Introductory Psychology – Unit III

J.R. Jones

Spring 2011

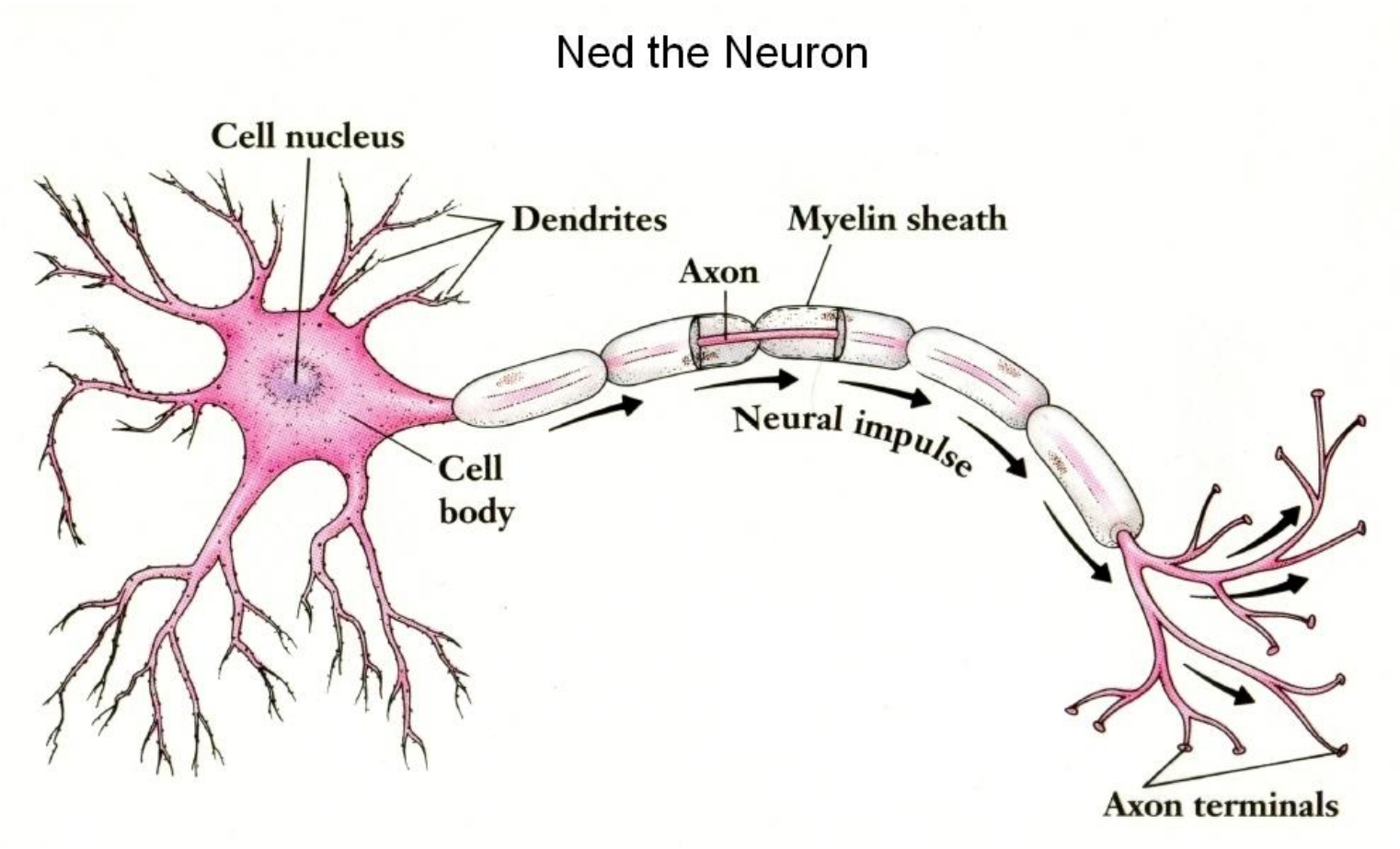
Neurons, Neurotransmitters, and Neuromodulators

Overview: The nervous system is the basis of all that we refer to as psychological--thoughts, feelings, moods, behaviors. The most fundamental structure of the nervous system is a single cell called a neuron. The neurons are different from other cells of the body in that they are capable of carrying signals and relaying information. Although neurons play different roles and come in a variety of sizes and shapes, all can be described in terms of the same functional parts, including dendrites, axons, and axon terminals. Some neurons bring sensory information to the brain, others carry commands from the brain to muscles and glands, and still others serve communication functions entirely within the brain and spinal cord. A neuron's dendrites receive incoming information; its axon carries the information to other cells through axon terminals, which send a chemical messenger to other cells. The signals carried by the neurons take the form of electrical impulses, or action potentials, which involve the movement of electrically charged particles across the cell's membrane. These movements result in changes in the electrical balance across the membrane, carrying the impulses down the axon to the axon terminal, where, through synaptic transmission, the neuron sends messages to other cells. In synaptic transmission, minute quantities of chemical messengers called neurotransmitters flow across a tiny gap between cells, called the synapse. Upon reaching the cell that is receiving information, neurotransmitter molecules bind to special receptor sites and in that fashion affect the electrical balance of the receiving cell. Synaptic connections are significantly modified by learning and experience.

Function of Neurons: Neurons are highly specialized cells designed for the single purpose of sending and receiving information. The means by which they accomplish the task of information transfer entails maintaining a delicate electro-chemical balance. Neurons do not perform a number of basic cellular functions, such as cellular reproduction (division) and nutrient storage, because such activities would alter the electro-chemical balance required or disrupt the ongoing task of information transfer.

Glia and Schwann Cells: Neurons have a high rate of metabolism, but no means of storing nutrients. In the central nervous system glia (glial cells) provide support for the neurons. In the peripheral nervous system Schwann cells do the same. These cells provide metabolic support by supplying oxygen and nutrients to the neurons, and by removing waste products. They also provide structural support. In the central nervous system one form of glial cells wrap around and surround the soma and dendrites of the neurons acting as a matrix to hold them in place. Another form of glial cells provides myelin, which consists of 80% fat. Myelin wrapped around the axons of neurons forms a sheath that provides structural support and insulation from other neurons. This *myelin sheath* also speeds up transmission of the neural impulse through the axon. In the peripheral nervous system Schwann cells provide the myelin sheath.

Major Parts of the Neuron:



Cell Body (Soma) - The part of the cell responsible for basic maintenance of the cell and production of the chemicals used by the cell. In some cases there are receptors for receiving incoming information on the cell body. Processing of the information received by the cell occurs here as well.

Dendrites - Long branching tendrils emanating from the cell body that are heavily laden with receptors. By way of *synaptic connections*, incoming information is received by these receptors. As noted, neurons do not reproduce, yet they die off like any other type of cell. Neural function and an ever growing body of stored information (memory) is maintained because the neurons continue to grow over the course of the individual's life. Specifically, the cell generates new dendrites and the existing ones get longer and branch out. This *dendritic branching* allows for an ever increasing number of connections to form. The result is an elaborately interconnected network.

Axon - This structure carries the neural impulse resulting in the output of information. Once initiated the neural impulse travels along the axon to the terminal buttons (end bulbs) where *synaptic vesicles* release *neurotransmitters* into the synapse resulting in the transfer of the information to other cells.

Synapse - Technically not a structure, just as the pupil of the eye is really just an opening not a structure. The synapse is the location wherein the sending neuron interfaces with the receiving neuron (other types of cells may also be involved). Here the axon terminal buttons of the sending neuron, referred to as the *pre-synaptic membrane*, release neurotransmitter molecules. These molecules float across a small gap, the *synaptic cleft*. Once across, the molecules attach to receptors on the receiving neuron, referred to as the *post-synaptic membrane*, and stimulate those receptors.

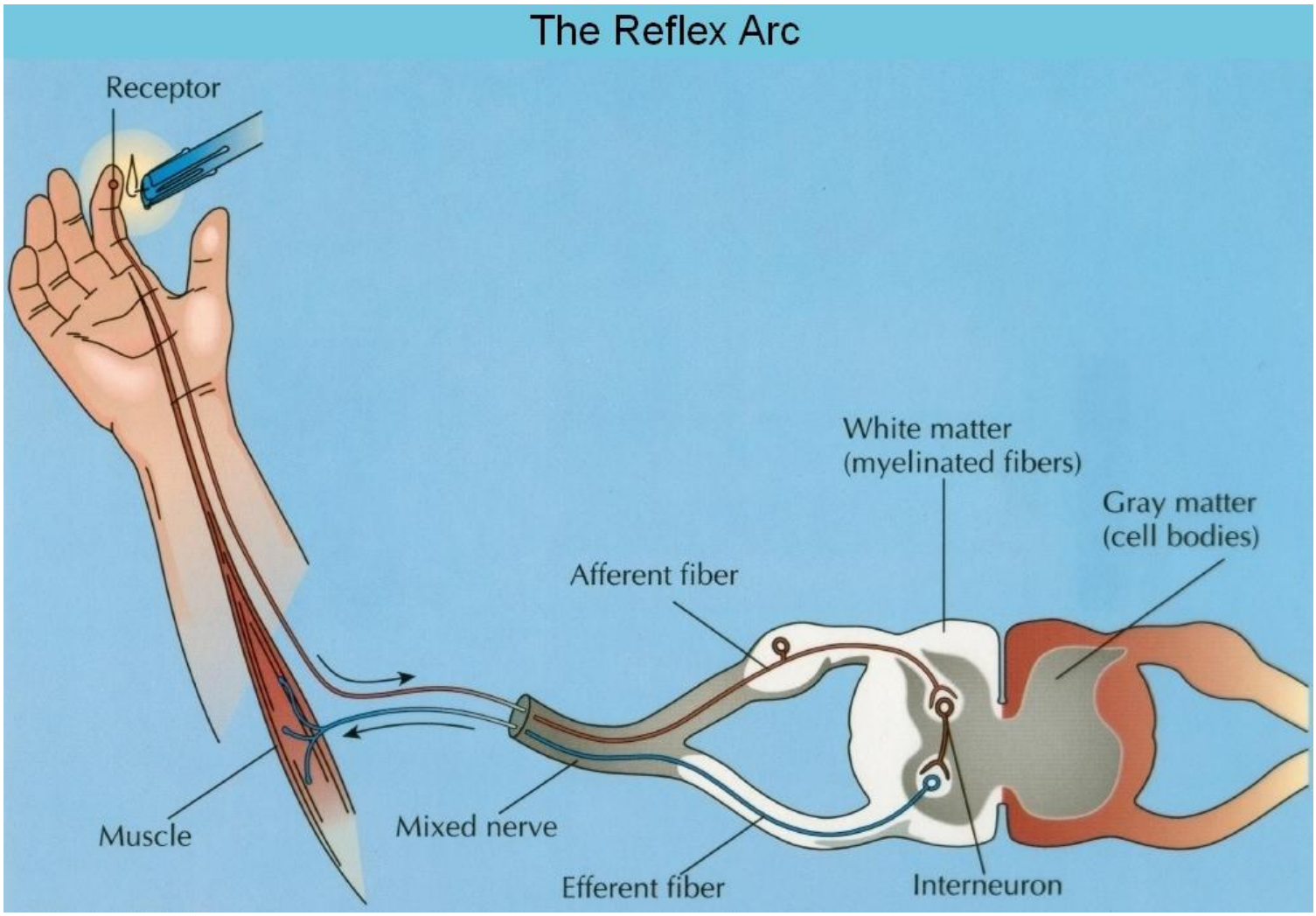
From Where Does the Input, the Information Coming to a Neuron, Originate?

Other Neurons - The vast majority of connections are between neurons. *Inter-neurons* relay information, and by way of dendritic branching vast networks are formed. This allows for the simultaneous processing of information on a tremendous scale.

Sense Receptors - Unique structures designed to respond to modality-specific stimuli, most coming from the external environment.

Proprioceptors - Provide information and feedback as to body positioning and movement.

The Endocrine System - A number of glandular secretions, particularly hormones, act as neural modulators and can induce neural activity.



Where Does the Output, the Information Being Sent by a Neuron, Go?

