. Deep grooves are called **fissures**. The fissures, sulci, and gyri are used as markers to identify locations or separate areas of the brain.

Each hemisphere consists of five lobes. However, only four of the lobes are visible on the surface of the brain. The frontal lobe is located beneath the frontal bone; the parietal lobe is beneath the parietal bone; the temporal lobe below the temporal bone, and the occipital lobe below the occipital bone. The fifth lobe is located by separating the lateral fissure between the frontal lobe and temporal lobe. This is the insula and is not visible anywhere in the laboratory.

The **frontal lobe** is located anterior to the **central sulcus**. The somatic motor cortex is found in the **precentral gyrus** of this lobe. The prefrontal areas are involved in emotions, motivation, and personality.

The **parietal lobe** is located posterior to the central sulcus. The **postcentral gyrus** in this lobe is the location of the somatic sensory cortex. The area behind the postcentral gyrus is involved in visual-spatial relationships and proprioception, which is the awareness of the position of body parts in space.

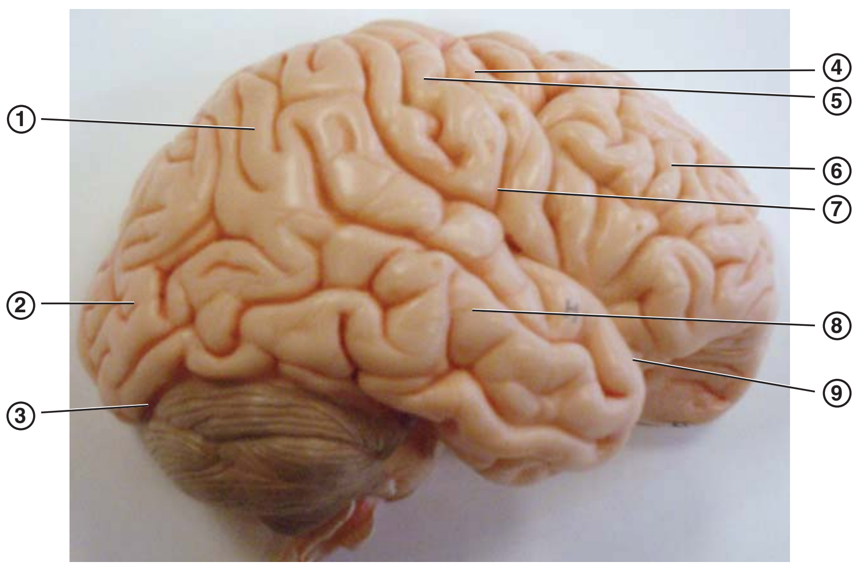
The **temporal lobe** is separated from the frontal lobe by the **lateral fissure**. This lobe contains the auditory cortex which is concerned with hearing. It also plays an important role in memory, language, and speech.

The **occipital lobe** is located in the posterior region of the brain. This lobe is primarily concerned with vision as it is the location of the visual cortex.

The **insula** is located under the lateral fissure of the brain and is not visible in lab. This lobe plays a role in some language functions as well as processes certain sensory input such as pain, temperature sensation, and possibly taste. It also integrates sensory and autonomic information from the viscera.

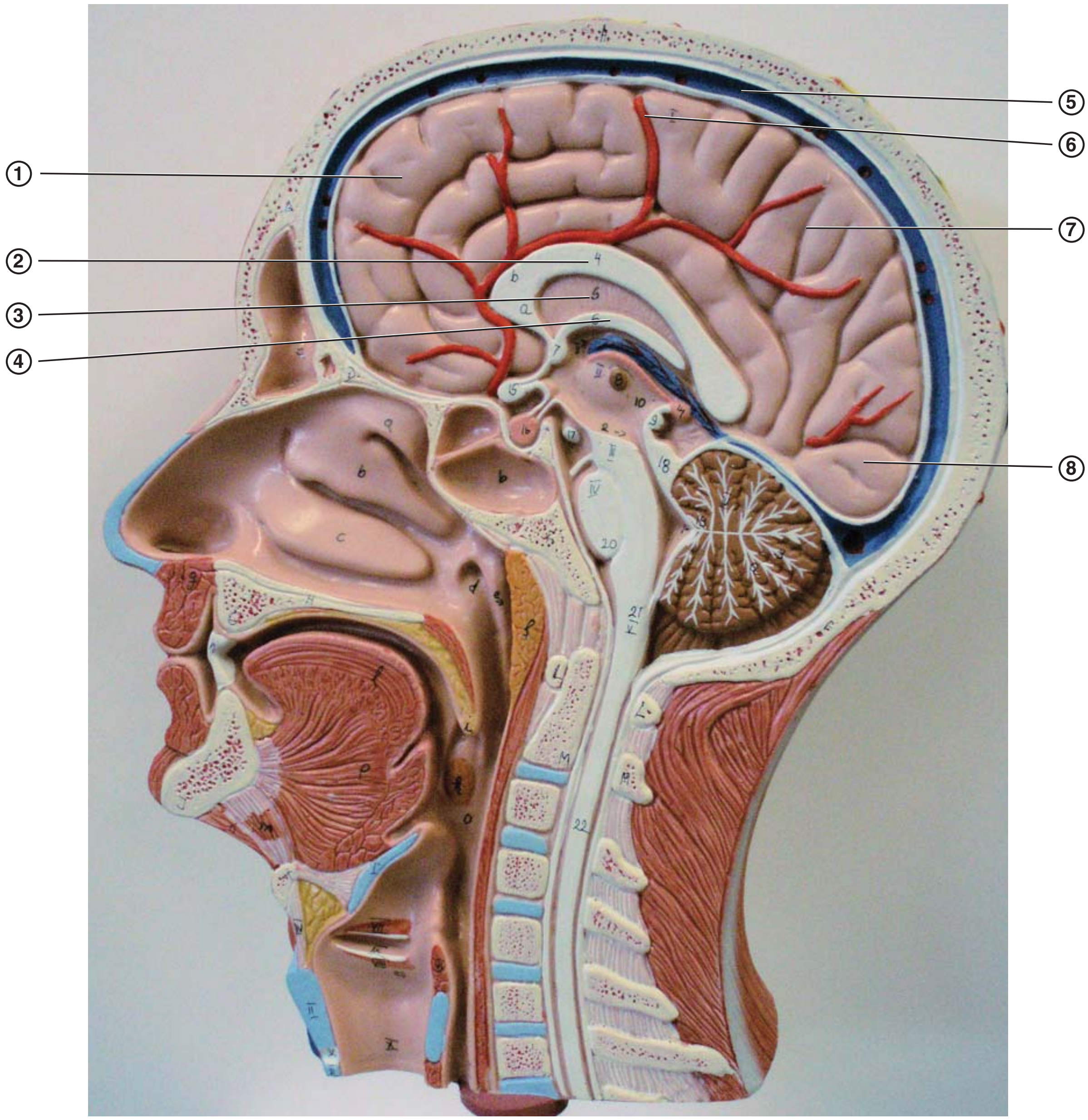
The crevice between the two hemispheres is the **longitudinal fissure**. The crevice between the cerebrum and the cerebellum is the **transverse fissure**. The **central sulcus** is the groove that separates the frontal and parietal lobes. The **lateral fissure** is the crevice between the frontal and temporal lobes.

Most structures that must be identified in the brain can be located by viewing the sagittal or inferior view. On the sagittal section there is a wide curved band of white fibrous tissue; this is the **corpus callosum** (KOR-pus kah-LO-sum). It is a band of commissural fibers that allows communication between the two hemispheres. This structure actually contains about 250 million fibers. When you dissect the sheep's brain you will be cutting through this structure.



1. Parietal lobe
2. Occipital lobe
3. Transverse fissure
4. Precentral gyrus
5. Postcentral gyrus
6. Frontal lobe
7. Central sulcus
8. Temporal lobe
9. Lateral fissure (sulcus)

Figure 2.7. Lobes, Gyri, and Fissures of the Cerebrum



Median Section of the Head LT-C12, 3B Scientific®

1. Frontal lobe
2. Corpus callosum
3. Septum pellucidum
4. Fornix
5. Superior sagittal sinus
6. Central sulcus
7. Parietal lobe
8. Occipital lobe

Figure 2.8. Structures of the Cerebrum

Below and attached to the corpus callosum is the **septum pellucidum** (SEP-tum pah-LOO-si-dum). This is a membrane that separates the lateral ventricles of the brain. Below this structure is another band of nerve fibers known as the **fornix** (FOR-niks). This connects the hippocampus, part of the limbic system, to the mamillary bodies of the hypothalamus.

Surrounding the outer perimeter of the cerebrum is a large vein-like structure called the **superior sagittal sinus**. This venous vessel collects the blood from the veins that drain the cerebral hemispheres. This is just one of a number of venous vessels known as the dural sinuses that drain the brain. Ultimately they drain into the internal jugular vein to return oxygen poor blood to the heart. The superior sagittal sinus is the location of the arachnoid granulations that return cerebrospinal fluid to the venous blood.

On the inferior surface of the cerebrum are the **olfactory bulbs** and **olfactory tracts**. These structures carry the sense of smell from the olfactory nerves in the roof of the nose to the brain.

Diencephalon

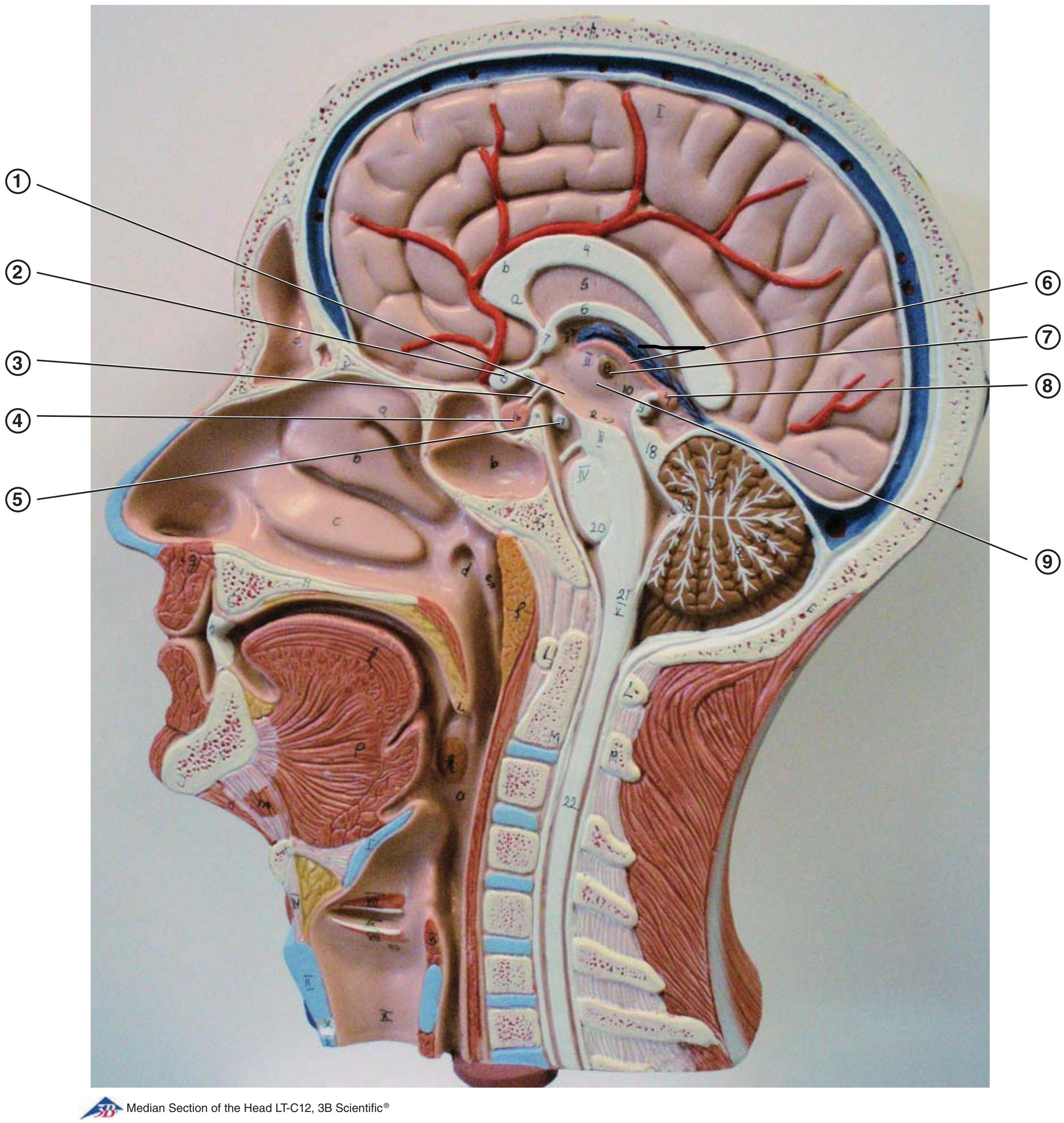
Located inferior to the cerebrum is the diencephalon. The thalamus, hypothalamus, optic chiasma, pituitary gland, and the pineal gland are all located in this division of the brain.

The **thalamus** (THAL-ah-mus) is located just below the fornix. The tissue of the thalamus makes up the walls of the third ventricle. In the center of this area there is the **intermediate mass of the thalamus**, which connects the two lobes of the thalamus. This area of the brain serves as a sensory relay station.

The **hypothalamus** (HY-po-TAL-ah-mus) is located below the thalamus and the tissue makes up the floor of the third ventricle. This area of the brain has an immense impact on life. It essentially regulates homeostasis. It controls the pituitary gland and actually produces two of the hormones released by the posterior pituitary gland.

The **hypophysis** (hi-POF-i-sis), which is also known as the **pituitary gland**, is situated below the hypothalamus and connected to it by the **infundibulum** (in-fun-DIB-u-lum). The infundibulum is a hollow stalk that serves as a passageway for hormones and regulatory factors. Two projections off the hypothalamus just posterior to the hypophysis are the **mamillary bodies** (MAM-ah-LAR-e). These serve as olfactory relay stations. Anterior to the hypophysis is the **optic chiasma** (OP-tik ki-AZ-mah). This is the point where optic nerve fibers from the nasal portion of each retina cross over to the opposite side of the brain. The **optic nerves** are anterior to the optic chiasma while the **optic tracts** are posterior. Chiasma means to cross over or form an X. When observed on the inferior brain the optic chiasma does have the appearance of an X. On the sagittal section, all that is visible is the center of the X so it appears as an oval structure.

The **pineal gland** (PIN-e-al) or body and the **choroid plexus** (KO-roid PLEK-sus) **of third ventricle** are structures of the epithalamus, which forms the roof of the third ventricle. The pineal gland is a neuroendocrine structure. It is stimulated by the nervous system and releases a hormone, melatonin. This gland can be found at the end of the choroid plexus of the third ventricle and slightly superior and posterior to the corpora quadrigemina of the midbrain. The choroid plexus is a structure found in the roof of every ventricle and is composed of a capillary bed, pia mater, and ependymal cells. It produces the cerebrospinal fluid (CSF) that is found in the ventricles of the brain, the subarachnoid space, and central canal of the spinal cord.



1. Hypothalamus
2. Optic Chiasma
3. Infundibulum
4. Pituitary gland (hypophysis)
5. Mamillary body
6. Choroid plexus of 3rd ventricle
7. Intermediate mass of thalamus
8. Pineal gland (body)
9. Thalamus (tissue) 3rd ventricle (space)

Figure 2.9. Structures of the Diencephalon

Cerebellum and Brainstem

The most inferior divisions of the brain are the cerebellum and the brainstem. The **cerebellum** is located on the dorsal aspect of the brain inferior to the occipital lobe of the cerebrum and posterior to the pons and midbrain. It is responsible for muscle coordination, posture, and balance. It consists of two hemispheres with gyri and sulci on the surface.