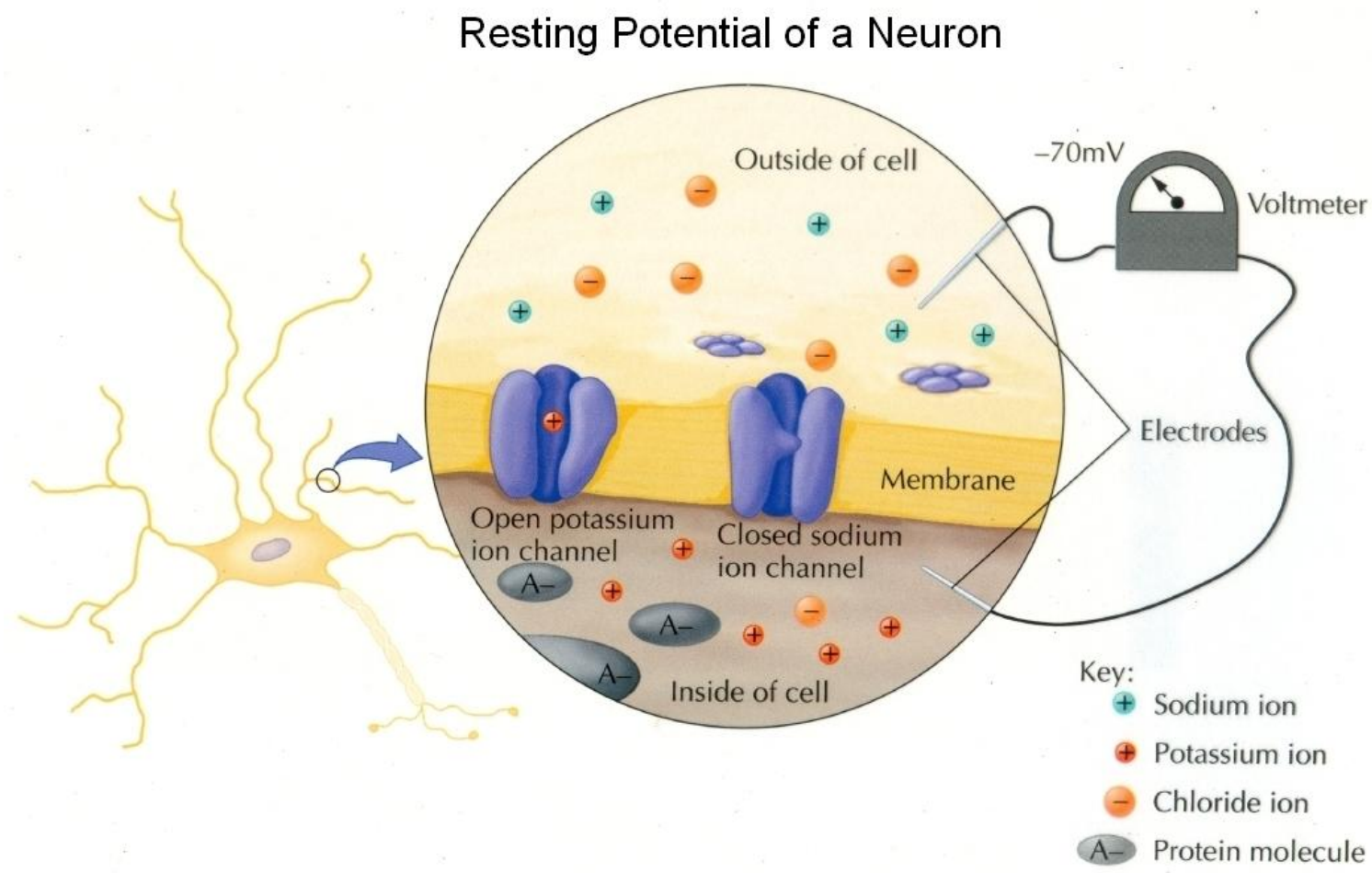
Other Neurons - The vast majority of connections are between neurons. Inter-neurons relay information, and by way of dendritic branching vast networks are formed. This allows for the simultaneous processing of information on a tremendous scale.

Muscles - Neurons interface with muscle spindle fibers to initiate movement.

The Endocrine System - The neurons interface with various glands to regulate the internal environment of the body.

The Internal Environment of the Neuron:

The Resting Potential - The neuron actively works to maintain it's internal environment, primarily the neuron's electrical charge relative to the extra-cellular environment (fluids outside of the neuron). In other words, the neuron maintains a state of polarization. Structures on the membrane dispel positively charged ions (sodium and potassium) from the cell. And large concentrations of negatively charged protein molecules inside the neuron cause it to have a -70mV charge relative to the extra-cellular environment.



The Action Potential - When the neuron sends an impulse, fires, an action potential is generated. The neuron's electrical charge relative to the extra-cellular environment changes from -70mV to +30mV. Note that this is an all or none effect. If an action potential is generated the electrical charge goes from -70mV to +30mV, no other value. There is no such thing as a partial firing of a neuron.

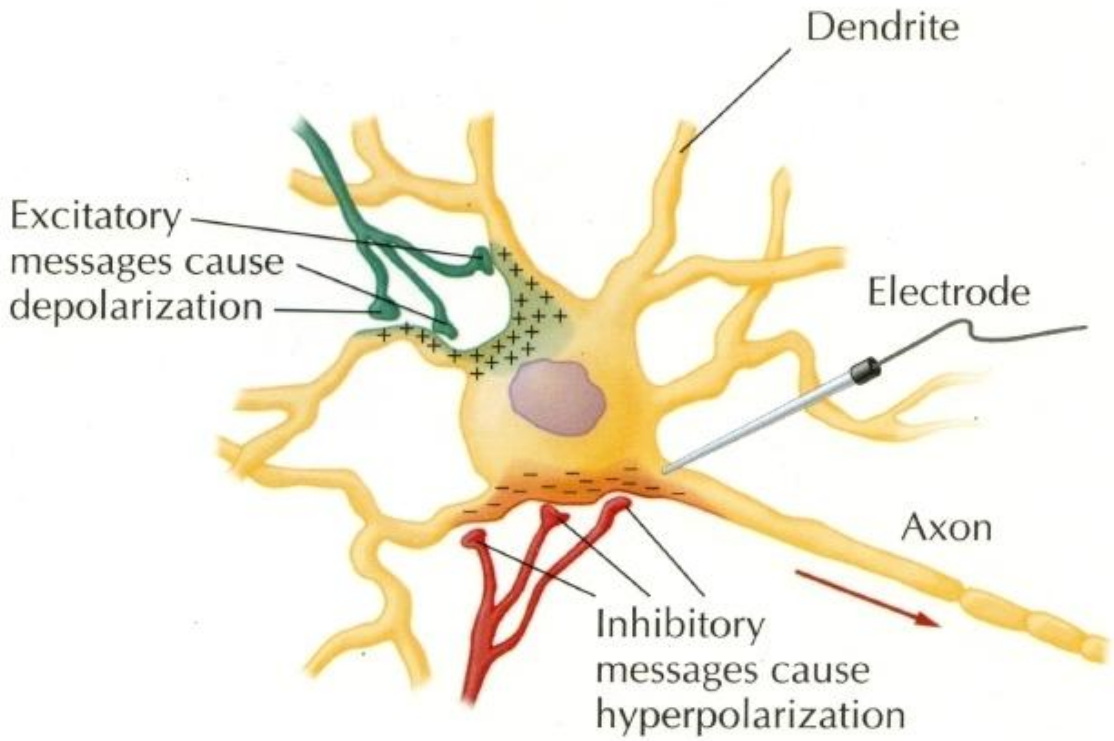
What Causes a Neuron to Initiate an Impulse, to Fire?

Incoming Signals - There are numerous connections (input) to the various receptive locations (synapses) on the neuron cell body and dendrites. This input, the incoming signals arriving at these locations, can be either excitatory or inhibitory. *Excitatory Input (+)* directs the neuron to fire. *Inhibitory Input (-)* directs the neuron not to fire.

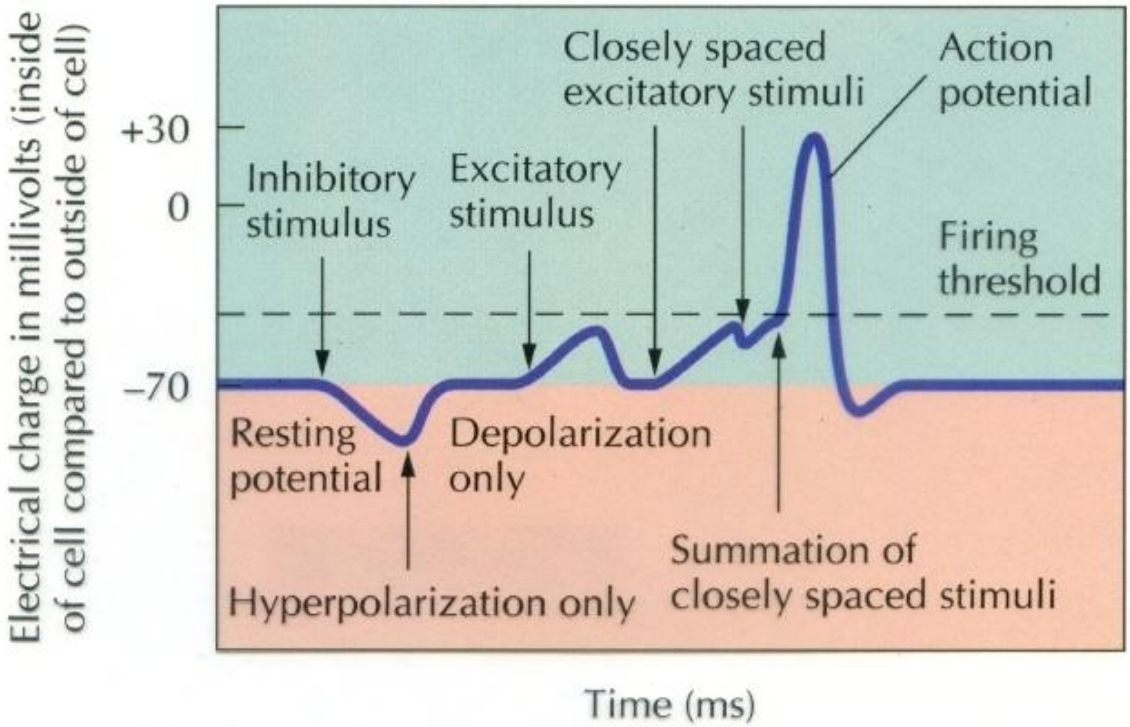
Additive Summation and Threshold - All of this information is relayed to one location, a nodule near the base of the axon, the *axon hillock*. Here an analysis is made on the aggregate of the signals received, additive summation. If the net total of all the inputs is inhibitory (-), then the degree of activation is below threshold and the neuron does not fire. If the net total of all the inputs is excitatory (+), then the degree of activation is above threshold and firing of the neuron is initiated.

Initiation - Firing of the neuron begins when ion channels on the cell membrane near the axon hillock are stimulated. These open, allowing positively charged ions to enter the cell. At the same time the pumps that normally dispel positively charged ions are temporally shut off. The result is a change in the neuron's internal electrical potential from -70mV to +30mV (relative to the extra-cellular environment) at that location.

Excitatory and Inhibitory Inputs

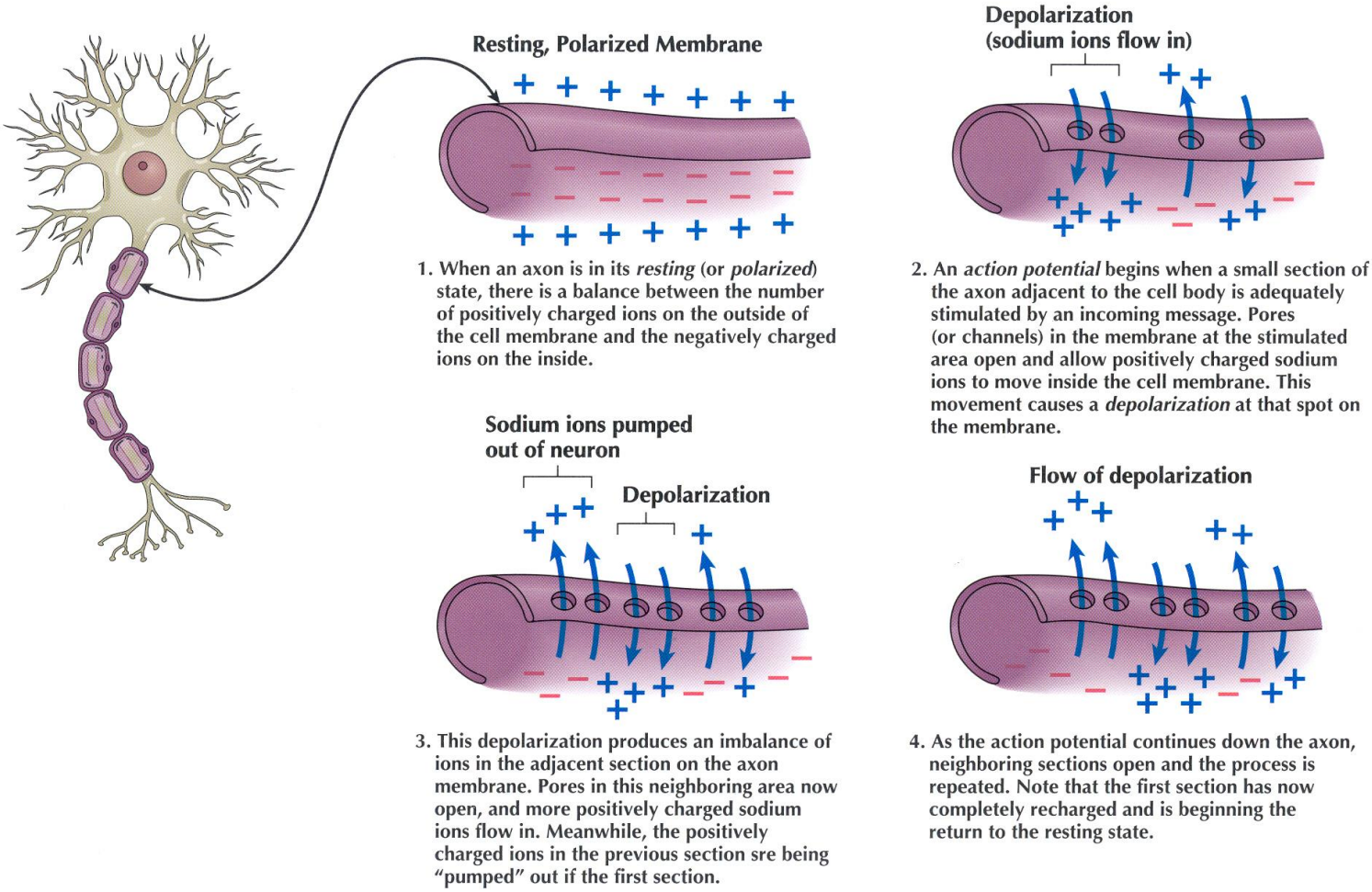


(a)



(b)

How is the Neural Impulse Propagated Along the Axon? A change in the internal electrical potential of the neuron at one location (beginning near the axon hillock) stimulates the ion channels of the cell membranes and shuts down the ion pumps at adjacent locations further along the axon. And so positively charged ions (sodium) enter the cell. Subsequently, a change in the neuron's electrical potential from -70mV to +30mV occurs at that location. That change stimulates the ion channels and shuts down the ion pumps at the next adjacent location along the axon membrane. And so the process continues along the axon. Behind this wave front the ion channels close, and the ion pumps are reactivated, dispelling positively charged ions (sodium and potassium) in order to return the cell's electrical potential to -70mV. There is a short time interval while the neuron recovers and re-establishes its resting potential in which it cannot fire (even being hyperpolarized for part of it). This *refractory period* has about a 2-3 millisecond duration. Once this period elapses the neuron is ready to fire again. However, this shows that there is a limitation to how fast neurons can fire (approximately 500 times per second).