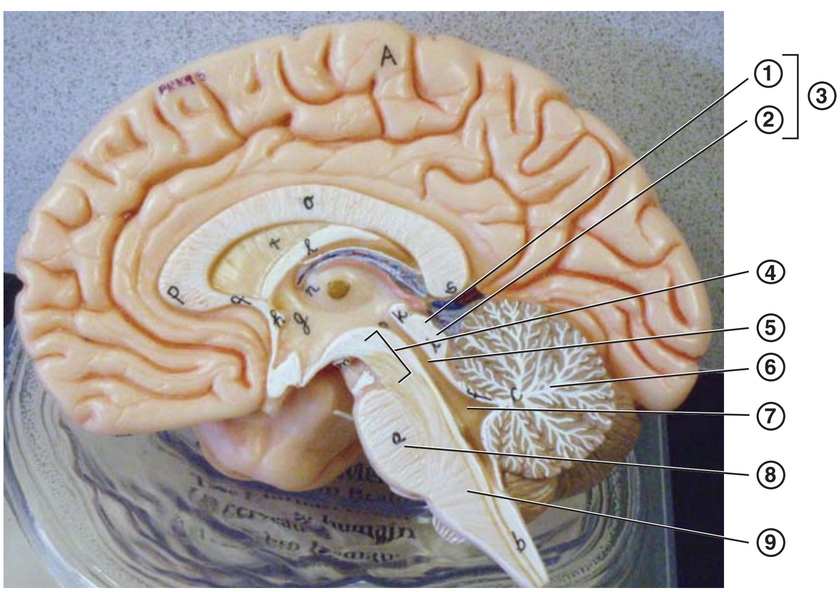
Anterior to the cerebellum is the **brainstem**. The most superior division of the brainstem is the **midbrain** or the **mesencephalon** (mez-en-SEF-a-lon). Below the midbrain is the **pons** and the most inferior portion is the **medulla oblongata**. As the nervous tissue from the medulla oblongata narrows and passes through the foramen magnum of the skull it becomes the spinal cord.

The midbrain contains a couple of important structures. On the sagittal section of the brainstem, it appears that the midbrain is dissected by a canal. This is the **cerebral aqueduct** (SUREE-bral AH-kwah-duct) or the **cerebral aqueduct of Sylvius** that connects the third ventricle with the **fourth ventricle**.

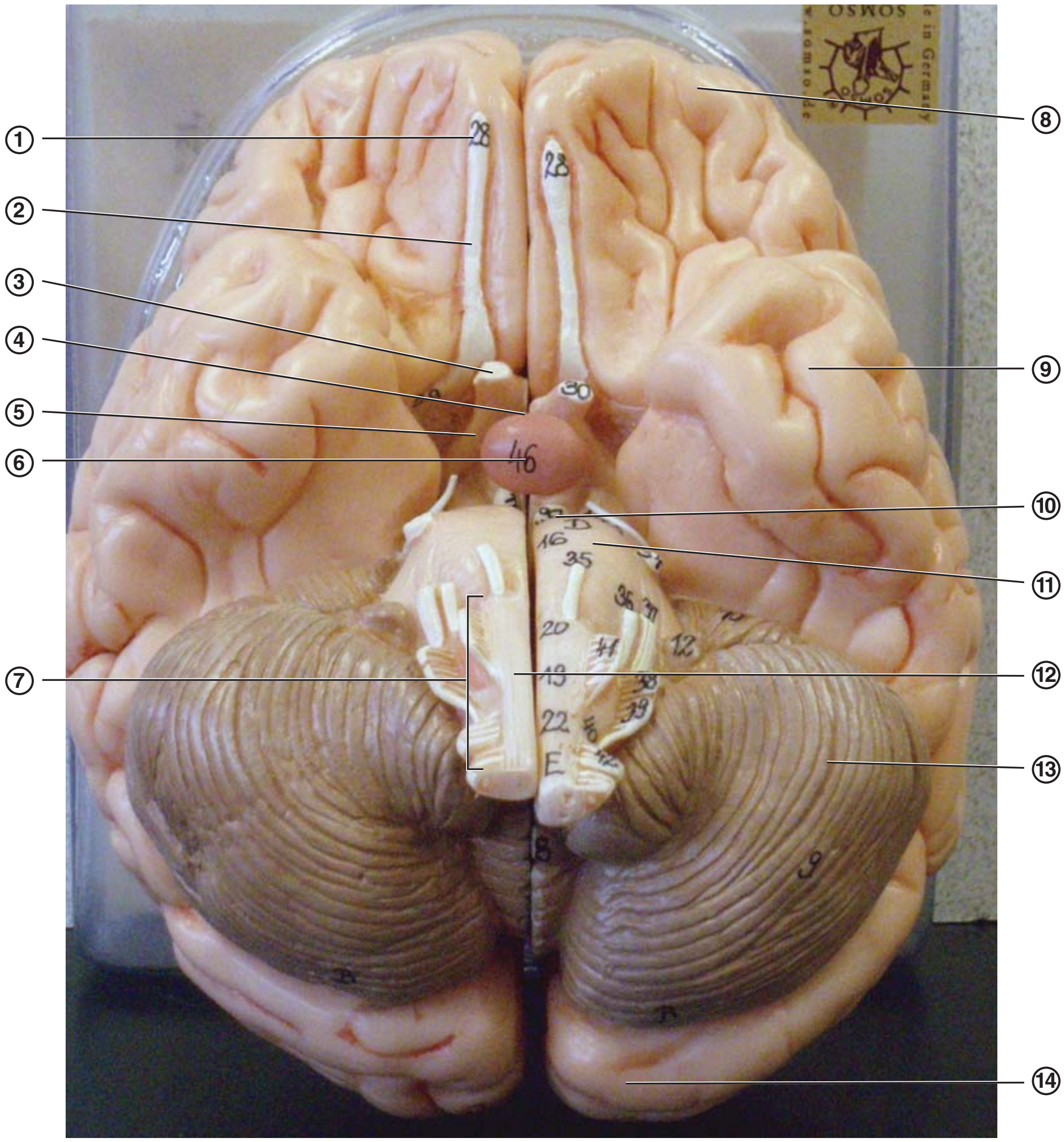
Posterior to the cerebral aqueduct there are two pairs of rounded processes. These four masses are known as the **corpora quadrigemina** (KOR-pour-ah KWAH-dri-JEM-i-nah). The two superior masses are the **superior colliculi** (ko-LIK-you-lye) (singular: colliculus) which are involved in visual reflexes. The two inferior masses are the **inferior colliculi** which are involved in auditory reflexes.

The **pons** is the rounded bulge of the brainstem below the midbrain. It serves to relay impulses between the medulla and the cerebrum as well as between the cerebrum and the cerebellum. It also contains reflex centers involved in inspiration (inhalation). Between the pons and the cerebellum there is a triangular cavity known as the fourth ventricle.

Between the pons and the foramen magnum is the **medulla oblongata**. It is a slightly enlarged continuation of the spinal cord. It contains several reflex centers, most importantly the reflex centers for heart rate, blood pressure, and respiration. The dorsal surface forms the floor of the fourth ventricle. The **pyramids** are a pair of elevations on the anterior surface of the medulla. Tracts entering and leaving the brain may pass through these structures and will be called pyramidal tracts. If the tracts pass around the pyramids they are extrapyramidal tracts.



1. **Superior colliculus**
2. **Inferior colliculus**
3. **Corpora quadrigemina**
4. **Midbrain**
5. **Cerebral aqueduct (of Sylvius)**
6. **Cerebellum**
7. **Fourth (4th) ventricle**
8. **Pons**
9. **Medulla** oblongata



1. Olfactory bulb
2. Olfactory tract
3. Optic nerve
4. Optic chiasma
5. Optic tract
6. Pituitary gland (hypophysis)
7. Medulla oblongata
8. Frontal lobe
9. Temporal lobe
10. Mamillary body
11. Pons
12. Pyramid
13. Cerebellum
14. Occipital lobe

Figure 2.10. Inferior Brain

Meninges

It is apparent that the brain and spinal cord are important. They are also delicate tissue. The skull provides a rigid protective case for the brain, and the vertebral column provides protection for the spinal cord. However, there are additional structures that are involved in the protection of the brain and spinal cord. Both the meninges and the cerebrospinal fluid aid in the protection of the brain. The meninges will be discussed first.

The **meninges** (meh-NIN-jes) are three layers of tissue that cover the brain and spinal cord—**dura mater** (DOO-rah MAY-ter), **arachnoid mater** (ah-RAK-noyd), and **pia mater** (PI-ah). The dura mater is the outermost layer. It is tough, white, dense connective tissue that contains blood vessels and nerves. It is the most durable of the meninges. In the skull it is attached to the inner surface of the bones and forms the internal periosteum, so there is no space between the dura mater and the skull bones.

Between the hemispheres of the cerebrum and cerebellum as well as between the cerebrum and cerebellum it extends inward to form partitions known as the **falx cerebri** (FALKS SER-ah-bri), **falx cerebelli** (ser-ah-BELL-i), and **tentorium cerebelli** (ten-TOE-ree-um). In some areas there are canals in the dura mater that contain venous blood, these are the dural sinuses.

The dura mater continues to cover the spinal cord. However, in the vertebral column it is not fused with the bones. This results in the space containing blood vessels and adipose tissue between the dura mater and the periosteum of the vertebrae. This space is the **epidural space**. The name refers to the fact that the space is on or above the dura mater. It is only present in the spinal cord, not in the brain. This space has a purpose in anesthesia. It can be used to administer anesthetics to block pain sensations.

The dura mater covering the spinal cord continues to the level of the second sacral vertebra, well beyond the end of the spinal cord. The dura mater and the pia mater continue beyond this point as a filament to secure the spinal cord at the end of the spinal canal. This is the **filum terminale** (FI-lum TER-min-NAL-ee). The pia mater and the dura mater also fuse together in places along the length of the spinal cord to form the **denticulate ligament** (den-TIK-you-late) which secures the spinal cord in the center of the spinal canal.

The second layer of the meninges is the arachnoid mater or sometimes known simply as the arachnoid. This is a thin membrane that has the appearance of a spider web, hence the name. It is located between the dura mater and pia mater. It does not follow the contour of the brain and spinal cord but it does have thin strands that extend from it and attaches to the pia mater. There are also projections of the arachnoid mater through the dura mater into the dural sinuses. These projections are the **arachnoid granulations** that consist of a number of arachnoid villi. These structures function to return cerebrospinal fluid to the venous blood.

Normally the arachnoid mater is pressed against the inner surface of the dura mater by cerebrospinal fluid pressure in the subarachnoid space. However, there is the potential for fluid to collect in the space between these two layers. This potential space is the **subdural space**, referring to the fact it would be located below the dura mater. In normal individuals there is no space, however, if there is damage to the dural sinuses it is possible for blood to collect in this space to cause a subdural hematoma.

The pia mater is the innermost meninges. It is a very thin membrane that contains blood vessels and nerves. It lies on the surface of the brain and spinal cord, following the contours. As mentioned earlier the pia mater along with the dura mater forms the denticulate ligament and the filum terminale.

Between the arachnoid mater and the pia mater there is a fluid-filled space that is the **subarachnoid space**. The fluid is the cerebrospinal fluid (CSF).

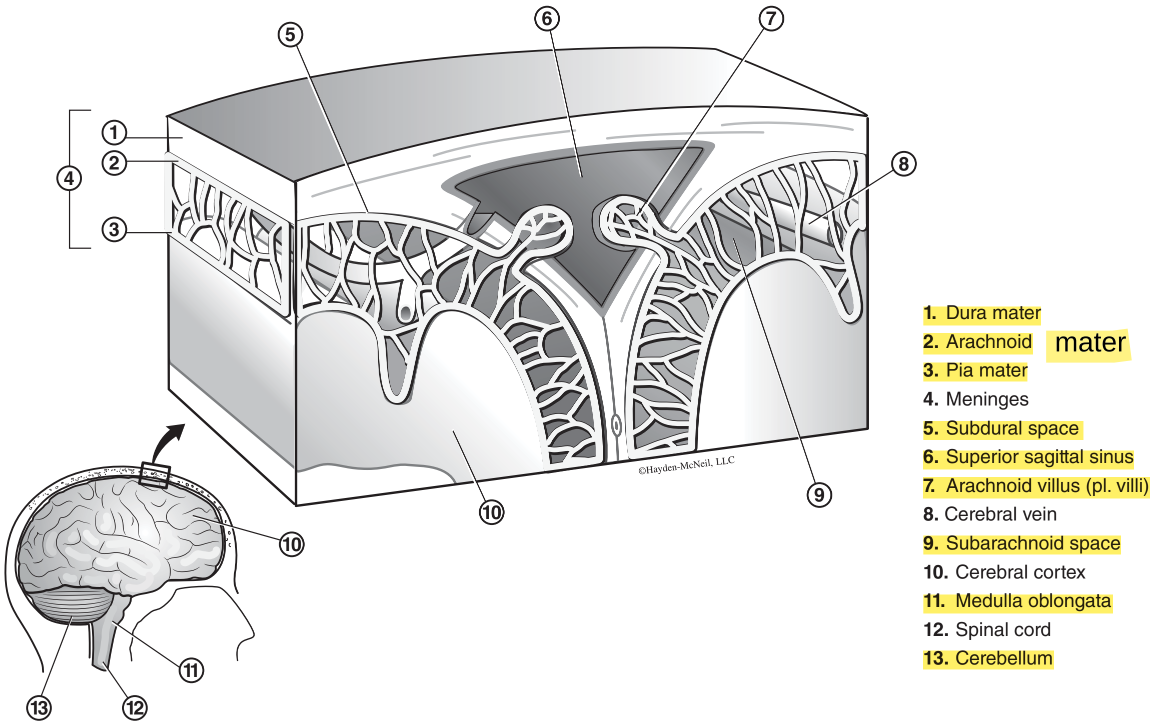


Figure 2.11. Meninges of the Brain

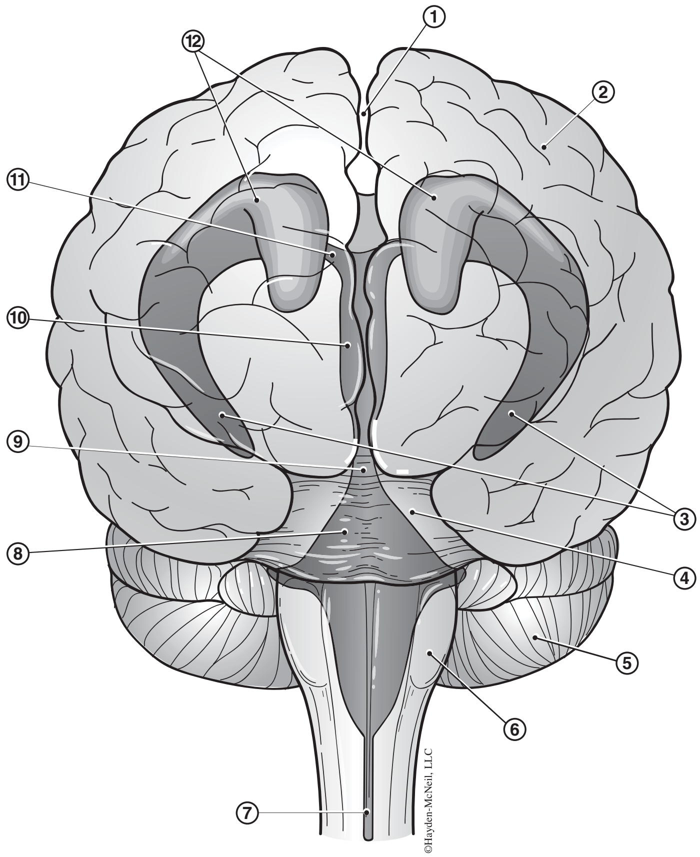
Ventricles

The **ventricles** are four fluid-filled cavities located in the cerebrum, diencephalon, and brainstem. The fluid found in the ventricles is cerebrospinal fluid (CSF). In the cerebrum there are two **lateral ventricles**, one in each hemisphere. These ventricles are connected by way of the **interventricular foramina** with the **third ventricle**, which can be found in the midline region of the diencephalon, between the two hemispheres. The thalamus makes up the walls of the third ventricle, while the floor is made up of the hypothalamus, and the epithalamus makes up the roof. The third ventricle is connected to the **fourth ventricle** by way of the cerebral aqueduct.

The cerebrospinal fluid is formed in the choroid plexuses of the ventricles. A choroid plexus is a specialized capillary bed located in the roof of each ventricle. Each plexus secretes CSF; however, the majority of the fluid is produced in the lateral ventricles.

Cerebrospinal Fluid

Cerebrospinal fluid is another protective factor for the central nervous system. The fluid serves as a shock absorber as well as a method for the brain to monitor conditions within the body. After the CSF is formed in the choroid plexuses it flows through the ventricles. The fluid in lateral ventricles flows through the interventricular foramina into the third ventricle. The fluid then flows through the cerebral aqueduct to the fourth ventricle. From the fourth ventricle the fluid flows into the central canal of the spinal cord which is continuous with the fourth ventricle. The CSF also enters the subarachnoid space through the 2 lateral aperatures in the walls and the single medial aperature in the roof of the fourth ventricle. After passing through the subarachnoid space the CSF is reabsorbed into the blood by way of the **arachnoid granulations**, which penetrate the dura mater into the superior sagittal sinus. This allows the cerebrospinal fluid to be replaced on a regular basis, usually about every 8 hours. There is 125 to 150 mL of CSF in the central nervous system. The body produces about 400–500 mL each day. The CSF also produces a pressure that can be measured during a lumbar puncture or by way of an intracranial pressure transducer. The normal pressure of the CSF is 70–180 mm H_2O.

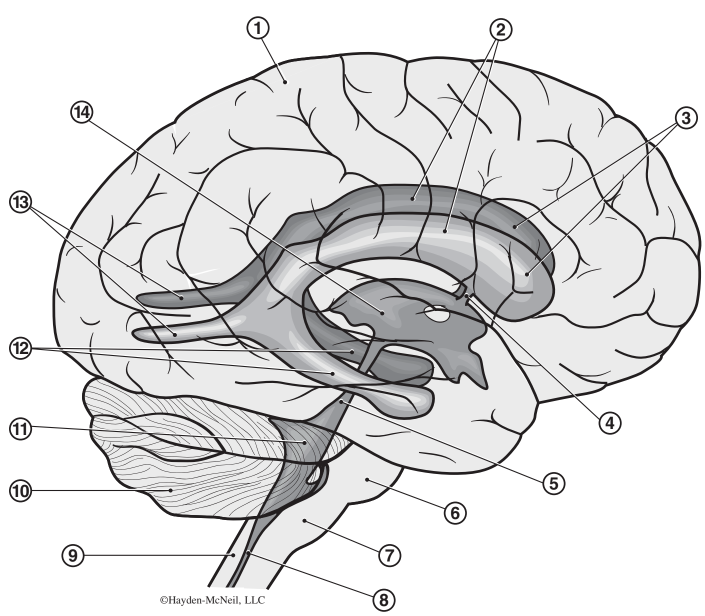


1. Longitudinal cerebral fissure

1. Longitudinal fissure
2. Cerebrum
3. Inferior horns of lateral ventricle
4. Pons
5. Cerebellum
6. Medulla oblongata
7. Central canal of spinal cord
8. Fourth ventricle
9. Cerebral aqueduct (aqueduct of Sylvius)
10. Third ventricle
11. Interventricular foramen
12. Lateral ventricles

Choroid plexus of lateral ventricles
Choroid plexus of fourth ventricle

Figure 2.12. Frontal View of Ventricles



1. Cerebral hemisphere
2. Lateral ventricles
3. Anterior horns of lateral ventricles
4. Interventricular foramen
5. Cerebral aqueduct (aqueduct of Sylvius)
6. Pons
7. Medulla oblongata
8. Central canal of spinal cord
9. Spinal cord
10. Cerebellum
11. Fourth ventricle
12. Inferior horns of lateral ventricles
13. Posterior horns of lateral ventricles
14. Third ventricle

Figure 2.13. Lateral View of Ventricles

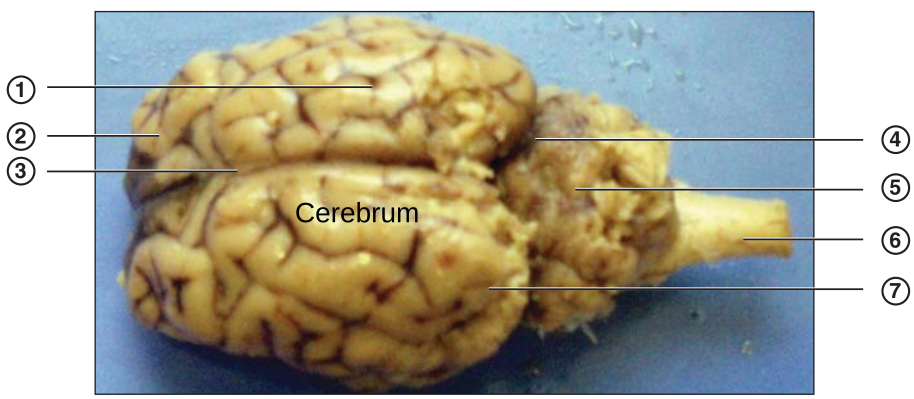
Sheep Brain Dissection

To assist in your understanding of the brain you will be dissecting a sheep's brain. You will need a preserved sheep's brain with the dura mater, a dissecting tray, a scalpel, scissors, and a probe. Remove the brain from the container. It will be covered with the dura mater. Carefully look over the brain and identify the pituitary gland on the inferior surface. You will note that the dura mater covers this structure. When you remove the dura mater you want to cut it around the pituitary so that you do not remove it with the dura mater.

Carefully remove the dura mater. Note how strong and durable it is. Fused with the dura mater is the arachnoid mater, and therefore, you will not be able to see it. You will note that the dura and arachnoid mater are not attached to the surface of the brain; this is due to the presence of the subarachnoid space. The pia mater adheres to the surface of the brain and will give the brain a glistening appearance. Carefully remove the falx cerebri and the tentorium cerebelli.

Before you perform a sagittal section on the brain, if you gently pull down on the cerebellum you will be able to visualize the corpora quadrigemina. Slightly superior to this structure you should be able to visualize the pineal gland. Turn the brain over and find the olfactory bulbs. Compare the sizes of the sheep's and the human's olfactory bulb.

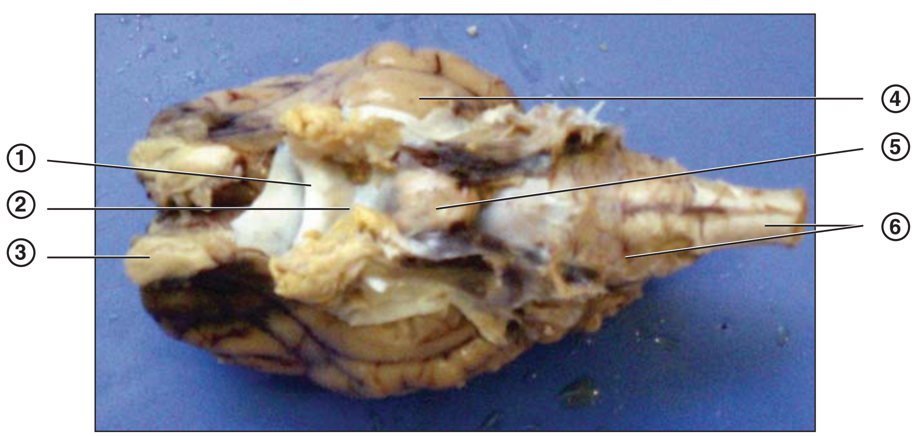
You will now perform a sagittal section on the sheep's brain. Using the scalpel cut down from the superior surface through the longitudinal fissure. Cut the brain completely in half. You should now be able to identify the major structures of the sheep's brain that are visible on sagittal section. Your lab objectives have a list of structures you should be able to identify on the sheep's brain.



1. Parietal lobe
2. Frontal lobe
3. Longitudinal fissure
4. Transverse fissure
5. Cerebellum
6. Brainstem
7. Occipital lobe

3. Longitudinal cerebral fissure

Figure 2.14. Superior View of Sheep's Brain



1. Optic nerve
2. Optic chiasma
3. Olfactory bulb
4. Temporal lobe
5. Hypophysis/pituitary gland
6. Brainstem

Figure 2.15. Inferior View of Sheep's Brain

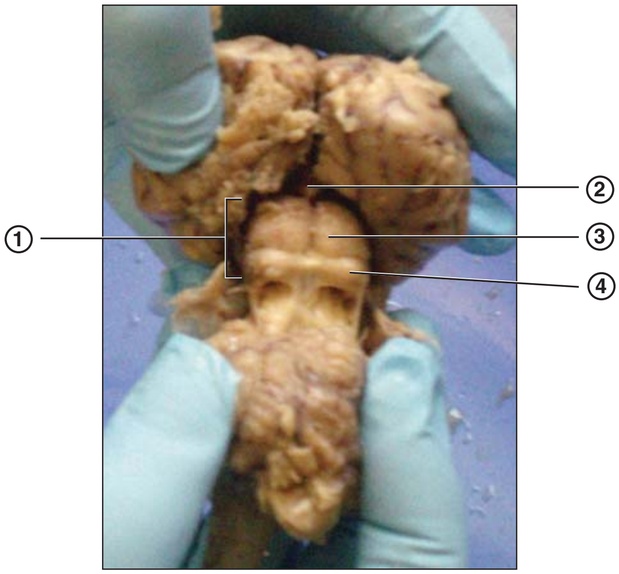


Figure 2.16. Posterior View of Sheep's Brain

1. Corpora quadrigemina
2. Pineal gland/body
3. Superior colliculus
4. Inferior colliculus

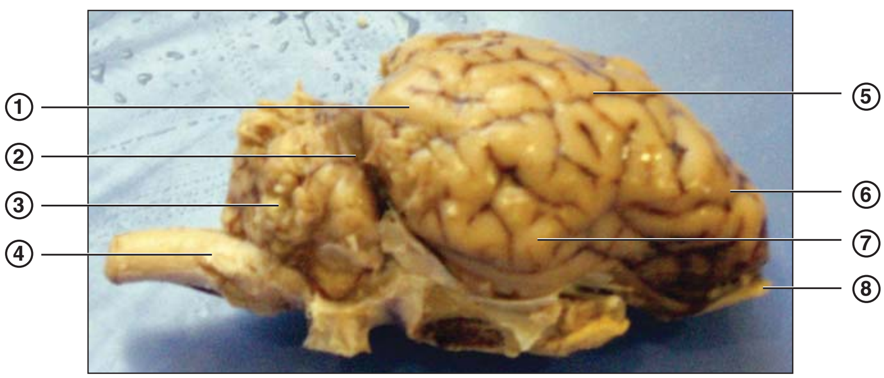


Figure 2.17. Lateral View of Sheep's Brain

1. Occipital lobe
2. Transverse fissure
3. Cerebellum
4. Brainstem
5. Parietal lobe
6. Frontal lobe
7. Temporal lobe
8. Olfactory bulb

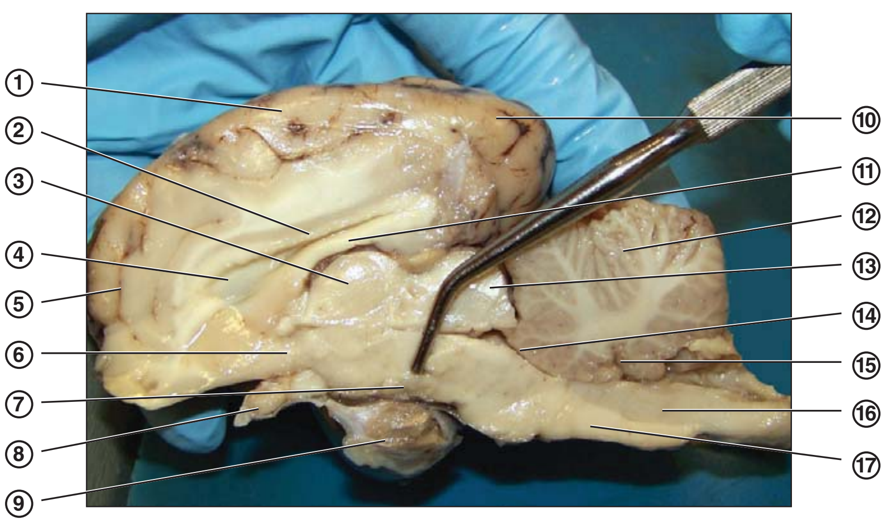


Figure 2.18. Mid-Sagittal View of Sheep's Brain

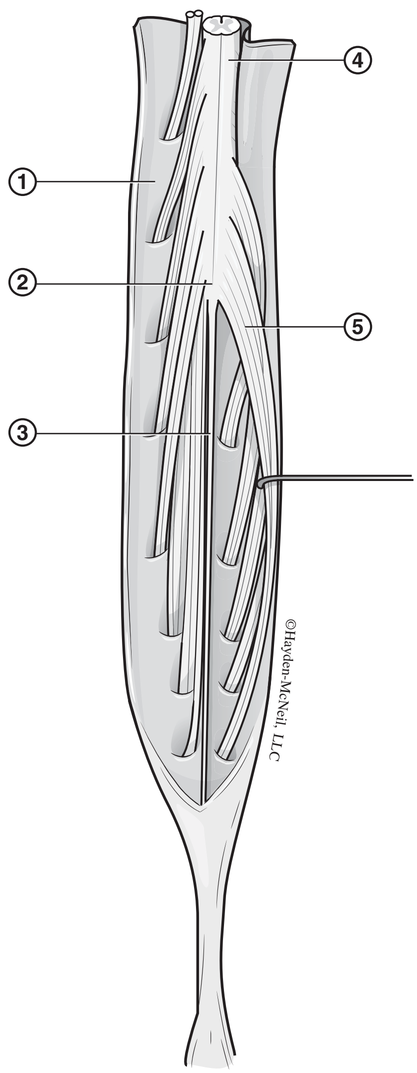
1. Parietal lobe
2. Corpus callosum
3. Space—3rd ventricle
   Tissue—thalamus
4. Septum pellucidum
5. Frontal lobe
6. Hypothalamus
7. Mamillary body
8. Optic chiasma
9. Pituitary/hypophysis
10. Occipital lobe
11. Fornix
12. Cerebellum
13. Corpora quadrigemina
14. Cerebral aqueduct
15. 4th ventricle
16. Medulla oblongata
17. Pons

Midbrain
Lateral ventricle

Part 3

The Spinal Cord, Somatic Reflex Arc, Visceral Reflex Arc

The central nervous system continues outside the cranium as the spinal cord. This structure weighs about 1.25 ounces, has a diameter at its widest point of about 1.5 inches and has a length of about 17–18 inches. It is not a very large structure, but it serves as a conduit between the brain and the body. The spinal cord extends from the foramen magnum to between the first and second lumbar vertebrae. It does not fill the entire vertebral column, which measures about 27.5 inches. After the spinal cord terminates at the **conus medullaris** the nerves exit the cord and stay within the spinal foramen of the vertebral column until they exit at the appropriate level. This mass of nerves within the vertebral column is the **cauda equina** (KAW-do ee-KWAY-nah).