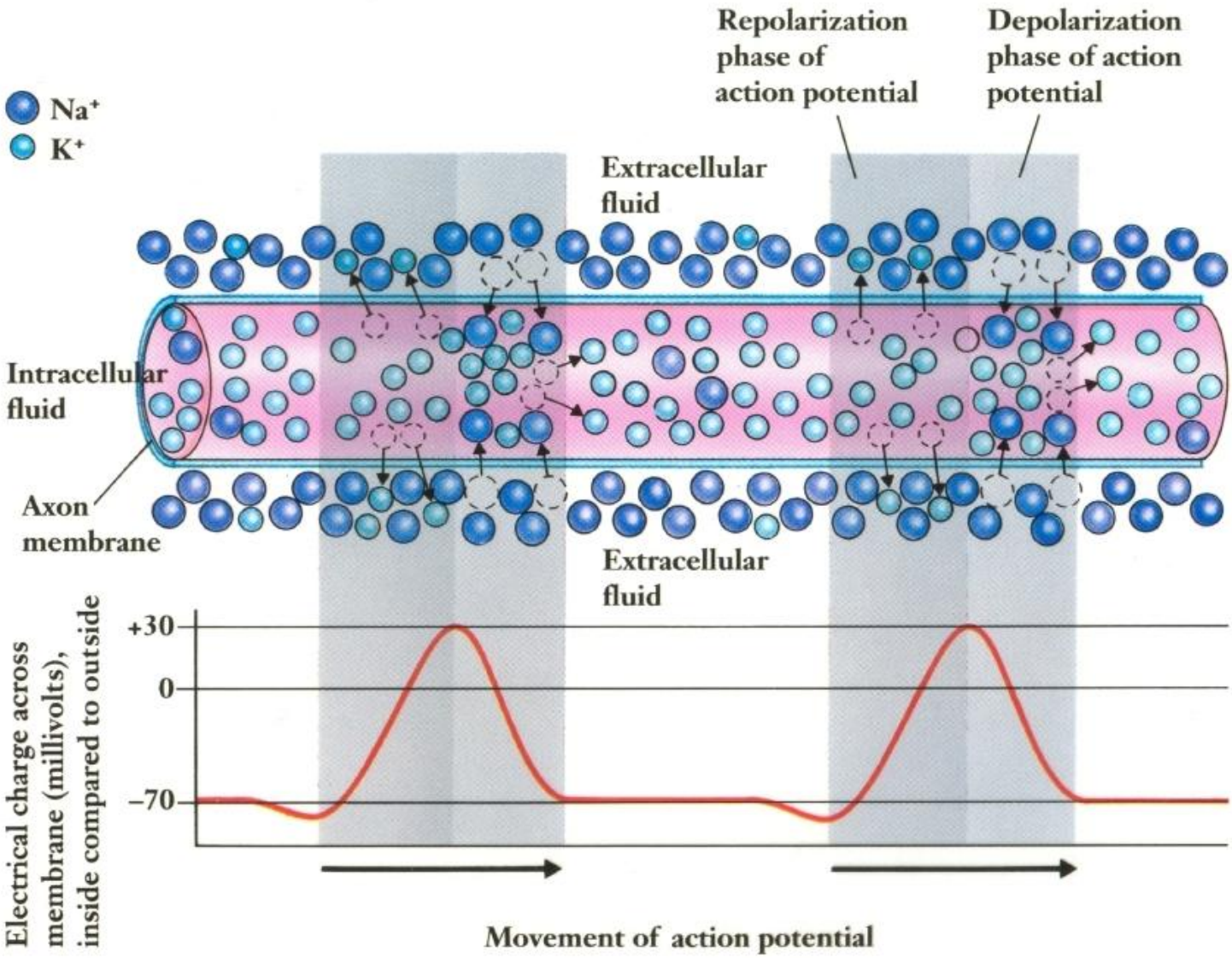
1. When an axon is in its *resting* (or *polarized*) state, there is a balance between the number of positively charged ions on the outside of the cell membrane and the negatively charged ions on the inside.

2. An *action potential* begins when a small section of the axon adjacent to the cell body is adequately stimulated by an incoming message. Pores (or channels) in the membrane at the stimulated area open and allow positively charged sodium ions to move inside the cell membrane. This movement causes a *depolarization* at that spot on the membrane.

3. This depolarization produces an imbalance of ions in the adjacent section on the axon membrane. Pores in this neighboring area now open, and more positively charged sodium ions flow in. Meanwhile, the positively charged ions in the previous section sre being "pumped" out if the first section.

4. As the action potential continues down the axon, neighboring sections open and the process is repeated. Note that the first section has now completely recharged and is beginning the return to the resting state.

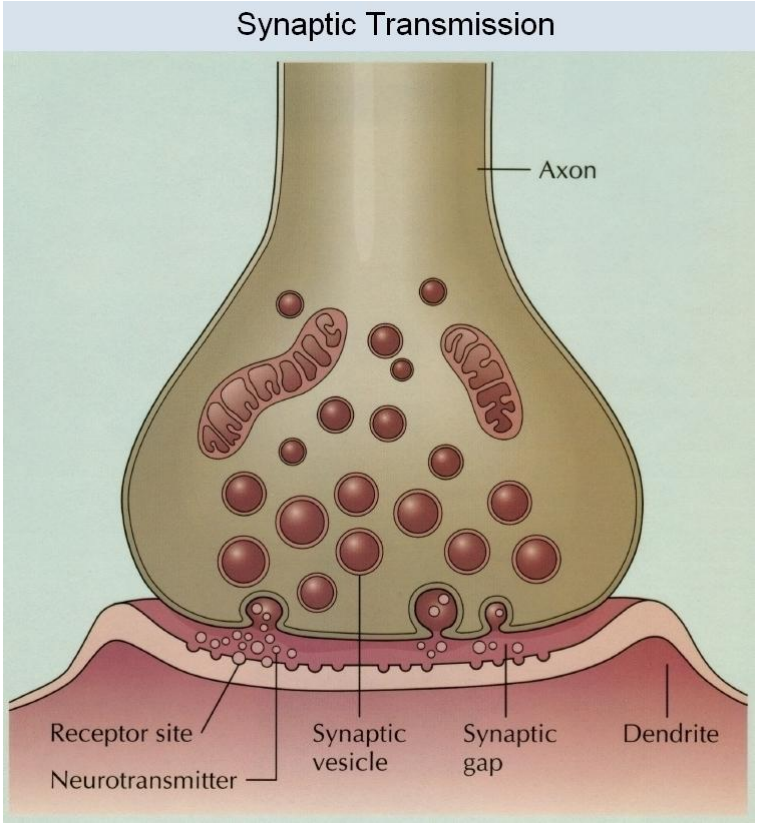
Propagation of the Action Potential



The Myelin Sheath: The axons of many neurons are wrapped in a fatty substance called myelin. This myelin sheath provides insulation preventing cross-circuiting and speeding up transmission. There are periodic gaps in this covering, the *Nodes of Ranvier*. For the most part, with myelinated axons, the ion channels and pumps are only functional at these gaps since little sodium enters elsewhere along the axon. The change in the neuron's electrical potential rapidly passes along from one Node of Ranvier to the next, a process known as *saltatory conduction*. This cable-like conduction of the impulse allows for substantially faster neural transmission. The fasted myelinated axons can conduct action potentials at a speed of 120 meters per second.

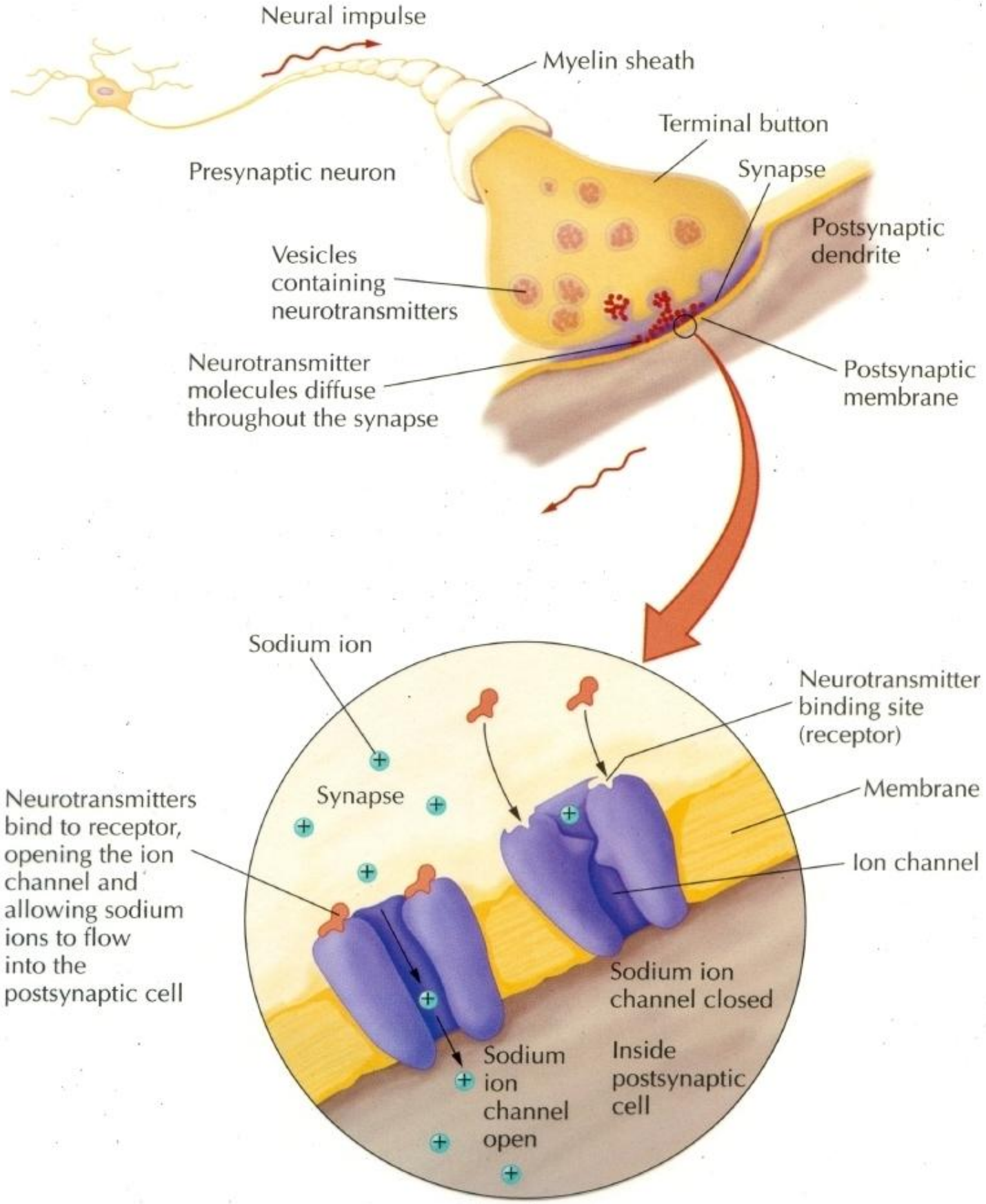
Transmission of Information:

Axon Terminal Buttons (End Bulbs) and Synaptic Vesicles - The axon typically branches out a bit at the end, so there is a cluster of terminal buttons (end bulbs). Chemical *neurotransmitter* molecules are produced by the neurons in the axon terminal buttons (bulbs), then pre-packaged and stored in the synaptic vesicles found there. The change in the electrical potential here causes some of these tiny containers to migrate to the cell membrane (*pre-synaptic membrane*). They bind with the membrane, then cause it to open to the outside, spilling their contents in the process.

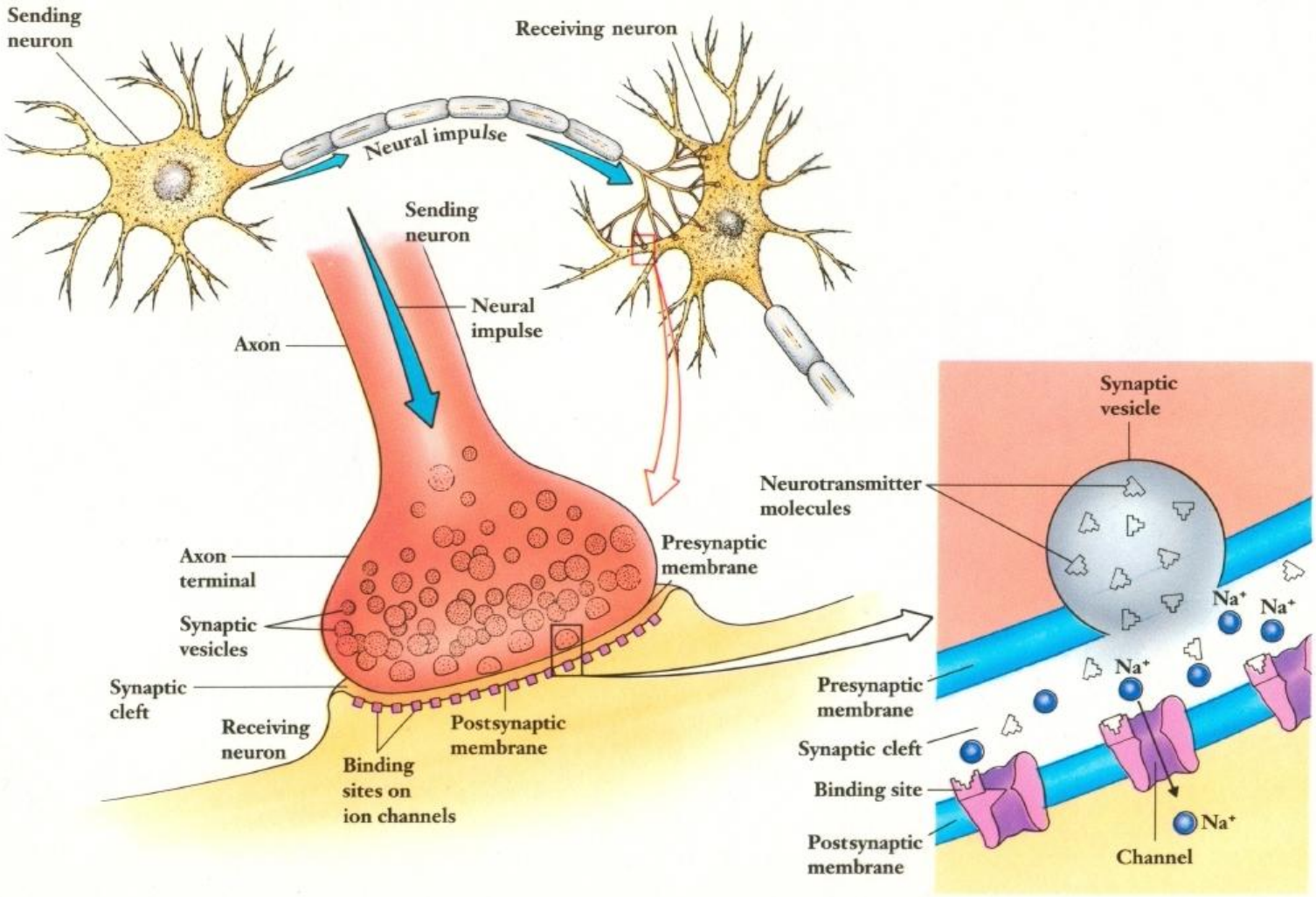


Neurotransmitters and Post-Synaptic Receptors - The neurotransmitter chemicals float across the *synaptic cleft* toward the receptors on the post-synaptic membrane. Their action is localized when released into the synapse so as to only affect receptors on an adjacent neuron, muscle, or gland. Those receptors are uniquely structured to accept only molecules having the molecular structure of the neurotransmitter normally encountered at a particular synapse. It has been called a 'lock and key' design, based on the unique three-dimensional molecular shape of the neurotransmitter at that synapse and the corresponding receptor sites. The neurotransmitters then bind with these receptors. This triggers changes in the cellular membranes near the receptors that allow for channels in the membranes to open and allow ions to enter. When this occurs an input is registered (excitatory or inhibitory), and the combined inputs from many receptors then begin to affect the internal environment of the receiving cell. Those changes are the basis of additive summation if the receiving cell is another neuron. If sufficient excitatory inputs are received the electrochemical charge of the cell relative to the surrounding environment is altered to the point of generating an action potential and neural transmission continues onward. Note also that it is primarily at this level that drugs affect the nervous system, often because a particular drug may have a molecular configuration that is quite similar to a specific neurotransmitter.

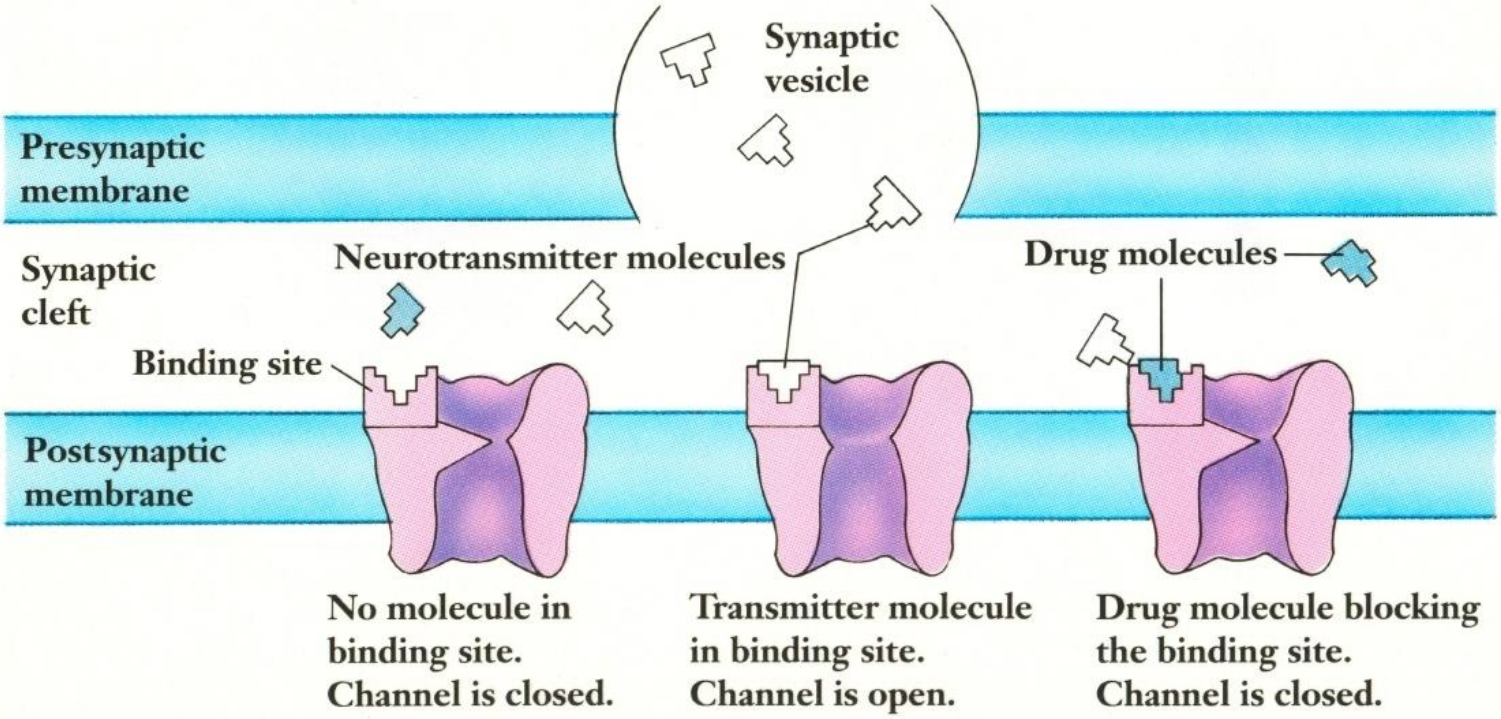
Transmission from Axon to Synapse

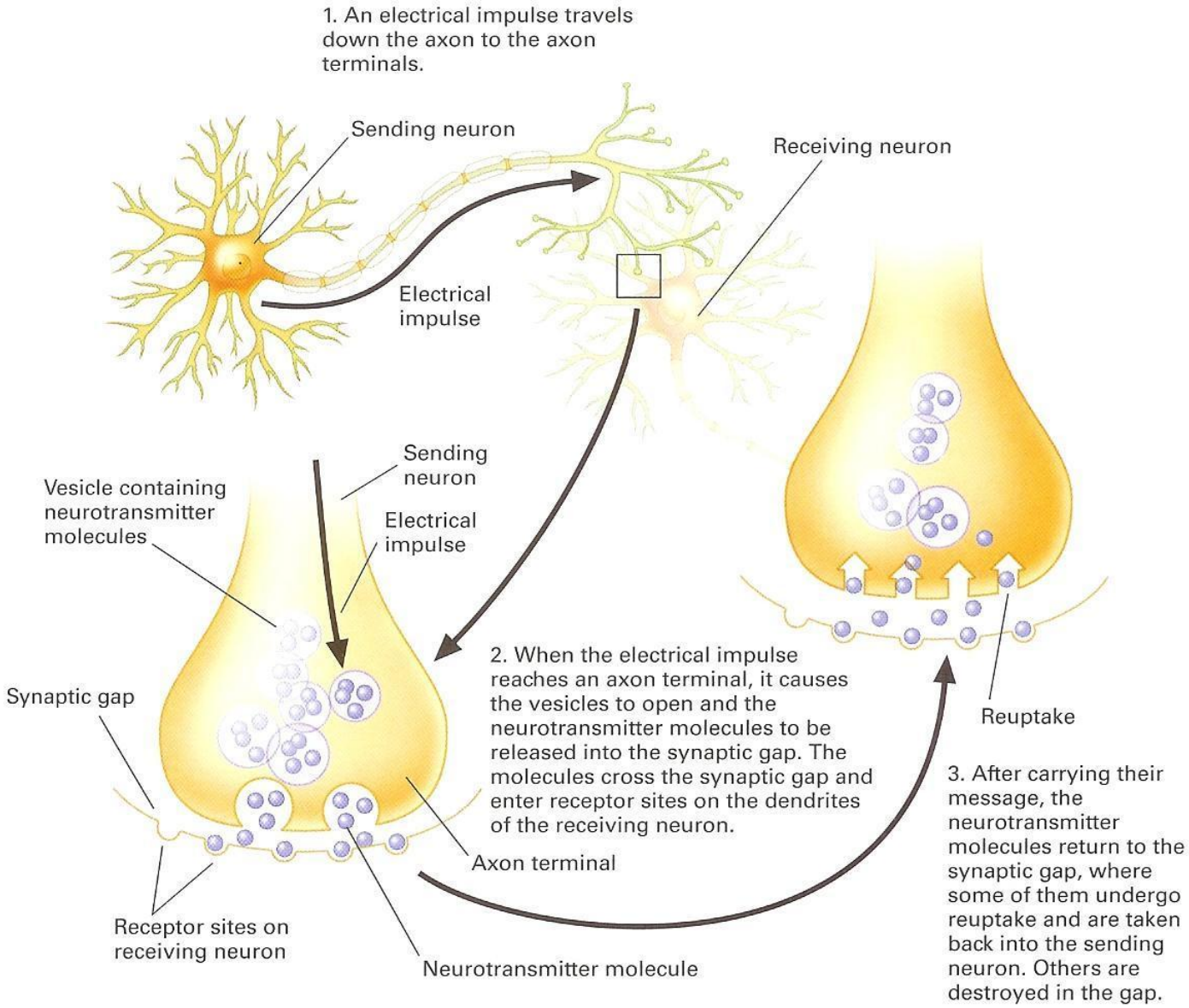


Transmission from Axon to Synapse



Receptor Binding Sites - Lock and Key Setup





Synaptic Communication Between Neurons Neurons communicate with each other chemically. As explained in the figure, there are three steps. (1) When the electrical impulse in a neuron reaches the axon terminals, it causes neurotransmitter molecules in the terminal vesicles to be released into the synaptic gap between neurons. (2) These molecules cross the gap and fit into receptor sites on the dendrites of other neurons, thereby carrying their messages. (3) The neurotransmitter molecules then go back into the gap, where they are either taken up by the sending neuron (reuptake) to be used again or are destroyed by enzymes.