1. Dura mater
2. Conus medullaris
3. Filum terminale
4. Spinal cord
5. Cauda equina

Figure 2.19. Cauda Equina and Filum Terminale

The spinal cord is protected by a bony covering, the vertebral column, a membranous covering, the meninges, and is surrounded by fluid, the cerebrospinal fluid, just like the brain. It is important to protect the delicate spinal cord just as the brain is protected. The spinal cord is also secured within the spinal canal by extensions of the dura mater and pia mater. The spinal cord is secured to the bottom of the spinal canal by the **filum terminale** and is secured at the sides by the **denticulate ligament**.

The spinal cord is covered by the three layers of meninges like the brain. However, in the spinal cord there is a space between the dura mater and the periosteum of the vertebrae, so in the spinal column there is an **epidural space**, unlike the brain.

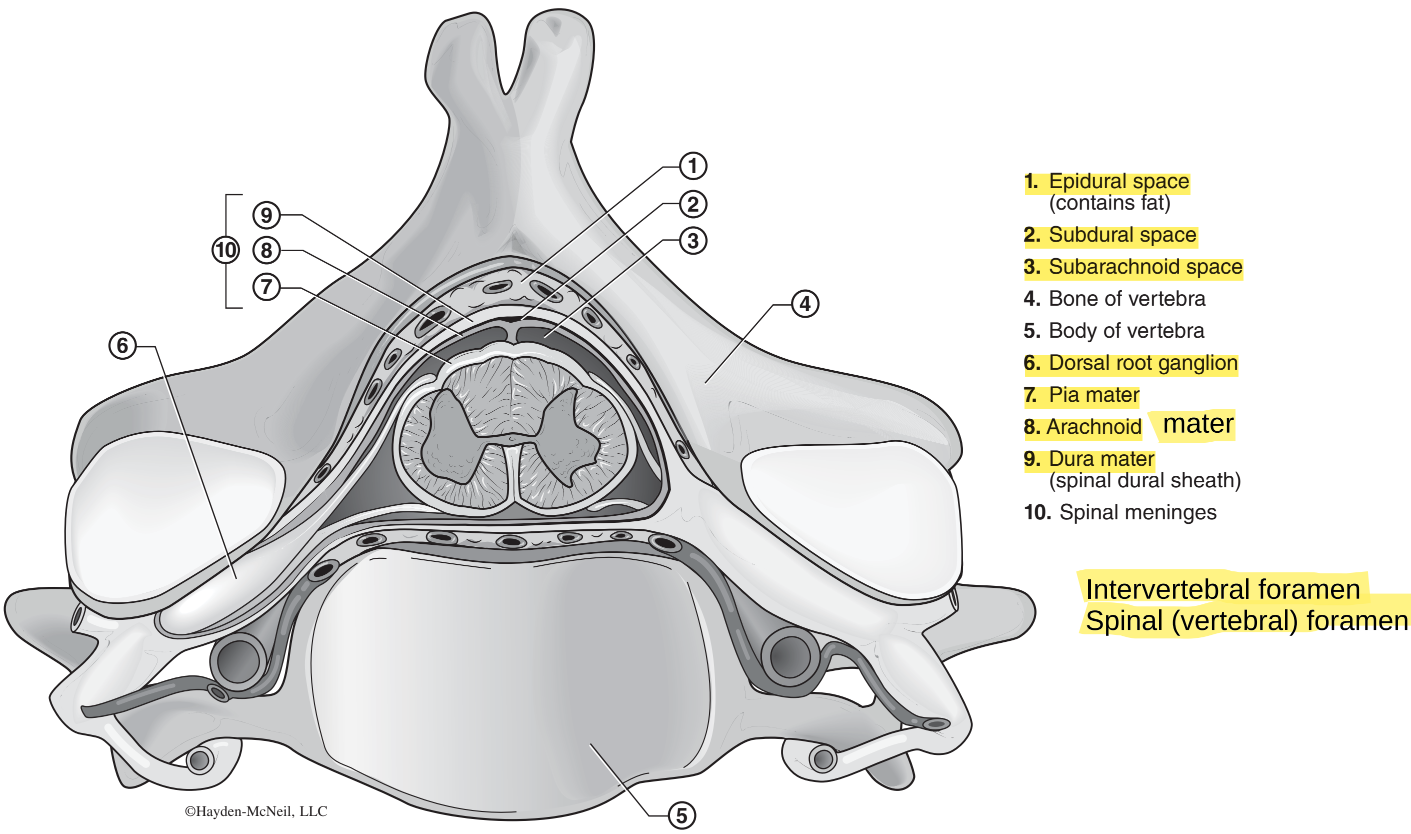


Figure 2.20. Meninges of the Spinal Cord

White myelinated fibers and gray cell bodies are found in the spinal cord. In this structure the white fibers, or nerve tracts, are on the exterior and the gray matter, or the cell bodies, are in the center of the spinal cord. The pattern the gray matter creates is described as a butterfly or an H-shape. In the midline it is divided by an **anterior median fissure** and a **posterior median sulcus**. The anterior fissure is deeper than the posterior sulcus so this characteristic can be used to determine the orientation of the spinal cord.

In the center of the spinal cord is the **central canal**. This is an extension of the fourth ventricle and contains cerebrospinal fluid. This fluid returns to the brain via the subarachnoid space between the arachnoid mater and pia mater in the spinal meninges.

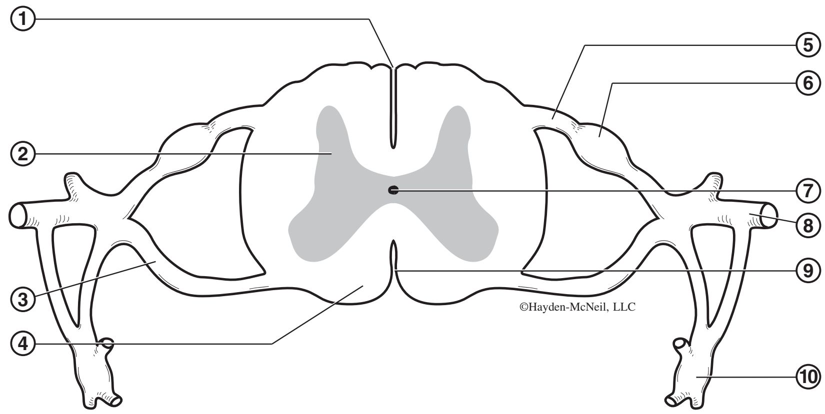


Figure 2.21. Transverse View of Spinal Cord without Vertebrae

Entering and exiting the ventral and dorsal spinal cord are nerve roots. The motor or efferent fibers exit the spinal cord via the **ventral nerve roots**. The sensory or afferent fibers enter the spinal cord by way of the **dorsal nerve roots**. On the dorsal nerve root you will notice an enlargement which contains the cell body for the sensory neuron. This is the **dorsal root** or **spinal ganglion** (plural, ganglia). A short distance outside the spinal cord, the ventral and dorsal nerve roots join to form a spinal nerve. There are 31 pairs of spinal nerves that exit the spinal cord and the vertebral column by way of the intervertebral foramina, except for the first nerve. The first spinal nerve exits between the skull and the atlas.

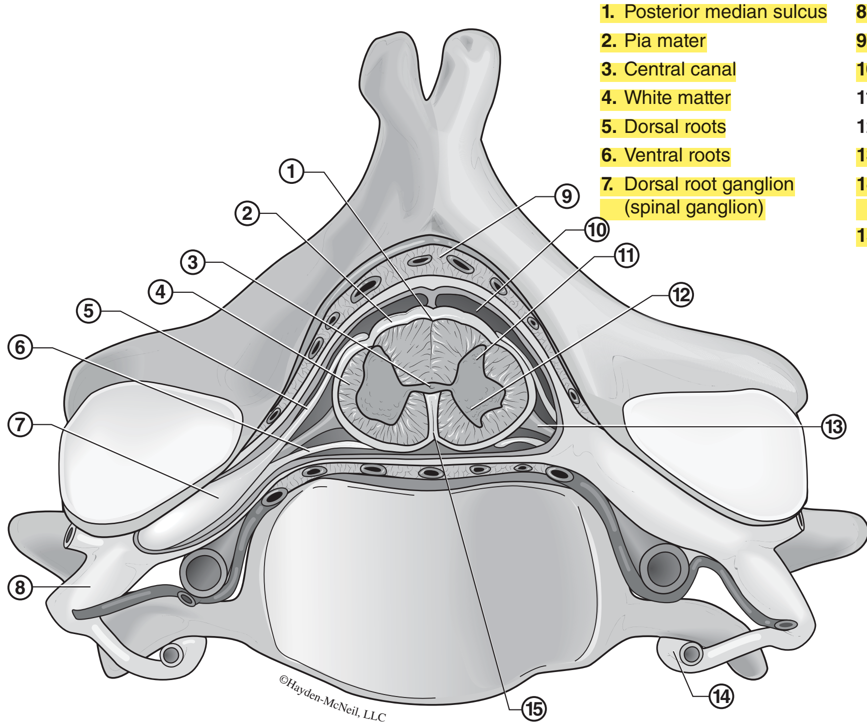


Figure 2.22. Transverse View of Spinal Cord with Vertebra

Somatic Reflex Arc

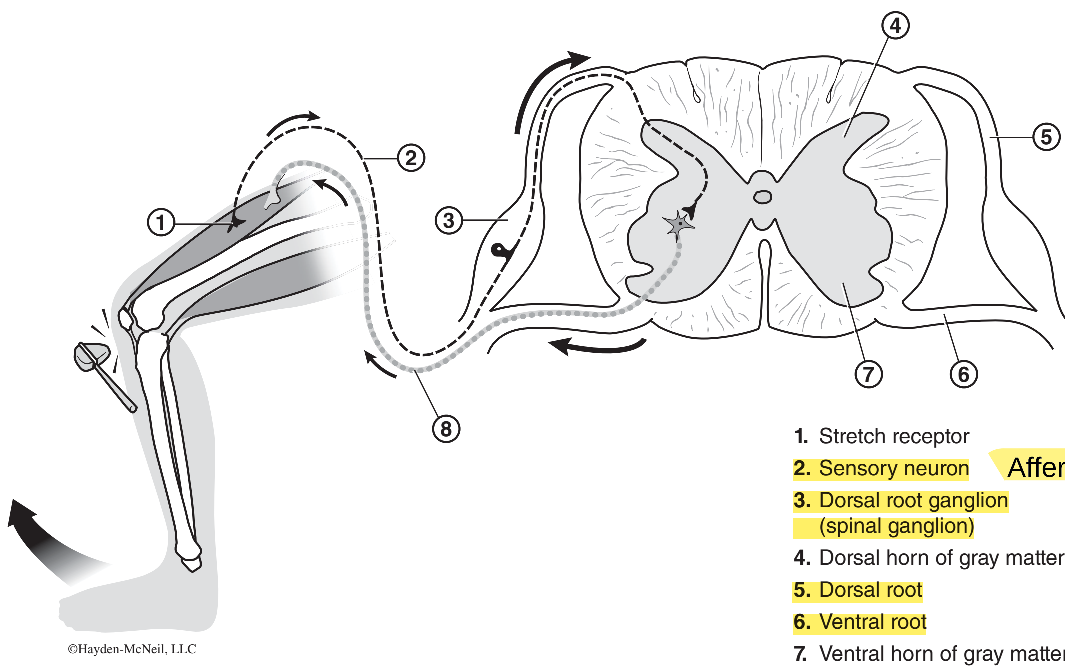
A reflex is a motor response to a stimulus without conscious thought. For example, when you touch something sharp you pull away from it. The pathway that the impulses follow to cause the motor response to a stimulus is called a reflex arc.

All reflex arcs have the following components:

1. A **receptor** which is the structure that is being stimulated.
2. A **sensory** or **afferent neuron** which carries the stimulus to the central nervous system.
3. An integration center which could be the brain or the spinal cord.
4. A **motor** or **efferent neuron** which carries the impulse for the response away from the central nervous system.
5. An **effector** or muscle which is responsible for the motor response.

If the effector is a skeletal muscle the reflex is called a somatic reflex. There are many different somatic reflexes, such as pulling away from pain or heat. Physicians use reflexes as an assessment tool for the condition of the nervous system.

At the minimum, a reflex arc requires two neurons: an afferent or sensory neuron and an efferent or motor neuron. In this situation the afferent neuron synapses with the efferent neuron in the central nervous system. However, frequently there is a third neuron located entirely in the central nervous system which is the **interneuron**. This additional neuron is situated between the afferent and efferent neurons.



1. Stretch receptor
2. Sensory neuron Afferent
3. Dorsal root ganglion (spinal ganglion)
4. Dorsal horn of gray matter
5. Dorsal root
6. Ventral root
7. Ventral horn of gray matter
8. Motor neuron Efferent

Figure 2.23. Two Neuron Reflex Arc

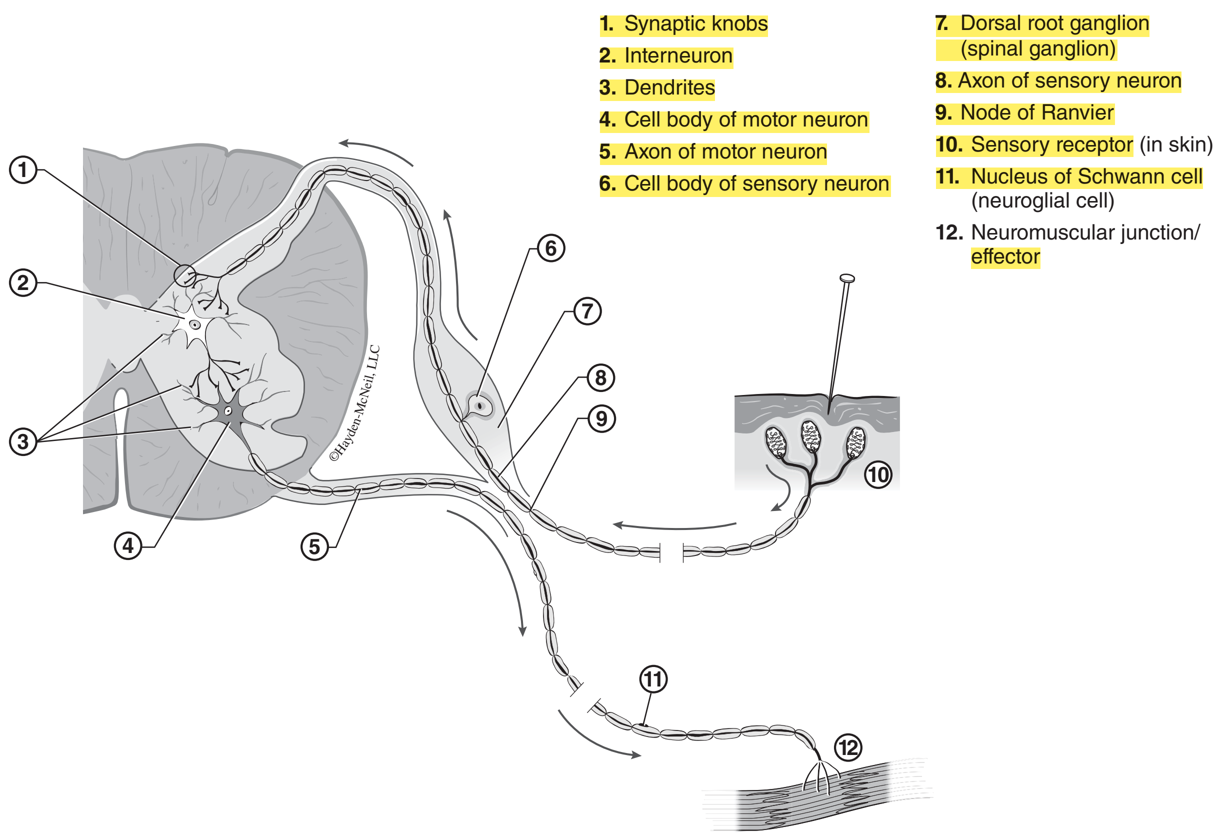


Figure 2.24. Three Neuron Reflex Arc

Visceral Reflex Arc

In the viscera, the effectors are smooth muscle, cardiac muscle, or glands, and the reflex arc is controlled by the autonomic nervous system. This changes the pathway for the reflex arc.