The Endocrine System: A question arises as to why such an elaborate system is employed in order to transmit information from one neuron to another. It would be easier and metabolically cheaper to simply connect the axons of one neuron to the receptors of another. Why are there synapses and neurotransmitters? Without them a simpler way would work to transfer information at the local level, such as from neuron to neuron. However, what about the need to quickly activate a number of neural systems at various different locations all at once? Sometimes local action, from neuron to neuron, is not enough. Sometimes systemic activation is required. Consider a general level of arousal, wherein a number of metabolic measures are elevated. This occurs when we are threatened and need to increase our metabolic functioning in order to better avoid a threat or fend off an attack. Most of these systems are monitored and either governed or in some way influenced by the nervous system. For the various nervous system connections to all come online independently to initiate, coordinate, and maintain this kind of elevated metabolic response would be problematic. It would also be metabolically costly. Instead, the *endocrine system* kicks in. *Neuromodulators* are chemicals (hormones) produced by the endocrine system (glands). Often these are chemically the same as neurotransmitters. However, they are released into the bloodstream and stimulate various systems at multiple locations throughout the body quickly, efficiently, and simultaneously. They are generally too large to cross the blood brain barrier, but interface at a few key locations in the brain (hypothalamus) to provide feedback. So besides the nervous system, another major mode of communication within the body is the endocrine system. Of course, the endocrine system and the nervous system are intimately related, with the endocrine system under the control of the brain to a certain extent.

Neurotransmitters: These are the chemicals produced by the body to control and regulate nervous system functioning. Neurotransmitters are produced by the neurons in the axon terminal buttons (bulbs) and stored in the synaptic vesicles. Their action is local when released into synapses to affect adjacent neurons, muscles, or glands. The action of these chemicals is due to the three-dimensional shape of the chemical molecules. Receptors at various sites only allow for particularly shaped molecules to trigger changes at the cellular membranes that then allow for channels in the membranes to open and allow ions to enter. This, in turn, alters the electrochemical charge of the cell relative to the surrounding environment, resulting in action potentials and neural transmission. It should be noted that both neurotransmitters and neuromodulators trigger decidedly varied reactions depending on their site of action. As many as 200 are postulated, but we will discuss only a few of the better known and most prominent in detail.

Neurotransmitter	Known or Suspected Effects
Serotonin	Affects mood, sleep, appetite, sensory perception, temperature regulation, pain suppression, impulsivity, and aggression; may play a role in some psychological disorders, such as depression
Acetylcholine (ACh)	Affects muscle action, cognitive functioning, memory, REM (rapid-eye-movement) sleep, emotion. Suspected role in Alzheimer's disease
Dopamine (DA)	Affects movement, attention, memory, learning, and emotion. Plays a role in both schizophrenia and Parkinson's disease.
Norepinephrine (NE) (or noradrenaline)	Affects learning, memory, dreaming, emotion, waking from sleep, eating, alertness, wakefulness, reactions to stress
Epinephrine (or adrenaline)	Affects emotional arousal, memory storage, and metabolism of glucose necessary for energy release
GABA (gamma aminobutyric acid)	Neural inhibition in the central nervous system; Tranquilizing drugs act on GABA to decrease anxiety

Acetylcholine -

[1] Voluntary muscle control (motor cortex of frontal lobes, somatic nervous system).

Blocking acetylcholine results in muscle paralysis, including the diaphram. Curae, insecticides, and nerve gases have their effects by way of blocking normal acetycholine functioning.

Enkephalins/Endorphins -

[1] Controls and regulates the perception of pain (somatosensory cortex of parietal lobes, somatic nervous system).

[2] Can generate euphoria (hypothalamus).

Overall, these chemicals allow the body to continue functioning despite being at or beyond the normal thresholds of endurance or pain. Opiate drugs are very similar chemically and mimic these effects.

Epinephrine (Adrenaline) -

[1] Arousal, excitation, anxiety, fear, and rage (hypothalamus, autonomic nervous system).

[2] Readiness for stress, combat, or flight (autonomic nervous system - sympathetic branch).

Norepinephrine (Noradrenaline) -

[1]Calming effects, relaxation, routine bodily functioning (autonomic nervous system - parasympathetic branch).

[2]Excesses in the brain are implicated in mania.

[3]Lack of sufficient usable norepinephrine in the brain implicated in depression.

(Dopamine is oxydized by an enzyme to produce norepinephrine.)

Most major tranquilizers (reserpine, chlorpromazine) decrease usable amounts of norepinephrine and dopamine. Antidepressants (MOA inhibitors, tricyclics such as imipramine) increase usable amounts of norepinephrine and dopamine.

Dopamine -

[1] Initiation of muscle movement (substantia nigra, caudate nucleus, cerebelleum)

[2] Muscle control related to posture, gait, regulation of opposing muscle groups (cerebelleum) Excess of usable dopamine affects this function in the form of rigidity such as the catatonia sometimes found in schizophrenia.

[3] Reflexive responses (cerebelleum)

Lack of usable dopamine affects these first three functions by causing an inability to control starting and stopping of movements, tremers, and motor/speech tics such as those found in Parkinson's patients and cases of tardive dyskinesia.

[4] Ability to sort/filter sensory inputs and information (frontal and temporal lobes)

[5] Ability to focus attention/concentrate (frontal lobes)

Excess of usable dopamine affects the fourth and fifth functions in the form of hallucinations (especially auditory) and delusions found in schizophrenia.

[6] Regulation of impulsivity (frontal lobes, hypothalamus, amygdala)

[7] Ability to experience pleasure (reward/punishment centers in hypothalamus)

Excess of usable dopamine affects the sixth and seventh functions by producing behavioral or emotional outbursts and inappropriate affect as found in schizophrenia.

Lack or excess may be due to actual amounts or improper regulation by way of other substances such as serotonin.

Nicotine, amphetamine, cocaine, and related drugs mimic dopamine at receptors and produce enhancment of functions 5, 6, and 7. Prolonged abuse of these drugs results in fourth and fifth functions being affected in much the same way as in Schizophrenia. Prolonged use also increases number of dopamine receptors, and by way of this the amount of dopamine or drug needed to activate these functions/systems is elevated (tolerance). Discontinuing use of drugs results in ahedonia as body cannot supply enough dopamine to activate the additional receptors in brain pleasure centers of hypothalymus, so relapse common.

The amino acid tyrosine is oxidized to produce L-Dopa, which is then transformed by an enzyme to produce dopamine.

Serotonin -

[1] Regulates sleep/wake cycle (reticular formation)

[2] Regulates overall mood (frontal and temporal lobes)

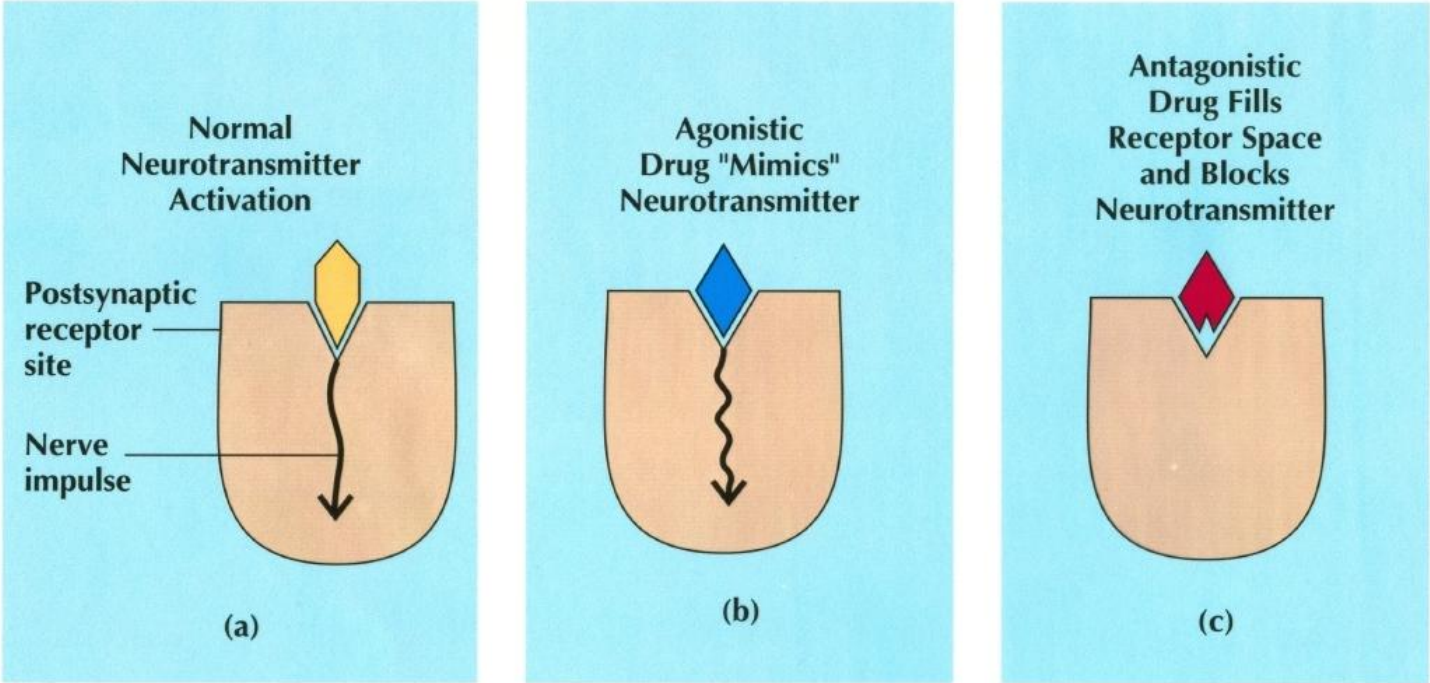
[3] Responsible for sleep disorders such as insomnia or excess sleep.

[4] Implicated in mood disorders such as chronic depression and bipolar disorder, as well as a number of other conditions. This is most likely due to an overall function designed to modulate the effects of the other neuro-chemicals across a wide range of locations and systems.

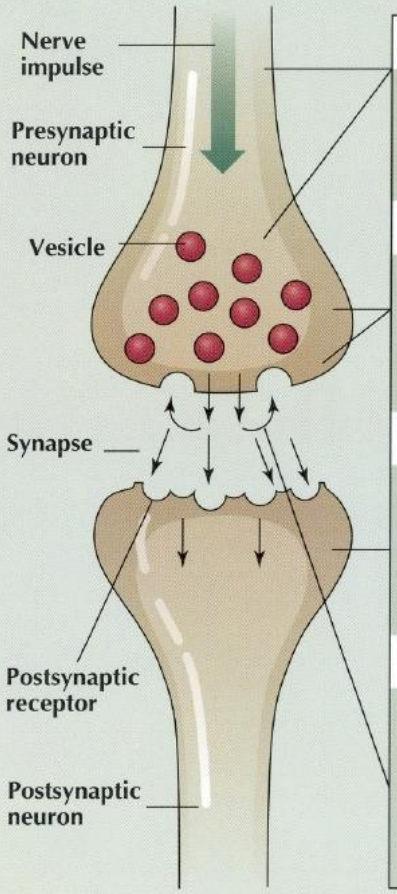
Serotonin is chemically related to the amino acid tryptophan, as well as the neurotransmitters norepinephrine and dopamine. All known hallucinogens believed to simulate the structural characteristics of either serotonin, norepinephrine, and/or dopamine.

Drugs: Drugs differ from hormones in that they are not produced inside the body but are introduced from outside. However, like hormones, drugs are carried by the blood and taken up in target tissues of the body including the nervous system. Once in the bloodstream drugs can have widespread effects and like hormones can affect synaptic transmission. Drugs often have molecular structures sufficiently close enough to those of neurotransmitters to allow them to bind with the post-synaptic receptors. Some drugs mimic the neurotransmitter and a false input is registered. Others simply block the receptor so the real neurotransmitter cannot bind, thereby rendering it inert. Also some drugs prevent the reuptake of neurotransmitter molecules causing them to repeatedly activate the receptors.

Drug Action



Neurotransmitters and Drug Action

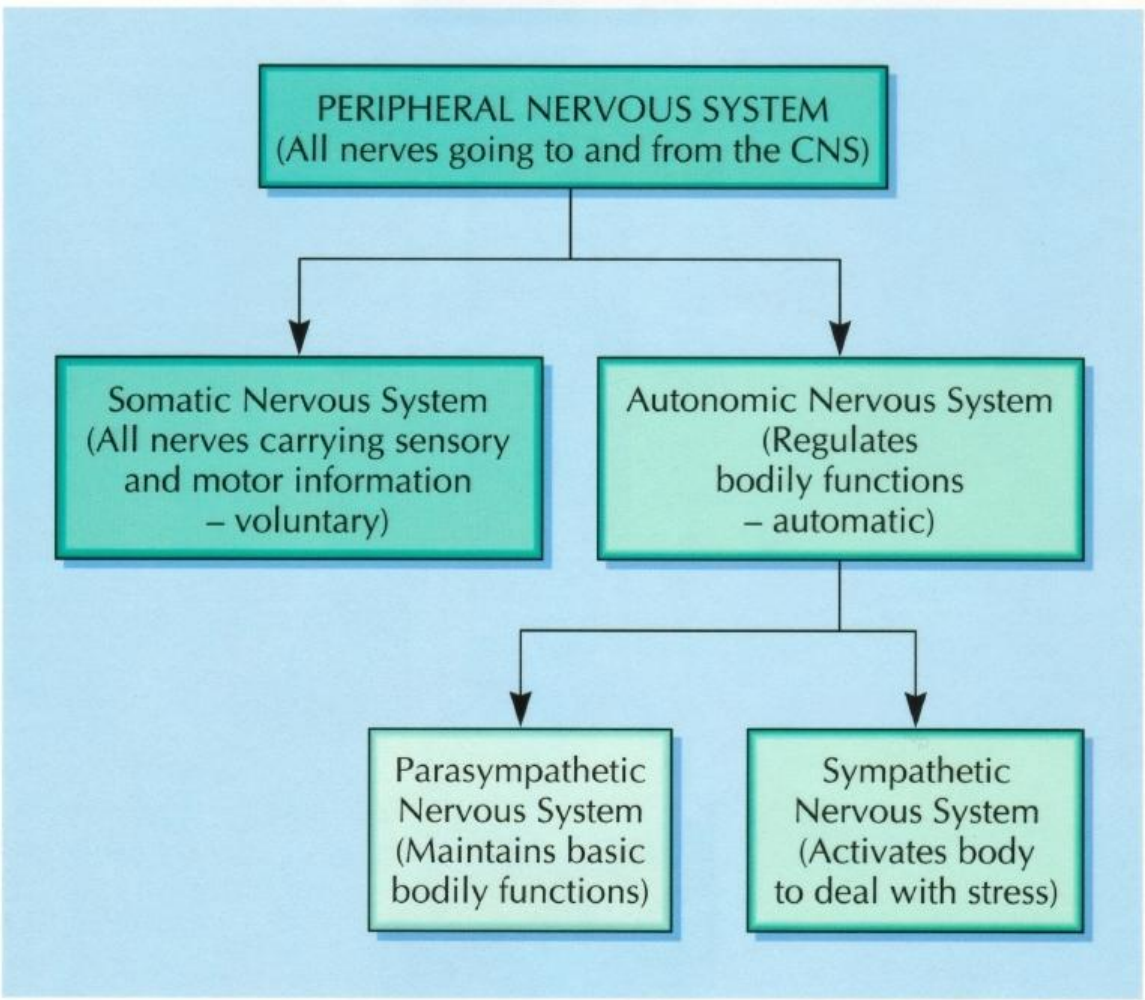


How neurotransmitters work	Agonist drugs (mimics neurotransmitter effects)	Antagonist drugs (blocks neurotransmitter effects)
(Step 1) Production		
(1) Neurotransmitter is produced.	Drug serves as a precursor for neurotransmitter synthesis (e.g., L-DOPA is used to make dopamine).	Drug blocks production.
(Step 2) Storage and release		
(2) Neurotransmitter is stored in vesicle. When impulse arrives, neurotransmitter is released.	Drug increases the release of neurotransmitter (e.g., black widow spider venom increases acetylcholine release).	Drug blocks neurotransmitter storage and/or release.
(Step 3) Reception		
(3) Neurotransmitter binds to postsynaptic receptors and activates them.	Drug attaches to receptors and activates them (e.g., Nicotine activates acetylcholine receptors and morphine activates endorphin receptors).	Drug blocks neurotransmitter by filling receptor space but doesn't activate the neuron (e.g., drugs for schizophrenia block dopamine).
(Step 4) Inactivation		
(4) Excess neurotransmitter is deactivated by reuptake or enzymatic breakdown.	Drug blocks inactivation of neurotransmitter leaving more in the synapse to stimulate receptors (e.g., cocaine and nicotine block reuptake of dopamine and norepinephrine).	

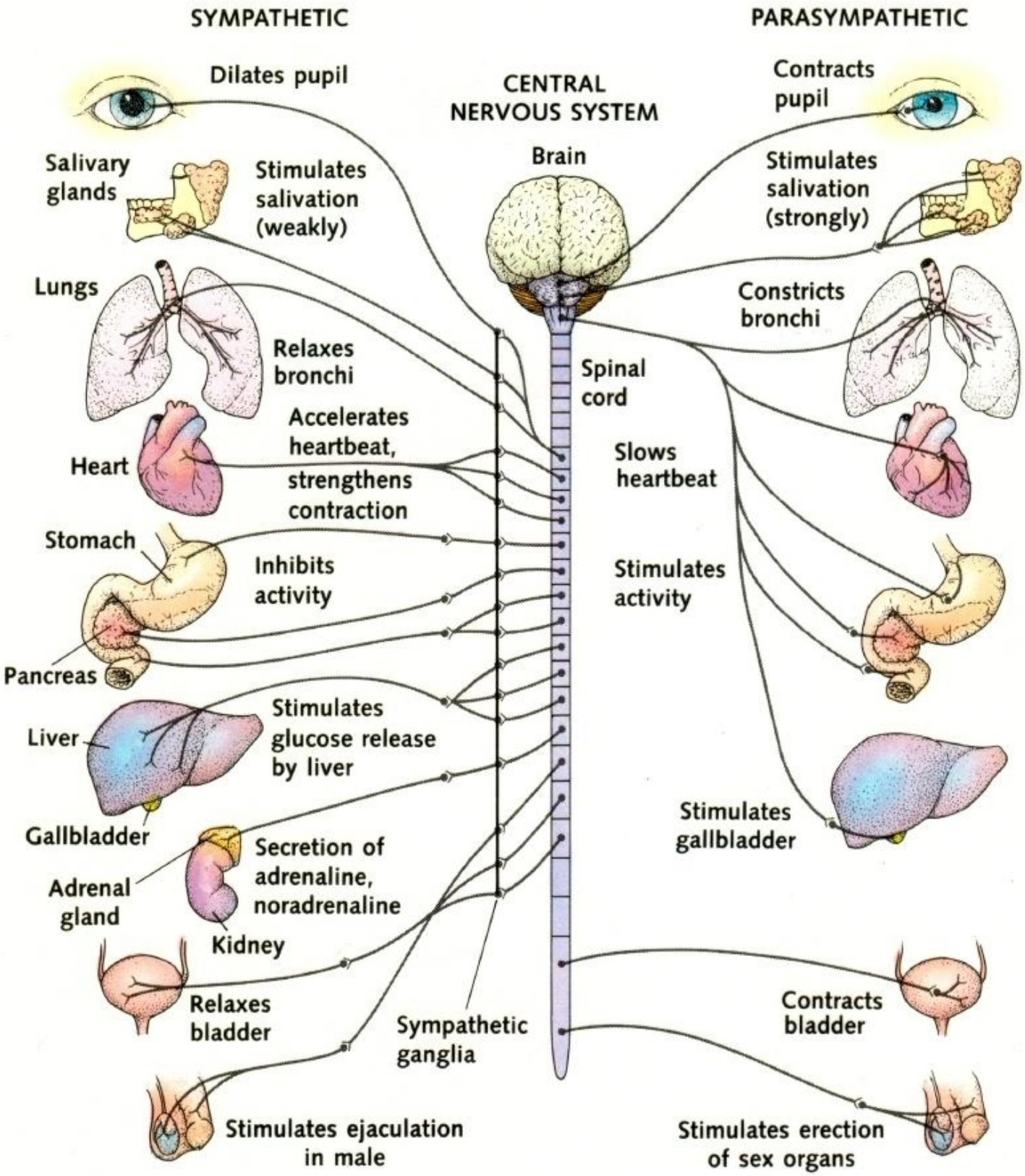
The Nervous System

Terminology: The nervous system is classified into the *peripheral nervous system* (PNS) and the *central nervous system* (CNS). In the PNS Schwann cells provide support for the neurons, in the CNS the glia (glial cells) do this. In the PNS a cluster of neurons is referred to as a ganglion, in the CNS such a cluster is referred to as a nucleus. In the PNS a bundle of axons of sensory neurons (which carry information to the central nervous system) or motor neurons (which carry commands to muscles and glands) is a nerve. In the CNS a bundle of axons connecting centers within the brain is called a tract.

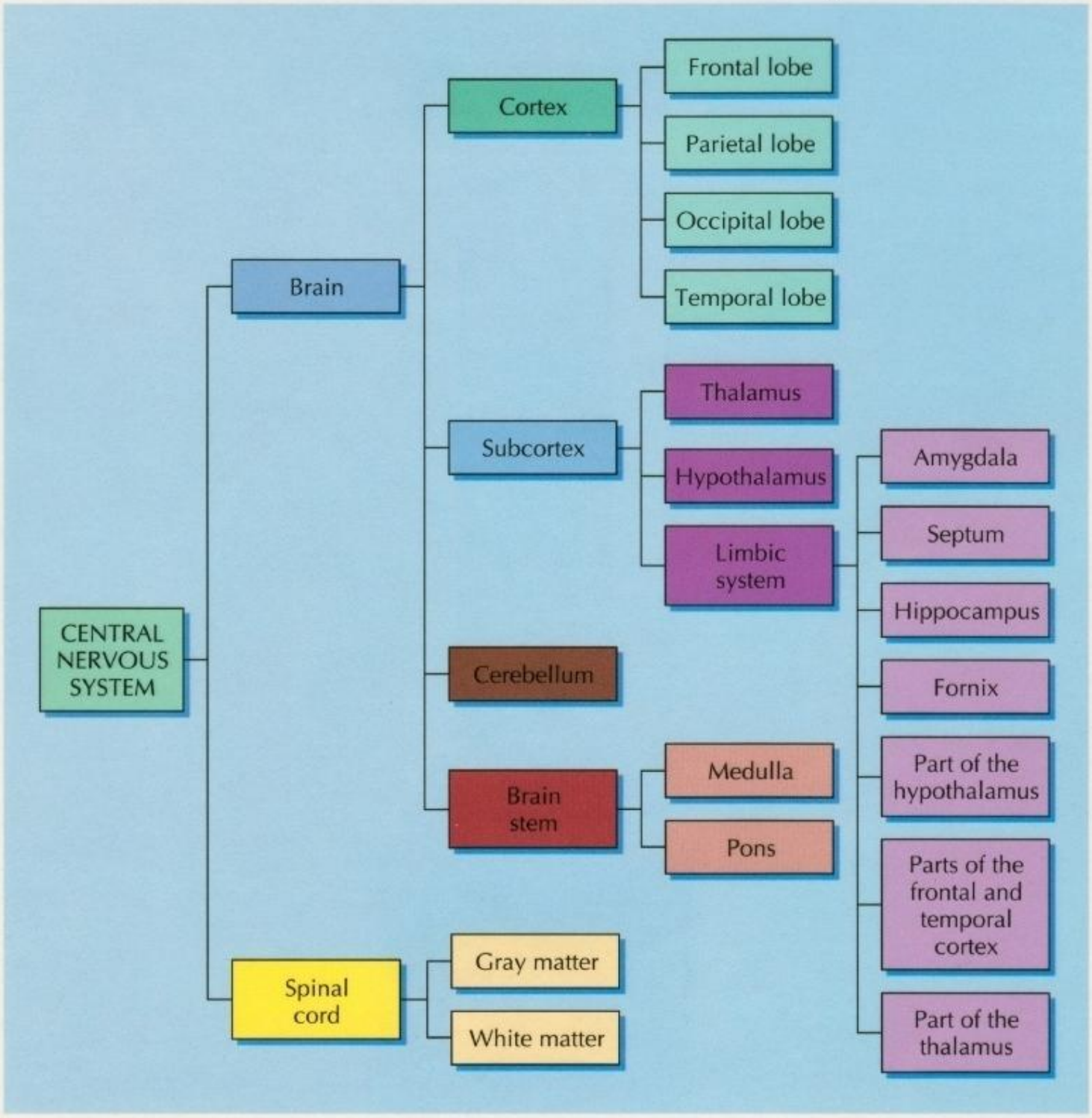
Peripheral Nervous System (PNS): The vast array of neurons and nerves that connect the brain and spinal cord to sensory organs, muscles, and glands. The peripheral nervous system has two divisions, the *somatic* (sensory input and voluntary muscle control) and the *autonomic* (internal bodily functions). The autonomic system is further subdivided into the *sympathetic* branch that mediates responses to stress (fight or flight) and the *parasympathetic* branch that controls regenerative and growth-promoting functions (rest and digest).