In the autonomic nervous system there is still an afferent neuron and there are two neurons in the efferent pathway: a **preganglionic neuron** and a **postganglionic neuron**. These two neurons synapse outside the central nervous system in an autonomic ganglion. The location of the ganglion depends on which branch of the autonomic nervous system is involved in the reflex.

In the sympathetic nervous system the ganglia are located in a chain of ganglia very near the spinal cord. There is a chain on each side of the spinal cord. These ganglia (singular: ganglion) are called the **vertebral autonomic** or **paravertebral** or **sympathetic chain ganglia**. The sympathetic preganglionic efferent neuron leaves the central nervous system and synapses with the postganglionic neuron in one of the ganglia near the spinal cord. The postganglionic neuron leaves the ganglion and carries the impulse to the effector.

In the abdominal region there is a special circumstance with the sympathetic efferent neurons. In this region the preganglionic neuron passes through the vertebral autonomic ganglia without synapsing and actually synapses in a ganglion closer to the viscera. This second ganglion is a **collateral ganglion**. The postganglionic neuron would then leave the collateral ganglion and continue on to the viscera. There are three collateral ganglia on each side of the spinal cord: the celiac ganglia, the superior mesenteric ganglia, and the inferior mesenteric ganglia.

The **celiac** ganglia (SEE-lee-ak) are located on the each side of the celiac artery near the adrenal gland. The postganglionic neurons leaving these ganglia innervate the stomach, liver, pancreas, gallbladder, small intestine, spleen, and kidneys.

The **superior mesenteric** (MEZ-in-TER-ik) ganglia are located near the point where the superior mesenteric artery branches off the abdominal aorta. The postganglionic neurons that innervate the small and large intestines leave these ganglia.

The **inferior mesenteric** ganglia are the most inferior of the collateral ganglia. They are located near the point where the inferior mesenteric artery branches off the abdominal aorta. The postganglionic neurons that innervate the lower colon and rectum, urinary bladder, and reproductive organs leave these ganglia.

In the case of the parasympathetic nervous system the preganglionic neuron is much longer than in the sympathetic nervous system. The ganglia of the parasympathetic nervous system lie close to or in the wall of the viscera. The postganglionic neuron is short; since the ganglia are in or near the viscera, the postganglionic neuron only has a short distance to travel to the effector.

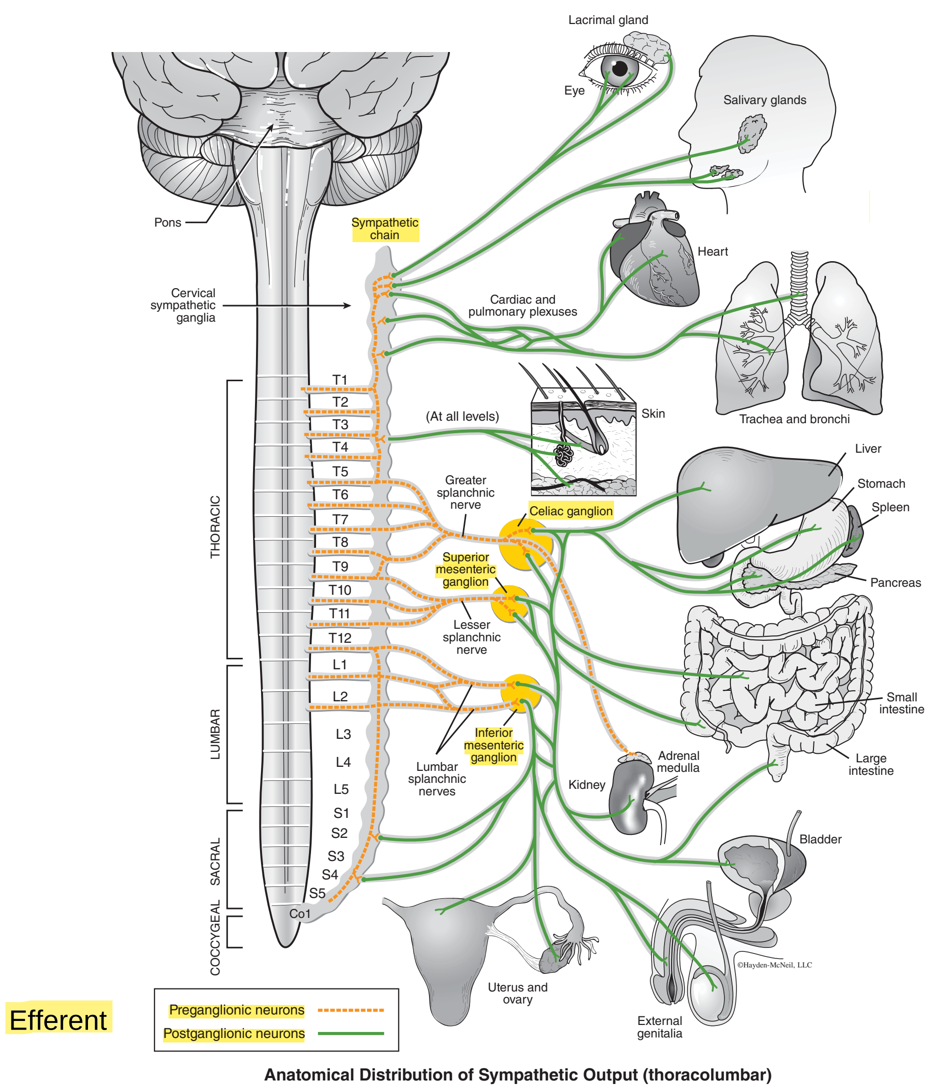


Figure 2.25. Sympathetic Nervous System

Part 4

Special Senses

We use our senses to observe and monitor our environment. Some of our senses, like pressure and temperature, are found in many areas of the body and are referred to as general senses. Other senses are localized in the head and are referred to as special senses. The more complex special senses in structure are the senses found in the ear—hearing and equilibrium. The most complex in function is the sense found in the eye—vision. We will first look at the structures of the ear followed by the structures of the eye.

Section A – The Ear

The ear is divided into three sections: the external, middle, and inner ear. The external ear consists of the area exterior to the eardrum or tympanic membrane. The middle ear is the section that contains the ossicles (bones) and the auditory (Eustachian) tube. The inner ear contains the structures that contain the sensory receptors—the cochlea, vestibule, and semicircular canals.

The part of the external ear that is visible on the outside of the body is the **pinna** (PIN-a) or **auricle** (AW-ri-kl) of the ear. The canal that leads from the pinna into the temporal bone is the **external auditory** or **acoustic canal**. The **tympanic membrane** (tym-PAN-ik) or eardrum is at the end of this canal and serves as the border between the external ear and middle ear.

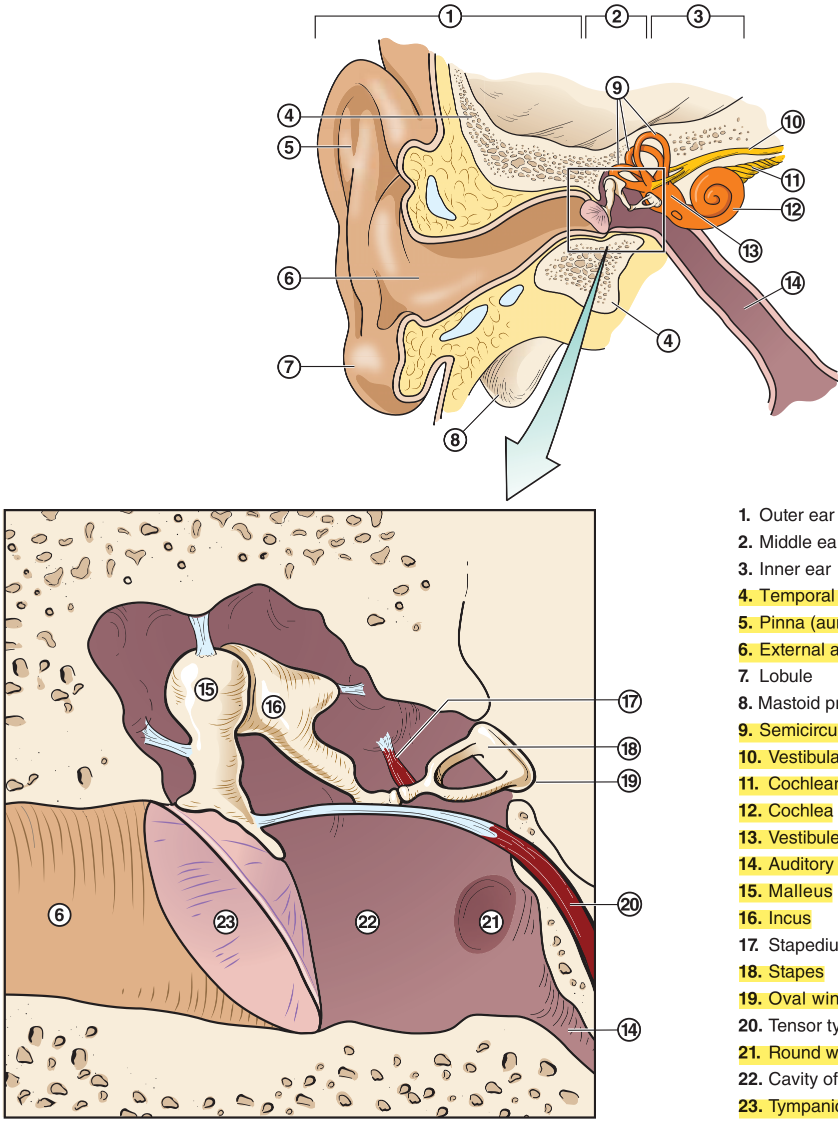
The middle ear is located between the tympanic membrane and the oval and round window. In the middle ear are the ossicles—**malleus** (MAL-ee-us), **incus** (ING-kus), and **stapes** (STAY-pez). The malleus is the ossicle attached to the tympanic membrane. It articulates with the incus or middle ossicle. This ossicle then articulates with the stapes, the innermost ossicle. The stapes sits in the oval window, an opening into the inner ear. Also found in the middle ear is the **auditory** or **Eustachian tube** (u-STAY-shun). This is a cartilaginous tube that connects the middle ear to the nasopharynx. It functions to equalize the pressure in the middle ear with the external air pressure. Normally the tube is closed except during yawning or swallowing. Unfortunately, the auditory tube can also be used by bacteria as a conduit into the middle ear and result in a middle ear infection.

The inner ear contains the **labyrinth** (**osseous** and **membranous**). The labyrinths are systems of tubular structures that make up the cochlea, vestibule, and semicircular canals. The osseous or bony labyrinth is the part of the tubular structures that are made up of bony walls. It forms the exterior of the inner ear. The membranous labyrinth consists of the ducts that are found inside the osseous labyrinth. The bony labyrinth can be subdivided into the cochlea, vestibule, and semicircular canals.

The **cochlea** (KOK-lee-ah) is a structure that resembles a snail shell. The outside of the cochlea is made up of the bony labyrinth and inside the membranous labyrinth is the **cochlear duct**. When the cochlea is observed on cross-section the cochlear duct has a triangular or wedge-like shape. The fluid-filled space superior to the cochlear duct is the **scala vestibuli** (SKAY-la ves-TIBU-lee) and the space inferior to the cochlear duct is the **scala tympani** (TIM-pa-nee). The **oval window** opens into the scala vestibuli. The scala tympani ends at the **round window**. On the floor of the cochlear duct is the **organ of Corti** or the **spiral organ** of the ear. This is the structure that contains the sensory receptors and nerve fibers for hearing. There are approximately 24,000 hair cells (neurons) in each cochlea. The nerve fibers of the cochlea leave as the **cochlear nerve** which merges with the vestibular nerve and leaves the ear as the eighth cranial nerve or the **vestibulocochlear nerve**.

The **vestibule** (VES-ti-bool) is involved in the sense of static equilibrium. It is found in the area between the cochlea and the semicircular canals. The oval window is on the side of the vestibule. The nerve fibers that carry the sense of equilibrium leave this area of the inner ear as the **vestibular nerve**, which will merge with the cochlear nerve as noted previously.

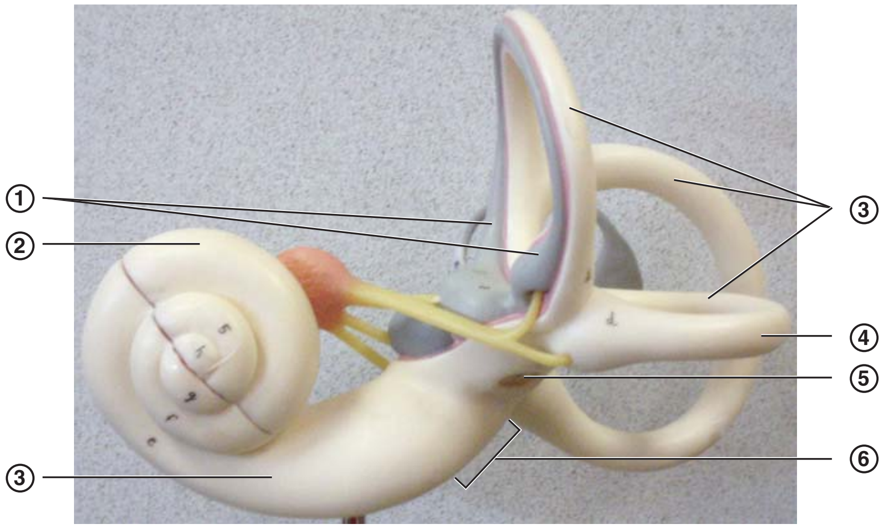
There are three **semicircular canals** situated at right angles to each other. This area of the inner ear is involved in the sense of dynamic equilibrium.