The Autonomic Nervous System



Divisions of the Central Nervous System



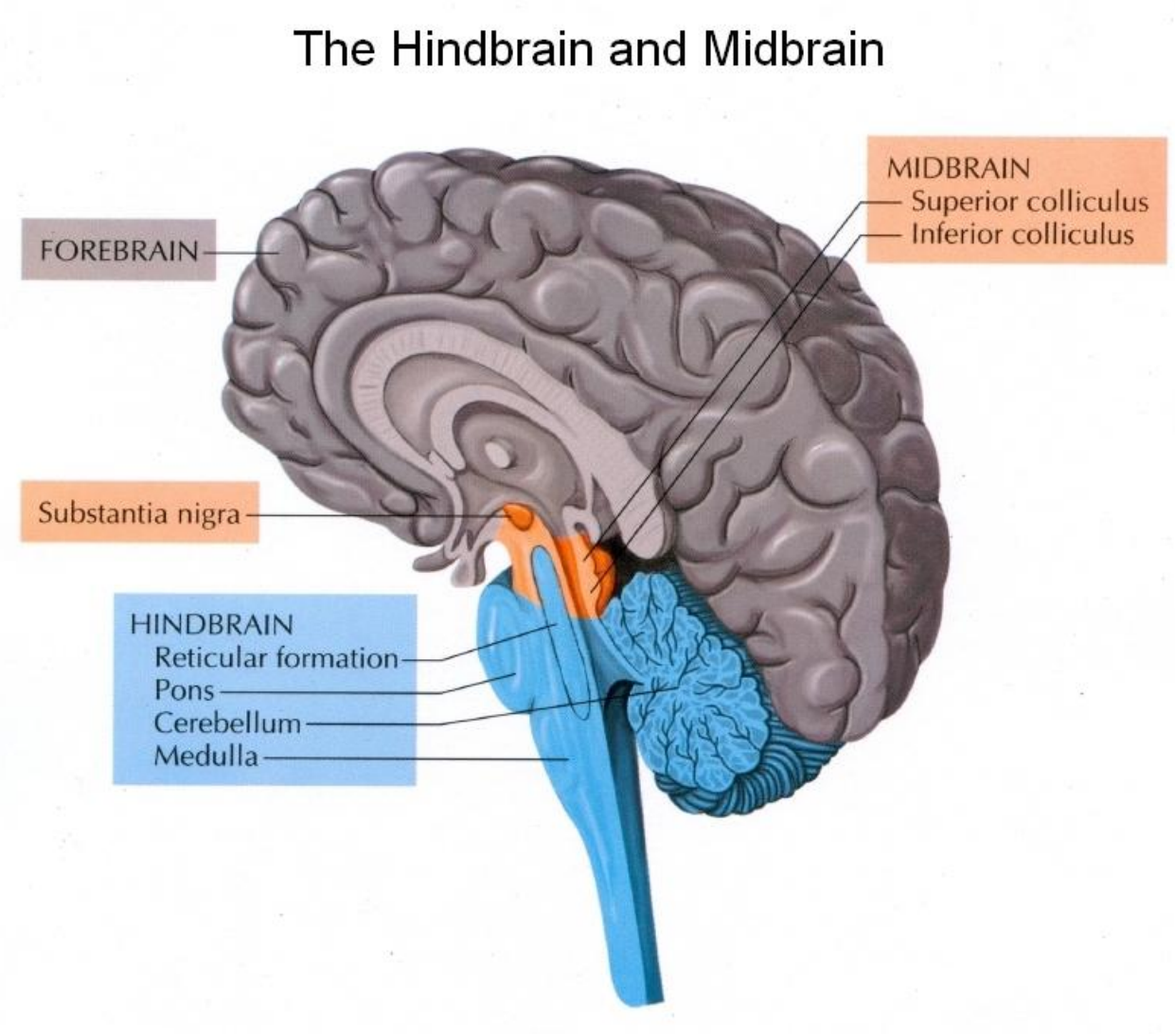
Central Nervous System (CNS): The brain and spinal cord comprise the central nervous system. The functions of the central nervous system are organized hierarchically, for the most part. The most primitive, reflexive responses are governed by the lower brain areas and the spinal cord. The most complex processing and precise control are governed by areas of the cortex. The control of movement illustrates this hierarchical organization. Reflexes are under spinal control. Gross motor functioning such as posture and gait are controlled by the cerebellum. Fine motor control is directed by the motor cortex of the frontal lobe.

The *spinal cord* functions as a conduit between the brain and the peripheral nervous system. It is also responsible for mediating spinal reflexes, behaviors that can be triggered and carried through to completion without the help of the brain. However, inter-neurons in the spinal cord allow the brain to monitor and override this activity when necessary.

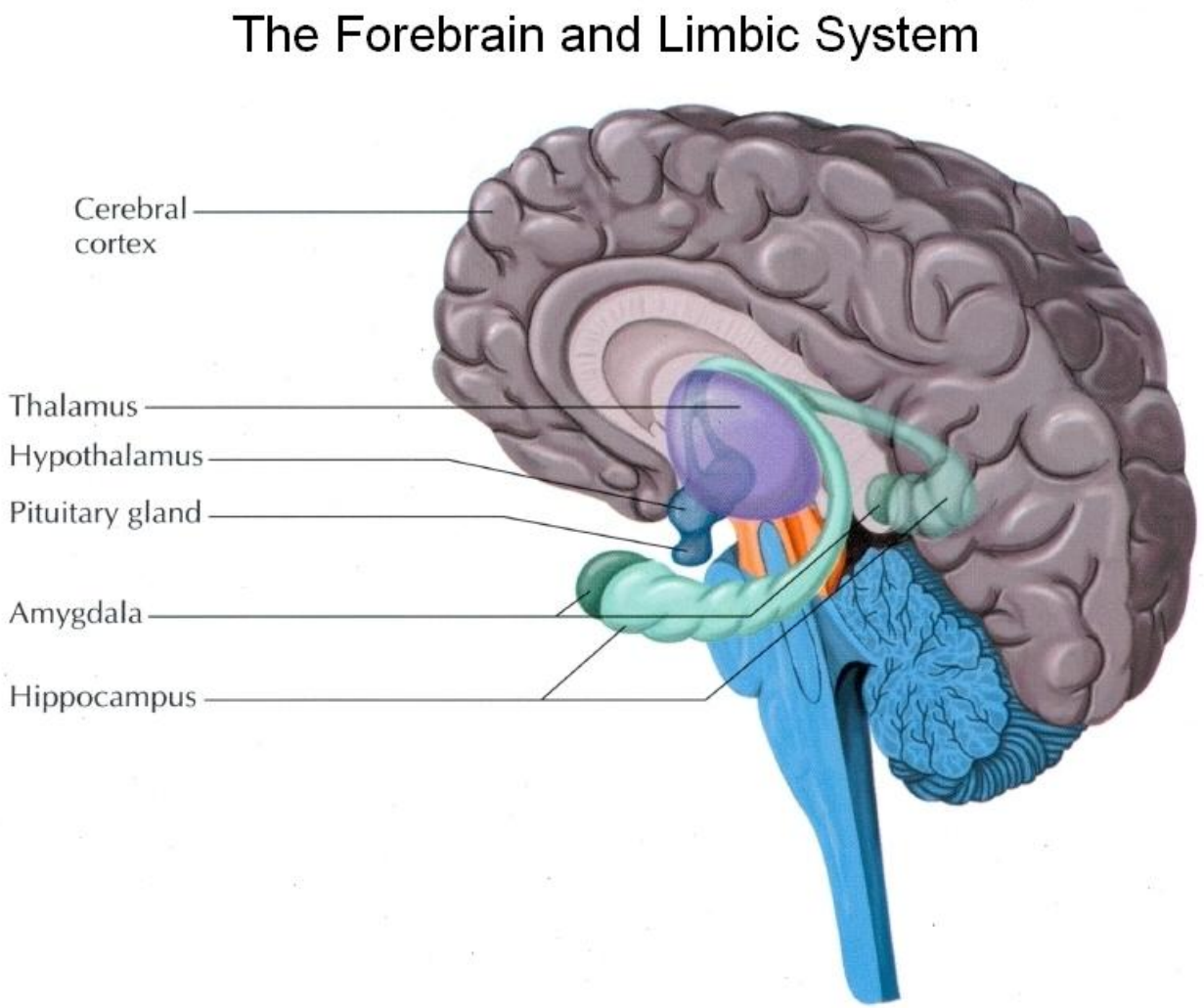
The *brain* controls all other behaviors. It is generally divided into specific sections related to level of function, with more basic functions found at lower levels. There are different ways of making these divisions and variations in what structures are assigned to particular divisions. For our purposes a simple way to divide the major areas of the brain would be as follows:

The *hind brain* is just above the spinal cord and controls very basic functions. Included are the brainstem (medulla oblongata, reticular formation, pons) and the cerebellum. The medulla governs basic bodily functions such as heart rate, blood pressure, and breathing. The reticular formation is responsible for general brain activation, attention, and alertness (plays a role in the sleep-wake cycle). The pons serves as a conduit for signals to and from the body (plays a role in the sleep-wake cycle). The cerebellum is responsible for general posture, balance, coordination, and gait. It also governs reflexive responding (including classically conditioned responses).

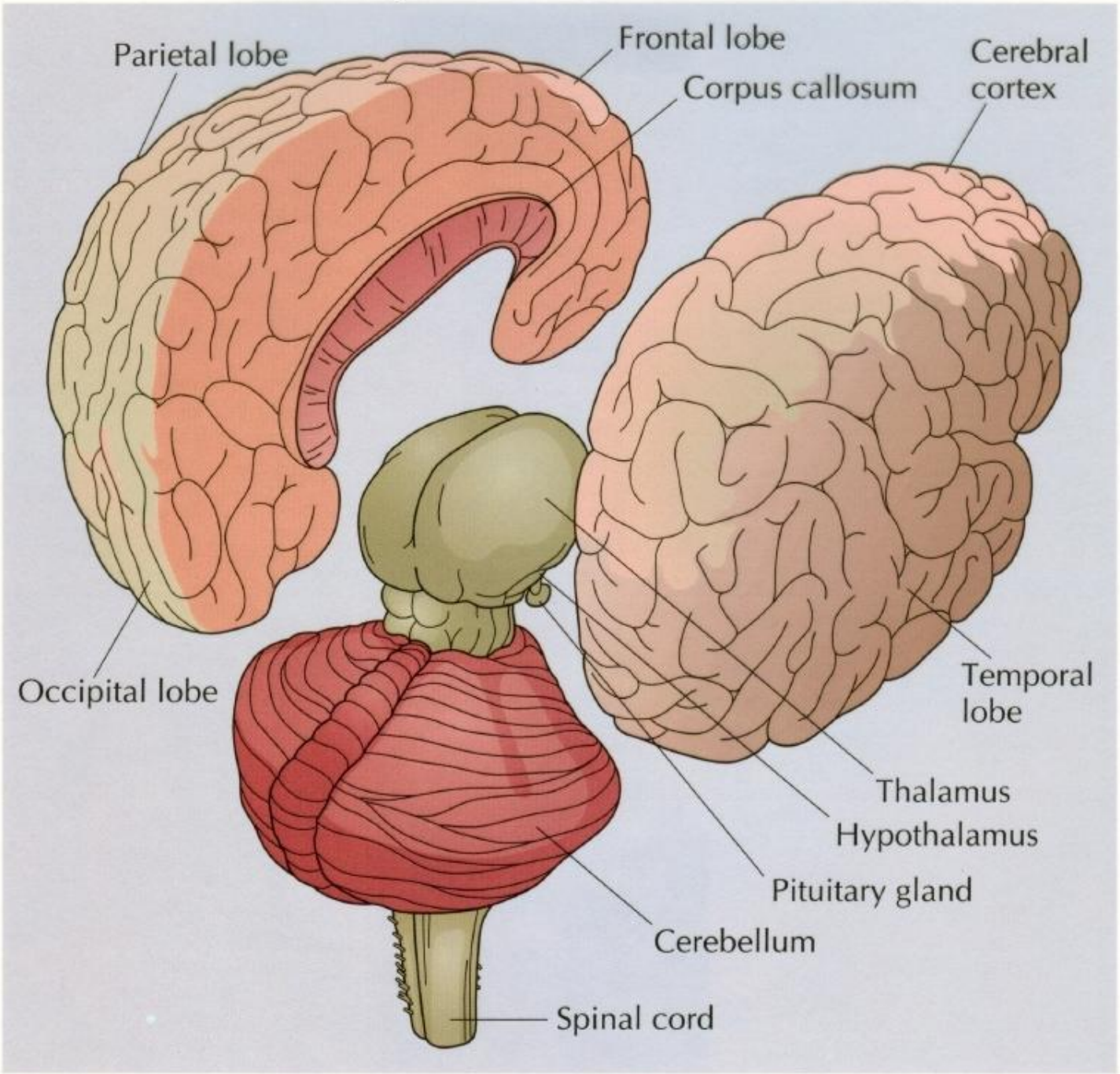
The *midbrain* is comprised of the colliculus and the substantia nigra. The colliculus channels sensory input. The substantia nigra initiates muscle movement.