1. Outer ear
2. Middle ear
3. Inner ear
4. Temporal bone
5. Pinna (auricle)
6. External auditory (acoustic) canal
7. Lobule
8. Mastoid process
9. Semicircular canals
10. Vestibular nerve
11. Cochlear nerve
12. Cochlea
13. Vestibule
14. Auditory (Eustachian) tube
15. Malleus
16. Incus
17. Stapedius muscle
18. Stapes
19. Oval window (under stapes)
20. Tensor tympani muscle
21. Round window
22. Cavity of the middle ear
23. Tympanic membrane (eardrum)

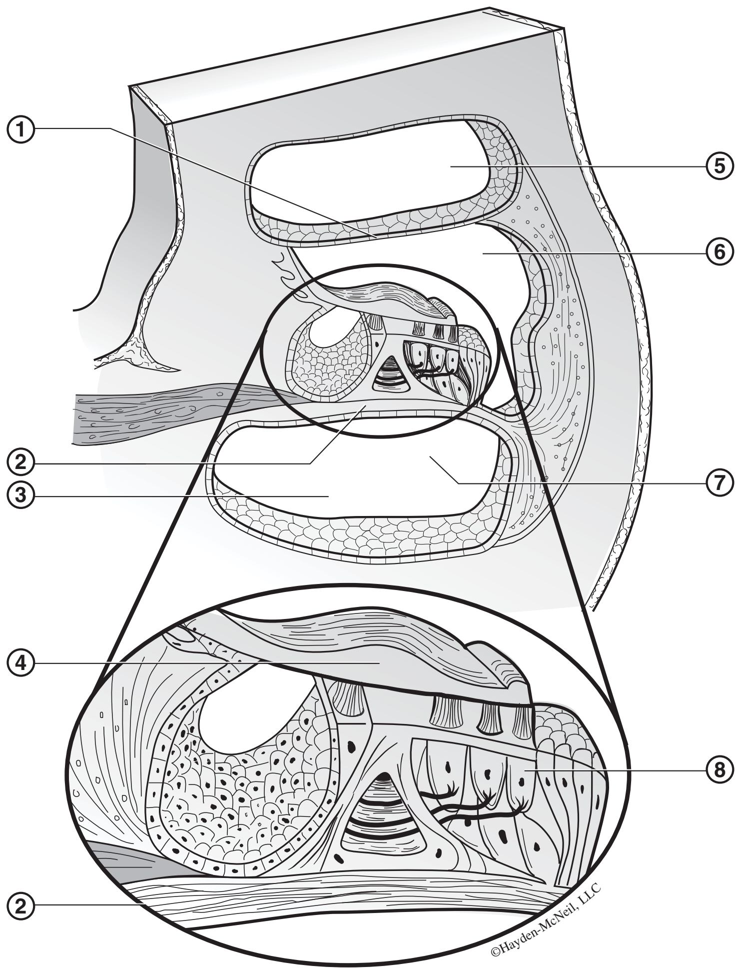
Vestibulocochlear nerve

Figure 2.26. Structures of the Ear



1. Membranous labyrinth
2. Cochlea
3. Bony labyrinth
4. Semicircular canals
5. Oval window
6. Vestibule

Figure 2.27. Structures of the Inner Ear



1. Vestibular membrane
2. Basilar membrane
3. Scala tympani
4. Tectorial membrane
5. Scala vestibuli
6. Cochlear duct
7. Organ of Corti (spiral organ)
8. Hair cell

Figure 2.28. Cross Section of Cochlea

Otoscope

An otoscope is an instrument that is used to examine the outer ear canal and tympanic membrane. It consists of a light source, a speculum, and a magnifier to allow the observation of the outer ear.

Before you begin make sure the instrument is working. Turn it on and make sure there is a bright light emitting from the instrument. You will need to attach the largest speculum that can be comfortably inserted into the ear canal.

There are two common ways to hold the otoscope. The first way is to hold the otoscope like a hammer by gripping the top of the handle close to the light source. The otoscope can also be held like a pencil, between the thumb and the forefinger, with the ulnar aspect of the hand resting firmly but gently against the patient's cheek. This is a better way to hold the otoscope because if the individual turns or moves, the otoscope will move in unison with the individual's head. This will avoid possible injury to the ear canal or even the tympanic membrane.

Hold the otoscope in one hand as you insert the speculum into the ear canal and use your free hand to pull the outer ear gently up and back. This straightens the ear canal and improves visualization. As you are inserting the speculum you will be observing the ear canal. The sides of the ear canal are sensitive so be careful not to put too much pressure on the walls of the ear canal.

Do not advance the otoscope without observing the ear canal. You must see the path through the ear canal. It is not necessary to insert the speculum very far into the ear—the light extends well beyond the viewing tip.

The tip of the speculum should be angled slightly toward the person's nose to follow the normal angle of the canal. While looking through the otoscope, move it gently at different angles so that you can see the canal walls and eardrum. Stop at any sign of increased pain.

The ear canal will normally be skin colored, contain some small hairs, and some yellowish-brown or reddish-brown earwax. The tympanic membrane is normally pearly white or light gray color and transparent. You can normally see the ossicles pushing on the tympanic membrane. You can see a cone of light at the 5:00 position in the right ear and at the 7:00 position in the left ear. This is known as the light reflex.

You will now observe the other ear using the same procedure. After completing your examination please remove the speculum and disinfect it with alcohol.

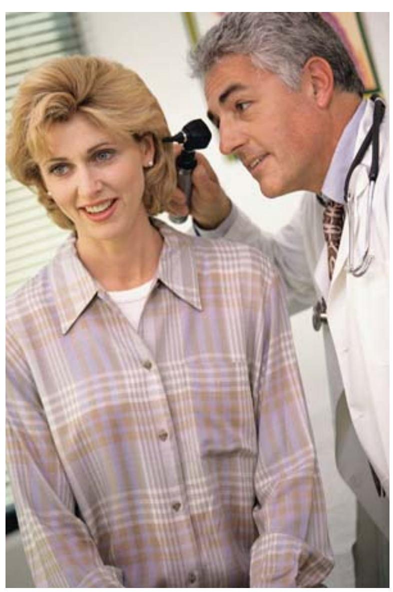
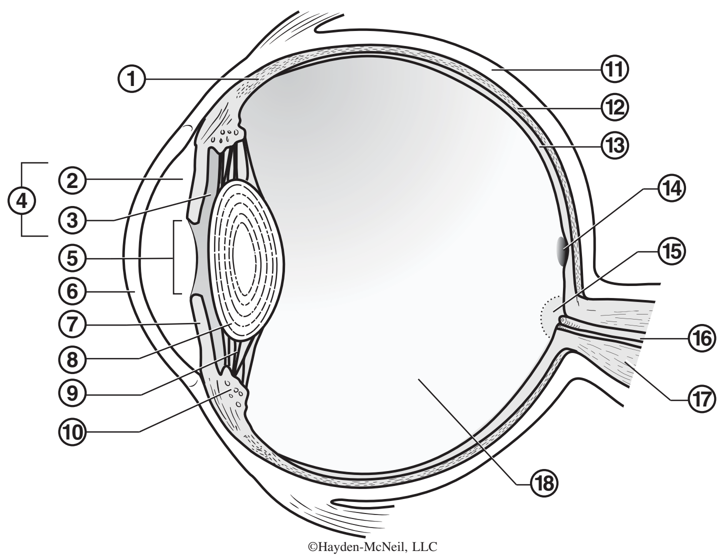


Figure 2.29. Use of Otoscope

Section B – The Eye

The eye is the organ of vision. It is small in size but complex in function. The eye is about an inch wide, an inch deep and an inch high. There are three layers to the eye: the sclera, the choroid, and the retina.

The outer layer is the **sclera** (SKLER-ah). The sclera is the white fibrous layer of the eyeball. When you look at the whites of someone's eyes you are looking at the sclera. The most anterior portion of the sclera is the transparent **cornea** (KOR-nee-ah). Contact lenses are placed on top of the cornea. This structure along with the lens helps focus an image on the retina. The cornea and the inside of the eyelids are covered by a protective mucous membrane called the **conjunctiva** (con-junk-TIE-vah). This is the membrane that is infected in pink eye or conjunctivitis.



1. Ciliary body
2. Anterior chamber
3. Posterior chamber
4. Anterior cavity (contains aqueous humor)
5. Pupil
6. Cornea
7. Iris
8. Lens
9. Suspensory ligaments
10. Ciliary process
11. Sclera
12. Choroid
13. Retina
14. Fovea centralis (center of visual field)
15. Optic disk (blind spot)
16. Retinal blood vessels
17. Optic nerve
18. Posterior cavity (contains vitreous humor)

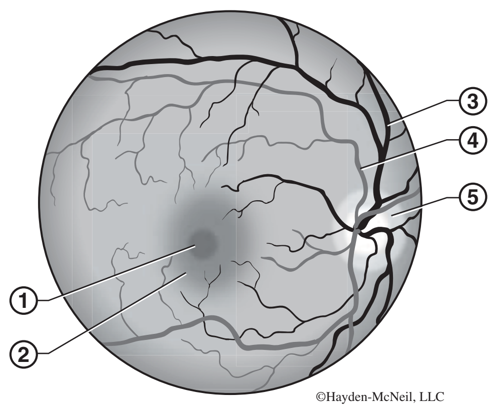
Figure 2.30. Sagittal Section of Eye

The middle layer is the **choroid** (KO-royd). This is the layer that contains the blood vessels and pigment in the eye. The pigment in the choroid layer helps absorb light and prevent the scattering of the light. The anterior portion of the choroid is the **iris**. This is the pigmented portion of the eye that you see. In the center of the iris is an opening, the **pupil**. The iris is a muscle that controls the size of the pupil to control the amount of light entering the eye. The **lens** is behind the iris. The lens is a clear, flexible structure that is capable of changing shape. Surrounding the lens and controlling its shape is the **ciliary body** (SIL-ee-ar-ee). The lens is attached to folds of the ciliary body called **ciliary processes** by the **suspensory ligaments**. Contractions and relaxation of the ciliary body allows the eye to adjust for close and far vision.

The region of the eye anterior to the lens is the **anterior cavity**. This cavity can be further subdivided into the **anterior chamber** from the iris to the cornea and the **posterior chamber** from the iris to the lens. The anterior cavity contains a watery liquid called the **aqueous humor**. This fluid is produced by the ciliary body and circulated through the pupil and is absorbed in the canals of Schlemm in the anterior cavity. The aqueous humor provides nourishment for the lens and cornea. The area posterior to the lens is the **posterior cavity**. This area of the eye contains a gel-like fluid called the **vitreous humor**. This gel helps the eye keep its shape.

The inner layer of the eye is the **retina**. This is the nervous tissue of the eye. It contains the photoreceptors known as the rods and cones. Each retina has 5–6 million cones and 120 million rods. At the back of the eye there is the **optic disk** or **blind spot**. This is the point where the **optic nerve** leaves the eye. It does not contain any rods or cones so no image can be formed here. However, you do not normally recognize the fact that you have a blind spot in each eye because the field of vision from one eye compensates for the blind spot in the other eye.

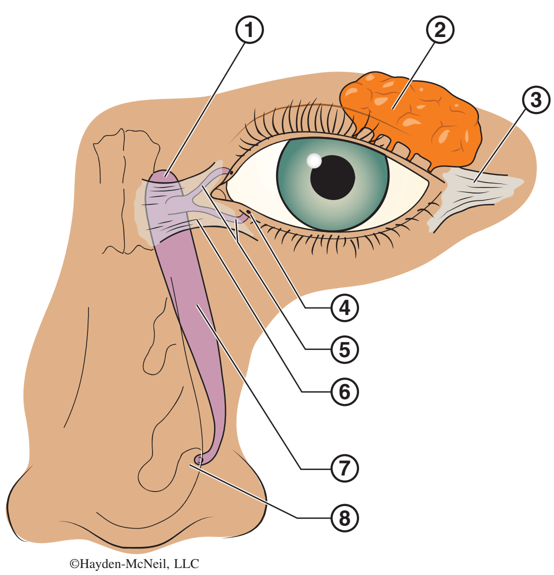
There is a small area on the retina that can be recognized by a yellowish ring. This is the **macula lutea** (MAK-u-lah LOO-tee-a). It contains a high concentration of cones. This is the area that is important for your central vision. In the center of the macula is the **fovea centralis** (Fo-vee-ah). The fovea is the most sensitive area of the eye and is the area of the sharpest vision. The macula lutea is the portion of the retina destroyed in age-related macular degeneration. This destruction results in the loss of the center of vision but the peripheral vision is retained.



1. Fovea centralis
2. Macula lutea
3. Vein
4. Artery
5. Optic disk

Figure 2.31. View of Retina through Pupil of Eye

External to the eyeball is the lacrimal apparatus. The **lacrimal glands** (LAK-ri-mahl) are found under the eyebrow at the outside edge of the eye. They produce the tears that cleanse and protect the eye. Tears contain lysozyme which has antibacterial activity. The tears wash across the surface of the eye and collect in the **lacrimal ducts** or **canals**. These ducts or canals empty into the **lacrimal sac** and eventually drain into the **nasolacrimal duct**. So tears eventually are drained into the nasal cavity. This is the reason the nose becomes congested when an individual cries.



1. Lacrimal sac
2. Lacrimal gland
3. Lateral palpebral ligament
4. Lacrimal punctum
5. Lacrimal ducts/canals
6. Medial palpebral ligament
7. Nasolacrimal duct
8. Inferior meatus

Figure 2.32. Lacrimal Apparatus of Eye

Ophthalmoscope

An ophthalmoscope is an instrument that is used to examine the interior of the eye. It consists of a series of lenses positioned in a rotating disk, a light source, and a series of mirrors to reflect the light source into the eye.

Before you begin make sure the instrument is working. Turn it on and make sure there is a bright light emitting from the instrument. The rotating disk of the ophthalmoscope should be on "0" to begin with.

Dim the lights in the room for the examination of a classmate. If the individual is wearing glasses request that he/she remove them. Ideally the classmate is seated comfortably. Instruct the individual to look at a fixed point in the room; it can be straight ahead or at a specific object somewhere in the room.

You will hold the instrument in your right hand to observe the classmate's right eye and in your left hand to observe the left eye. In addition, you will use your right eye to examine the classmate's right eye and your left eye for his or her left eye. Hold the ophthalmoscope so that your index finger is on the rotating disk.

Begin the examination at arm's length. You should see the red reflex. This is a reddish-orange reflection from the eye's retina. Move the ophthalmoscope closer to the eye until you are about 2 inches away. Do not let the instrument touch the eye. Look through the instrument and you should see a reddish, circular area—this is the interior of the eye. You will need to rotate the disk of the lenses to sharpen the focus. You should be able to observe the optic disk and blood vessels in the eye. The optic disk will be located towards the nasal side of the retina and will appear as a slightly oval, blood vessel free, slightly pinkish structure.

To observe the macula lutea, have your classmate look directly into the light of the ophthalmoscope. The macula lutea will be located on the temporal side of the optic disk, near the center of the retina. It should appear as a yellowish circle. You should not have your classmate looking directly at the light for more than 1–2 minutes.

Images of a normal retina as well as various pathological conditions will be available for viewing in the laboratory.

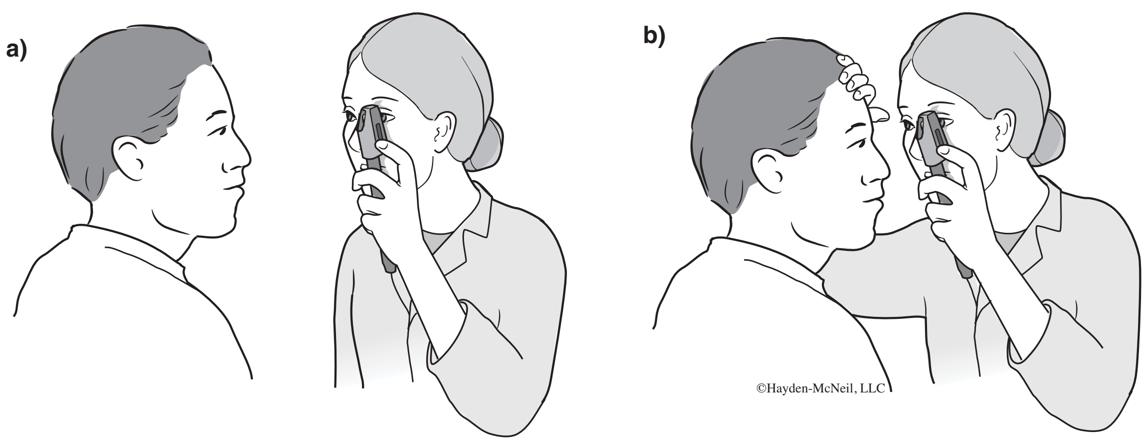


Figure 2.33. Procedure for Ophthalmoscope

Blind Spot

For this exercise you will use an illustration similar to the following available in the laboratory. This illustration will be used to detect the presence of the blind spot in each eye.

To test the right eye, close the left eye and stare at the plus sign on the illustration in the lab as it is moved from about 18 inches from the eye toward the face. At first, you will be able to see both the plus sign and the negative sign. Then as the image is moved closer to the face, at some point the negative sign will disappear. This will be the point at which it becomes focused on the optic disk of the retina.

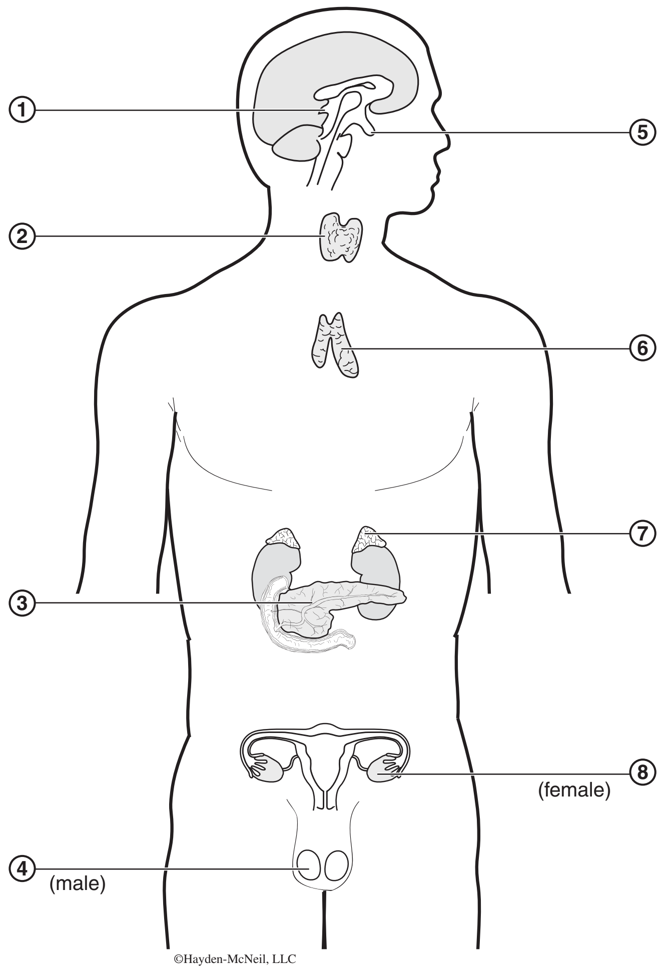
Now you will perform this on the left eye. To test the left eye, close the right eye and stare at the negative sign and find the point at which the plus sign will disappear.

Part 5

The Endocrine System

Communication within the body is achieved by both the nervous system and the endocrine system. The nervous system is responsible for rapid and precise responses. The endocrine system is responsible for sustained long-term control that is necessary for homeostasis.

The glands in the body are divided into exocrine and endocrine glands. Exocrine glands release the secretion into a duct, which will carry it to a specific location. For example, the salivary glands are exocrine glands and saliva is delivered by ducts to the oral cavity. Endocrine glands release the secretion into the bloodstream. It is carried through the blood by the body and will communicate with any cell that has a receptor for the particular chemical messenger. The endocrine system is a collection of glands that has the primary function of releasing hormones into the bloodstream. There are other organs and tissues in the body that produce and release hormones but are not included in the endocrine system. This is because the primary function of these other tissues, like the kidney, heart, and stomach, is not hormone production. The target tissues of the hormones are only the tissues that have a receptor for a specific hormone.



1. Pineal gland
2. Thyroid gland
3. Pancreas
4. Testes
5. Pituitary/hypophysis
6. Thymus
7. Adrenal gland
8. Ovary

Figure 2.34. Endocrine Glands

Hypophysis/Pituitary

The **hypophysis** or **pituitary gland** is located inferior to the hypothalamus of the brain. It sits in the hypophyseal fossa of the sella turcica in the skull and is connected to the hypothalamus by way of the **infundibulum**. This is actually two different glands. The **anterior pituitary**, which is also known as the **adenohypophysis**, and the **posterior pituitary**, also called the **neurohypophysis**.

The anterior pituitary synthesizes seven different hormones, while the posterior pituitary does not synthesize any hormones. The posterior pituitary is the storage site for two hormones produced by the hypothalamus.

Pineal gland

The **pineal gland** or body is also located in the brain. It is a pinecone-shaped gland located posterior to the third ventricle and superior to the corpora quadrigemina of the midbrain. It is a combination of nervous tissue and endocrine tissue. The hormone secreted by the pineal gland is melatonin, which affects the diurnal rhythm and reproductive development.

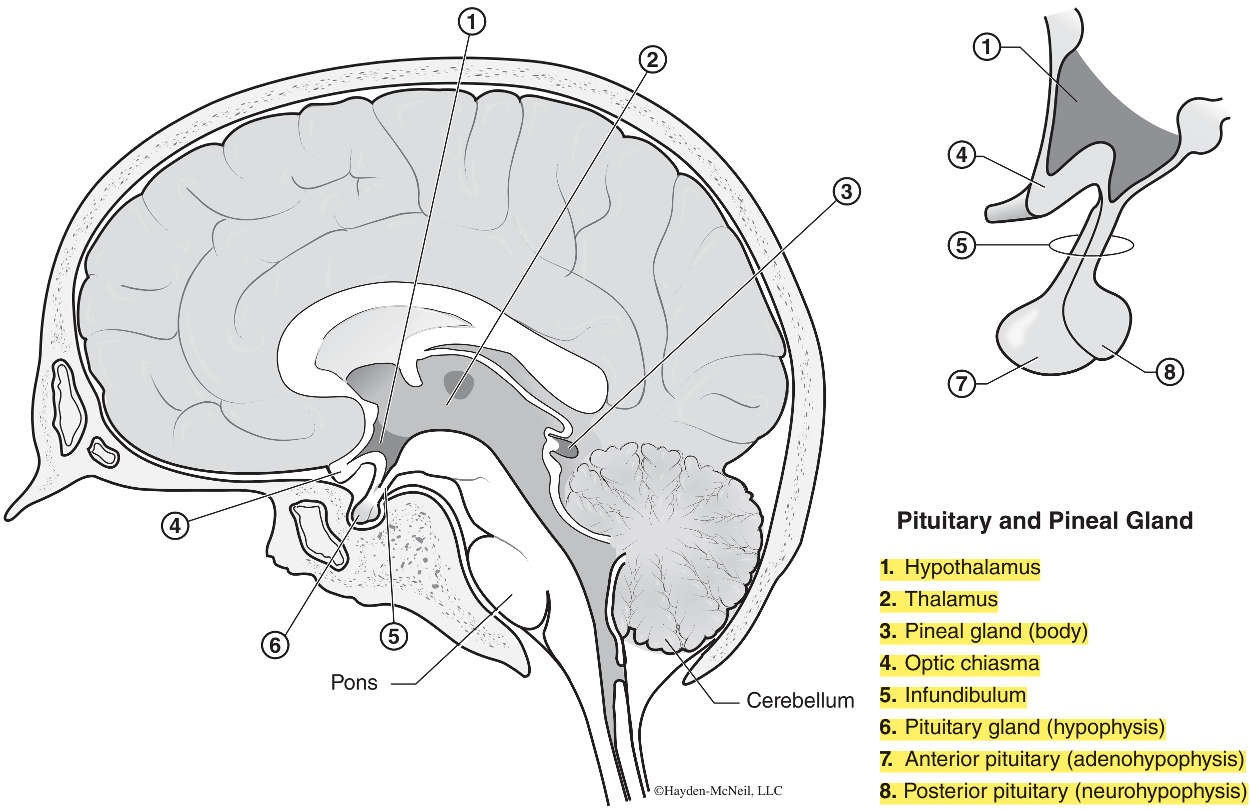


Figure 2.35. Pituitary and Pineal Gland

Table 2.1: Pituitary Hormones

Hormone	Target	Principal Function(s)
Anterior Pituitary/Adenohypophysis		
Growth Hormone (GH) Somatotropin (STH)	General body cells	Accelerates growth rate, especially muscle, bones
Thyroid-Stimulating Hormone (TSH)	Thyroid gland	Stimulates synthesis and secretion of thyroid hormones
Adrenocorticotropic Hormone (ACTH)	Adrenal Cortex (Zona Fasciculata)	Stimulates the synthesis and secretions of glucocorticoids and Cortisol
Follicle-Stimulating Hormone (FSH)	Ovary or Testis	Women: Stimulates development of ova in Graafian follicles and secretion of Estrogen Men: Promotes spermatogenesis in the seminiferous tubules
Luteinizing Hormone (LH in women); in men it is called Interstitial Cell Stimulating Hormone (ICSH)	Women: Ovary, especially the Corpus Luteum Men: Interstitial cells of testes	Women: Causes ovum to finish maturation then triggers ovulation; afterward, causes development of corpus luteum and production/secretion of Progesterone. Men: Stimulates production and secretion of testosterone.
Prolactin (Lactotrophic Hormone or LTH)	Mammary Glands	Stimulates (with progesterone) the maturation of the alveolar tissue and the production of milk.
Melanocyte Stimulating Hormone (MSH)	Melanocytes of skin	Increases melanin in skin to darken it, especially during pregnancy.
Posterior Pituitary/Neurohypophysis		
Antidiuretic Hormone (ADH)	Cells of the distal convoluted tubules of the kidneys	Stimulates reabsorption of water from urine back into the blood; causes dilution of blood plasma and increases blood pressure.
Oxytocin (OT)	Smooth muscle of the uterus; duct tissues of the mammary glands	Stimulates vigorous contractions of the uterus during labor; causes the release of milk from the alveoli of breasts (“letting down of milk”).

Thyroid gland

The **thyroid gland** is located in the neck just below the larynx on either side of the trachea. It consists of two lobes on either side of the trachea and they are connected by a band of tissue that is called the isthmus. This gland secretes 3 hormones: tetraiodothyronine (thyroxine), triiodothyronine, and calcitonin. The thyroid is the target of TSH released by the anterior pituitary (adenohypophysis). Tetraiodothyronine (thyroxine), and triiodothyronine controls the metabolic rate. Calcitonin is involved in calcium homeostasis.

Parathyroid gland

The **parathyroid glands** are four very small nodules embedded into the back of the thyroid gland. They are not part of the thyroid gland. These glands are about the size and shape of a grain of rice, yet they are essential to life. The parathyroid hormone is the principal hormone in the homeostasis of calcium.

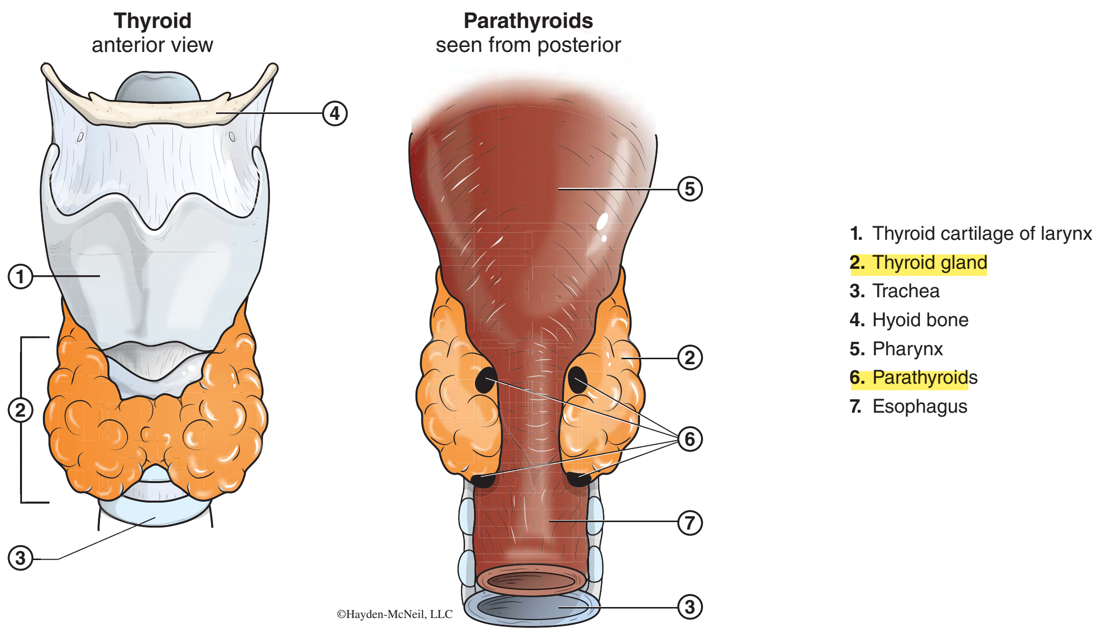
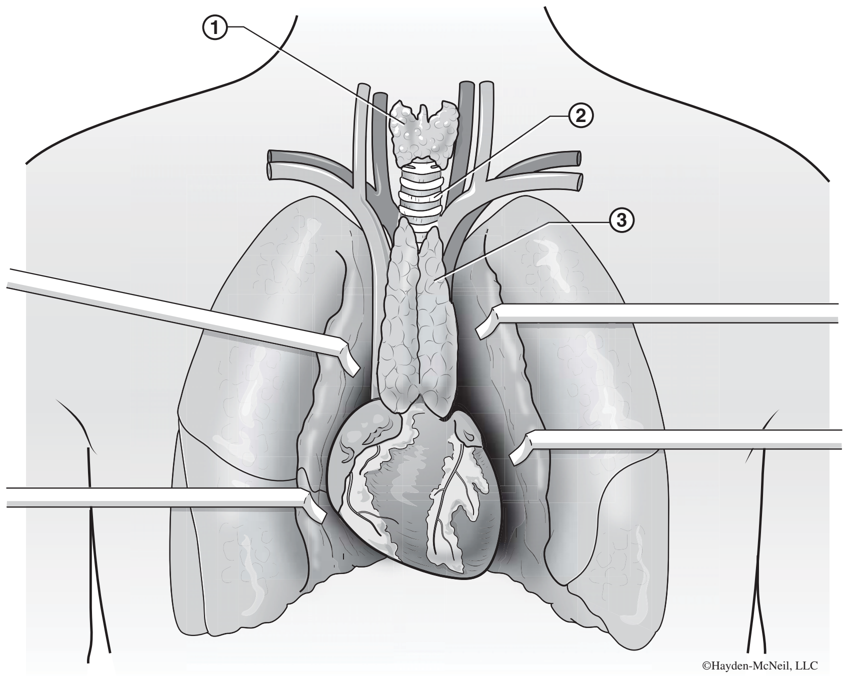


Figure 2.36. Thyroid and Parathyroid Glands

Thymus gland

The **thymus gland** is located in the upper thorax behind the sternum. It is at its largest and most active during childhood. Usually the thymus is at its maximum size by age two. After puberty the gland starts shrinking and is replaced by adipose tissue. The gland secretes thymosin, which is responsible for stimulating the growth and activity of T lymphocytes. As the gland shrinks, the amount of hormone production and T-cell production decreases. This results in a decrease in immune function with age.



1. Thyroid gland
2. Trachea
3. Thymus

Figure 2.37. Thymus Gland

Table 2.2: Thyroid, Parathyroid, and Thymus Hormones

Hormone	Target	Principal Function(s)
Thyroid Gland		
Thyroxine (T_4) and Triiodothyronine (T_3)	All body cells	Accelerates all metabolic processes and increases the use of oxygen (raises the metabolic rate). Stimulates growth and maturation of nervous system, bone, muscle.
Calcitonin (Thyrocalcitonin)	Cells of skeleton	Stimulates deposit of calcium salts in bone matrix by osteoblasts; lowers blood calcium ion concentration.
Parathyroid Gland		
Parathormone (PTH)	Skeleton, kidneys, and gastrointestinal tract	Increases blood calcium by stimulating osteoclasts to dissolve calcium salts from bone matrix into the bloodstream; by increasing reabsorption of calcium ions and excretion of phosphate ions into urine; enhances the uptake of calcium salts and phosphate from the gut.
Thymus Gland		
Thymosin	Structures of lymphatic system	Stimulates the development and maturation of the lymphatic system; B cells and T cells.

Pancreas

The **pancreas** is a long organ that extends across the abdomen from the spleen to the duodenum of the small intestine. This gland has both exocrine and endocrine functions. Its exocrine function is the production of digestive enzymes, which are delivered into the duodenum of the small intestine. The pancreas produces enzymes capable of digesting carbohydrates, lipids, proteins, and nucleic acids. When there is a blockage of the duct to carry these enzymes to the duodenum pancreatitis develops.

Its endocrine function is responsible for the homeostasis of blood glucose levels. The pancreas produces several hormones, but the two responsible for maintaining the blood glucose levels are insulin and glucagon. Individuals with type 1 diabetes mellitus have lost the ability of the pancreas to produce insulin. With type 2 diabetes the pancreas can still produce insulin but the cells are resistant to its stimulation.

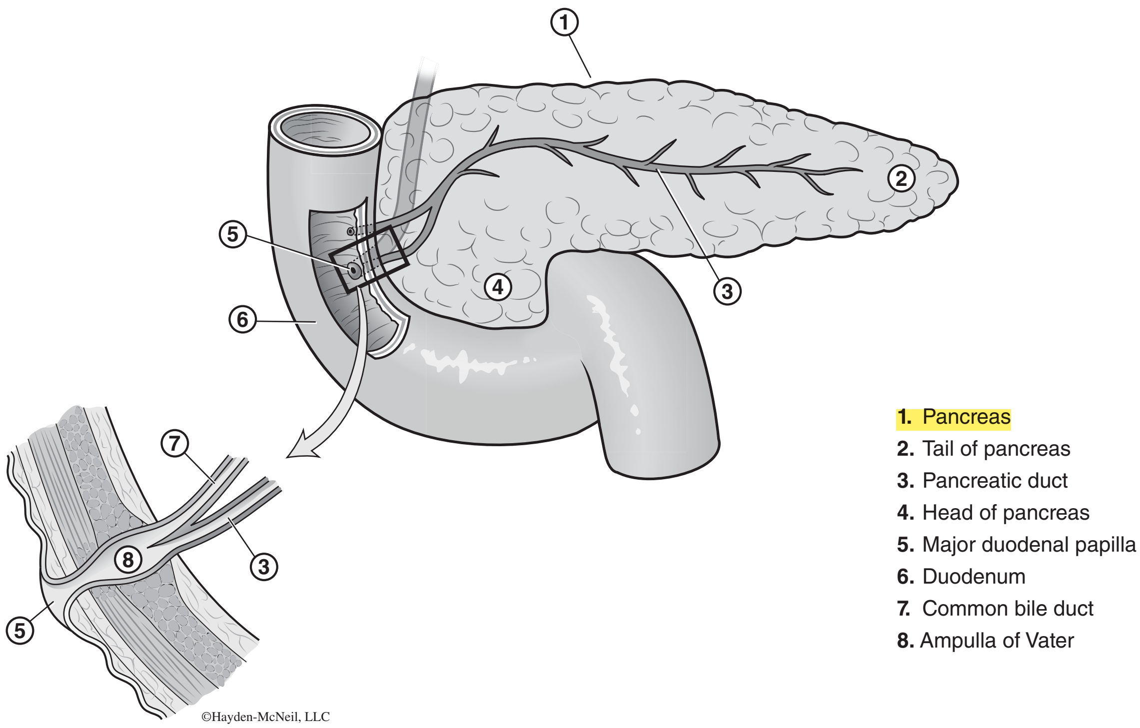
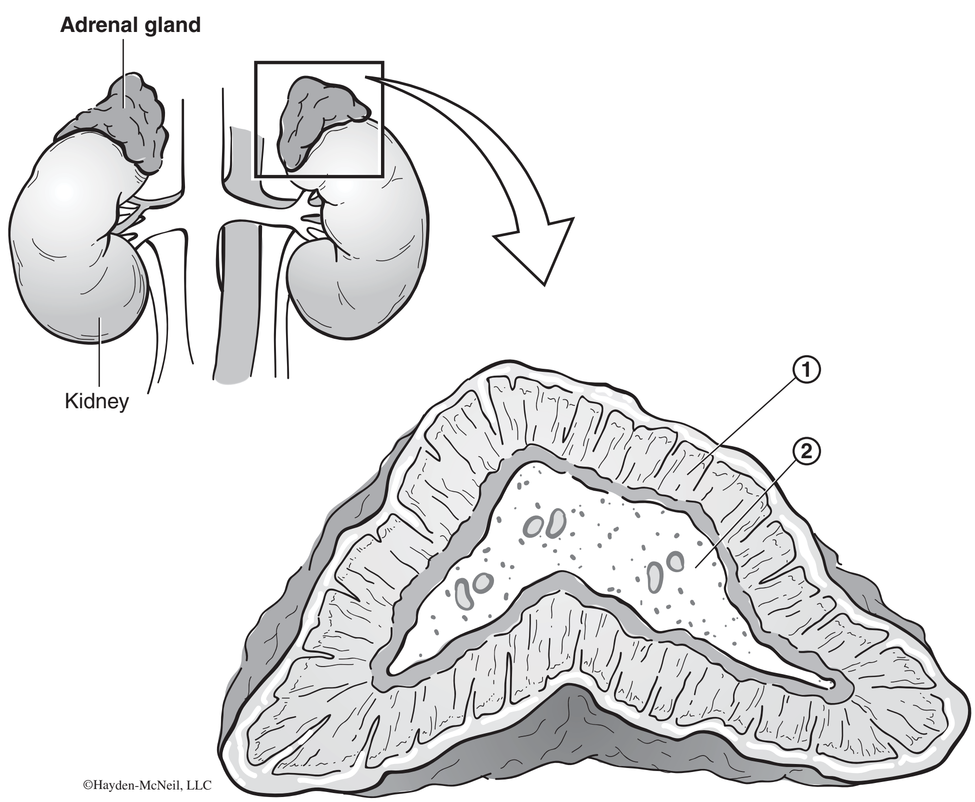


Figure 2.38. Pancreas

Adrenal Gland

The **adrenal** or **suprarenal glands** are on top of each kidney. This gland has an outer layer, the **cortex**, and the inner region, the **medulla**. Each region is unique in its functions. The cortex secretes glucocorticoids such as cortisol, mineralocorticoids such as aldosterone, and small amounts of gonadocorticoids. The adrenal cortex is stimulated by ACTH from the pituitary glands, particularly regarding the glucocorticoids. Aldosterone is responsible for regulating sodium levels in the body. Cortisol and its derivatives promote gluconeogenesis as well as functioning as anti-inflammatory agents. The gonadocorticoids are sex hormones, androgens and estrogens in small quantities.

The medulla is regulated by nerve impulses from the sympathetic nervous system. The adrenal medulla develops from neural tissue and secretes two hormones, epinephrine and norepinephrine. These two chemicals are also neurotransmitters in the sympathetic nervous system. Stimulation of the adrenal medulla by sympathetic fibers allows a sustained fight-or-flight response. Nervous system stimulation causes a rapid response, but it is not long-lasting, whereas hormones take longer to cause a response but last much longer.



Adrenal

1. Cortex
2. Medulla

Figure 2.39. Adrenal Gland

Table 2.3: Pancreatic and Adrenal Hormones

Hormone	Target	Principal Function(s)
Pancreas		
Insulin	Cells throughout the body, especially in the liver, fatty tissues, and muscles	Facilitates movement of glucose into cells across cell membranes; causes a drop in the blood sugar level; promotes glycogenesis and synthesis of proteins and fats; inhibits gluconeogenesis.
Glucagon	Liver	Opposes the action of insulin and helps prevent hypoglycemia; promotes glycogenolysis and gluconeogenesis; stimulates the breakdown of fats and use of fats as an energy source; causes a rise in blood sugar.
Adrenal Cortex		
Mineral corticoids (ex. Aldosterone)	Distal convoluted tubules of the kidney	Increases the reabsorption of sodium ions (and secondarily, chloride ions and water) from developing urine back into the blood.
Glucocorticoids (Cortisol and Corticosterone)	Cells throughout the body in general	Promotes gluconeogenesis in the liver; decreases protein synthesis; depresses the immune system; has a general anti-inflammatory effect.
Adrenal sex hormones (androgens and estrogen in tiny quantities)	Cells throughout the body	Usually minor effects in augmenting the promotions of secondary sex characteristics; adrenal tumors may cause over-secretion and development of sex-inappropriate characteristics; causes slight masculinization after menopause.
Adrenal Medulla		
Epinephrine and Norepinephrine	Circulatory, Respiratory, and Digestive systems; body cells in general	Increase blood pressure; increase vigor and rate of heart beat; increase blood flow to skeletal muscle and brain; increase airway diameter; decrease digestive function; general stimulation of metabolism; enhance the “fight-or-flight” response.

The Ovaries

The **ovaries** are paired organs found laterally to the uterus in the pelvic cavity in the female. They are about the size of an almond. The ovaries are responsible for producing the female sex cell, the ovum or egg. They also produce the female sex hormones, estrogens and progesterone. Estrogens are responsible for the development of secondary female sex characteristics such as breast development. Also, along with progesterone, estrogens control the menstrual cycle. In addition to the participation in the control of the menstrual cycle, progesterone is responsible for maintaining the uterine lining and inhibiting uterine contractions during pregnancy. Both hormones are under the control of the gonadotropins, FSH and LH, secreted by the anterior pituitary.

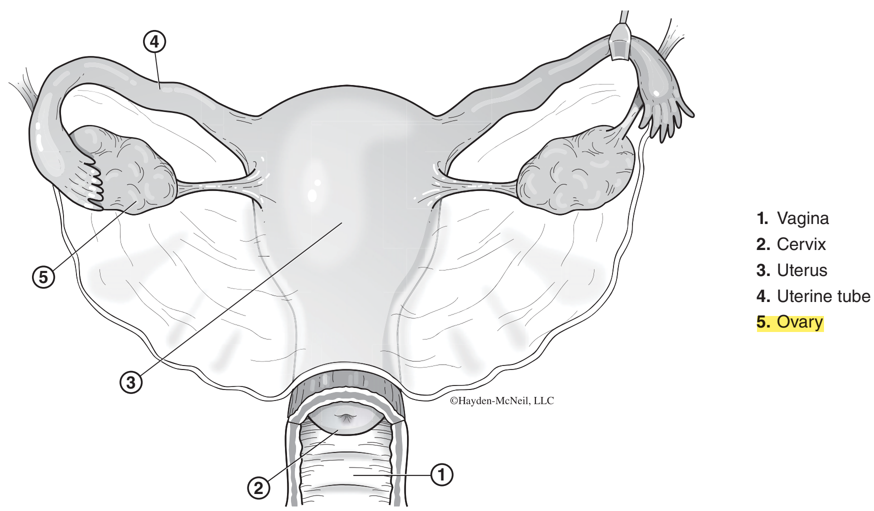


Figure 2.40. Ovary

The Testes

The **testes** (singular: testis) are paired organs found in the scrotum of the male. The testes are responsible for producing the male sex cell, sperm. In addition, testosterone is produced by the testes. Testosterone is responsible for development of the male secondary sex characteristics and the sexual drive.

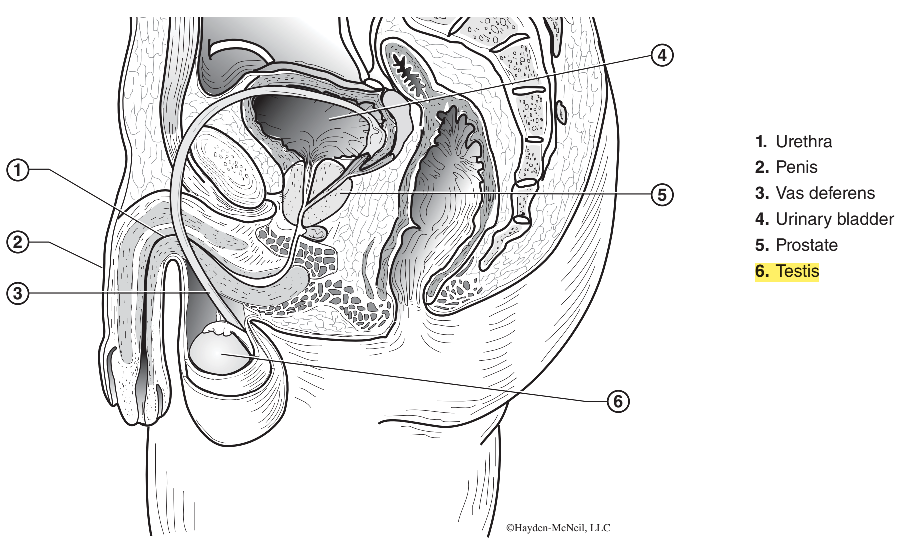


Figure 2.41. Testis

Table 2.4: Ovarian and Testicular Hormones

Hormone	Target	Principal Function(s)
Ovaries		
Estrogens (beta-estradiol, for example)	Female reproductive system, mammary glands, selected body tissues	Development and maintenance of female reproductive system; growth of the endometrium in the uterus; promotion of female secondary sex characteristics; feedback relationship with pituitary regarding production of LH, FSH; promotes closure of metaphyses.
Progesterone	Endometrium and mammary glands	Promotes the maturation of the endometrium to prepare it for implantation of embryo; continues to stabilize the endometrium throughout pregnancy; causes development and maturation of alveolar tissue within breasts; inhibits milk production by the mature alveolar tissue throughout pregnancy (sometimes unsuccessfully).
Testes		
Testosterone	Skeleton, muscle tissue, selected body tissues, male reproductive system	Promotes the development of male reproductive organs; promotes development of male secondary sex characteristics; promotes closure of metaphyses.