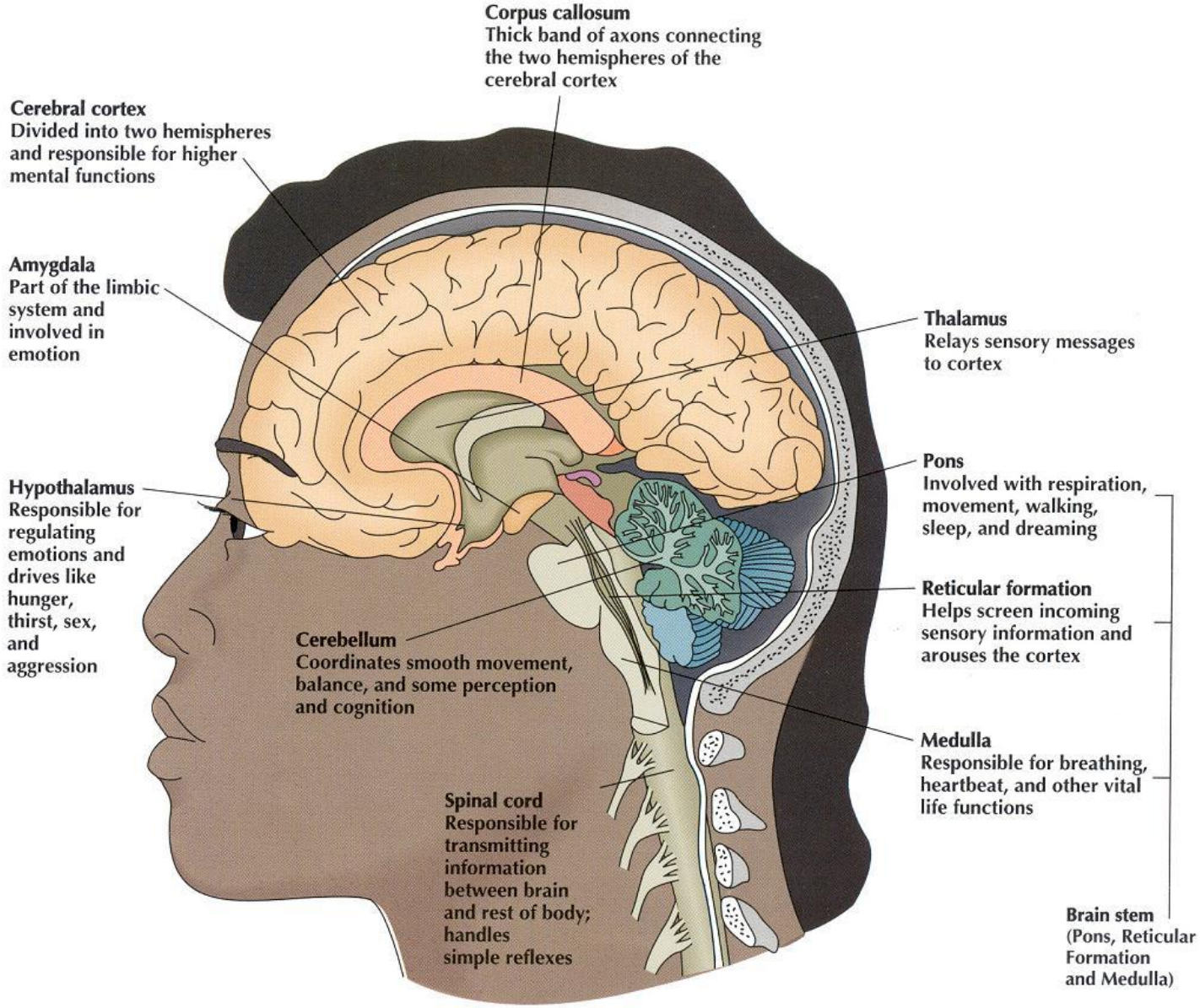


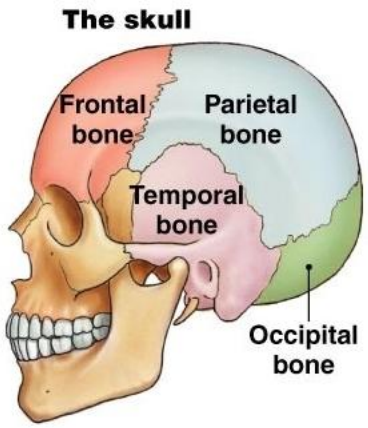
The *fore brain* is subdivided into the lower structures (thalamus, hypothalamus, limbic system) and the cerebrum. Some methods of dividing up the areas of the brain group these lower structures as part of the midbrain. However, they are well connected to, and influenced by, the cerebrum. The thalamus acts as a sensory weigh station and relay center, where initial processing and coordination of sensory input begins. The hypothalamus maintains bodily homeostasis, governs stress reactions, influences and regulates emotional responses, triggers motivation, and is where sensations of pleasure are registered. The *limbic system* itself consists primarily of the hippocampus and amygdala. However, the fornix, septum, and various connections to the corpus callosum, thalamus, olfactory bulbs, hypothalamus, and pituitary gland may all be considered part of the limbic system. The hippocampus has much to do with our immediate experience and the formation of memories. The amygdala, in concert with the hypothalamus, is involved with impulsive actions and emotions (especially those related to self-preservation). Parts of the hypothalamus and amygdala are larger in heterosexual men than in either women or homosexual men. This results in heterosexual men being more physically aggressive and competitive.

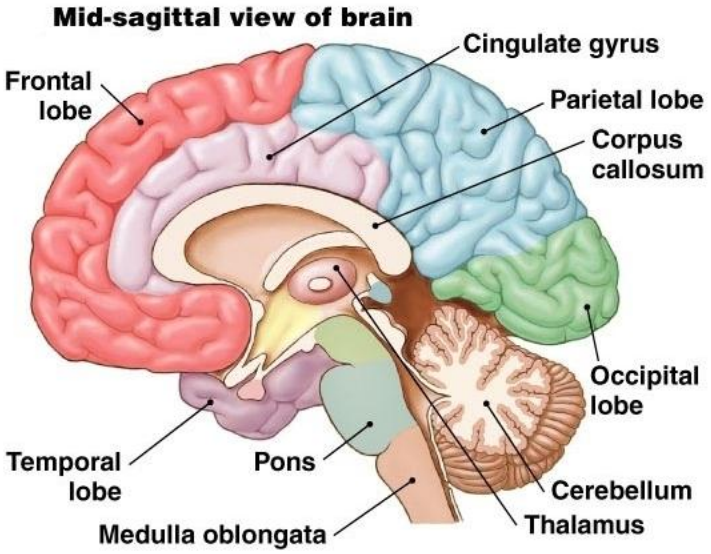


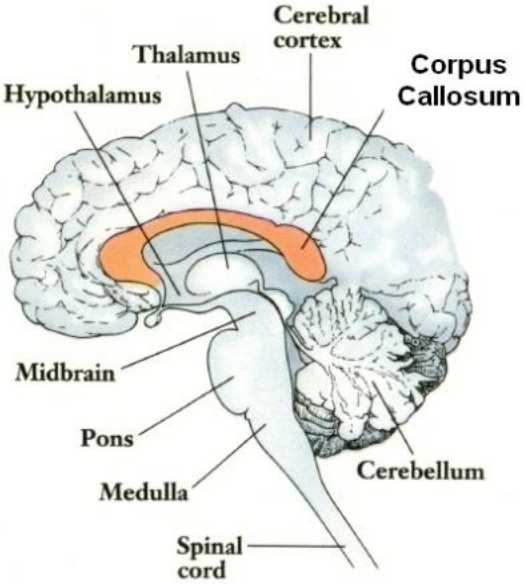
Major Brain Structures

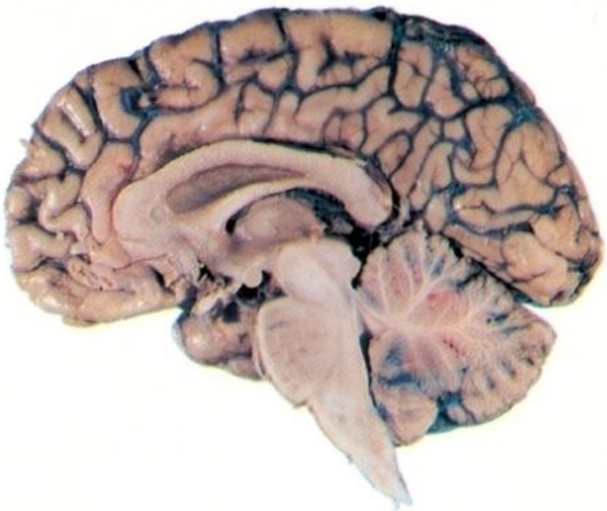



Corpus callosum
Thick band of axons connecting the two hemispheres of the cerebral cortex
Cerebral cortex
Divided into two hemispheres and responsible for higher mental functions
Amygdala
Part of the limbic system and involved in emotion
Thalamus
Relays sensory messages to cortex
Hypothalamus
Responsible for regulating emotions and drives like hunger, thirst, sex, and aggression
Pons
Involved with respiration, movement, walking, sleep, and dreaming
Reticular formation
Helps screen incoming sensory information and arouses the cortex
Cerebellum
Coordinates smooth movement, balance, and some perception and cognition
Medulla
Responsible for breathing, heartbeat, and other vital life functions
Spinal cord
Responsible for transmitting information between brain and rest of body; handles simple reflexes
Brain stem
(Pons, Reticular Formation and Medulla)

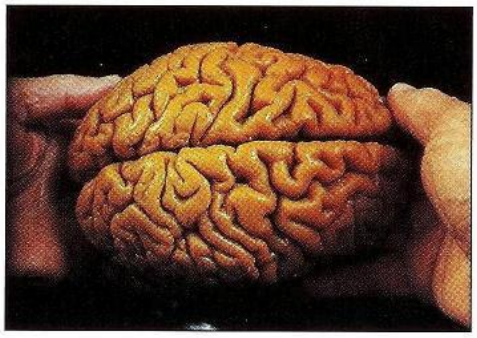

The skull
Frontal bone
Parietal bone
Temporal bone
Occipital bone


Mid-sagittal view of brain
Cingulate gyrus
Frontal lobe
Parietal lobe
Corpus callosum
Occipital lobe
Temporal lobe
Pons
Cerebellum
Thalamus
Medulla oblongata


Cerebral cortex
Thalamus
Corpus Callosum
Hypothalamus
Midbrain
Pons
Medulla
Cerebellum
Spinal cord



Central fissure
Frontal lobe
Parietal lobe
Occipital lobe
Limbic system
Corpus callosum
Pineal gland
LEFT HEMISPHERE
Lateral fissure
Temporal lobe
Thalamus
Hypothalamus
Olfactory bulb
Right eye
Pituitary gland
Pons
RIGHT HEMISPHERE
Cerebellum
Medulla
Spinal cord



The human brain, viewed from the top. Its relatively small size belies its enormous complexity.

hindbrain Area containing the medulla, pons, and cerebellum.

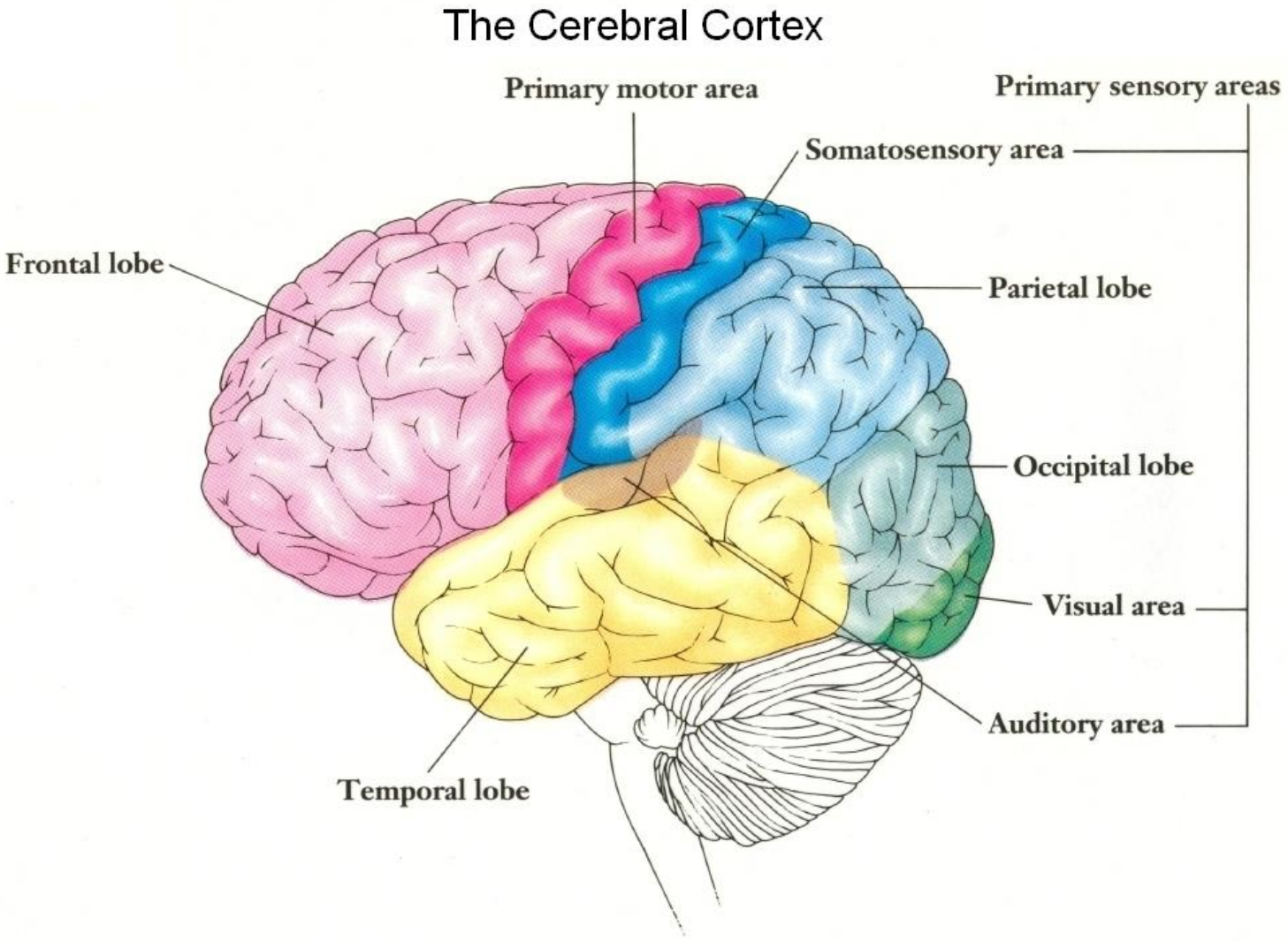
cerebellum Structure in the hindbrain that controls certain reflexes and coordinates the body's movements.

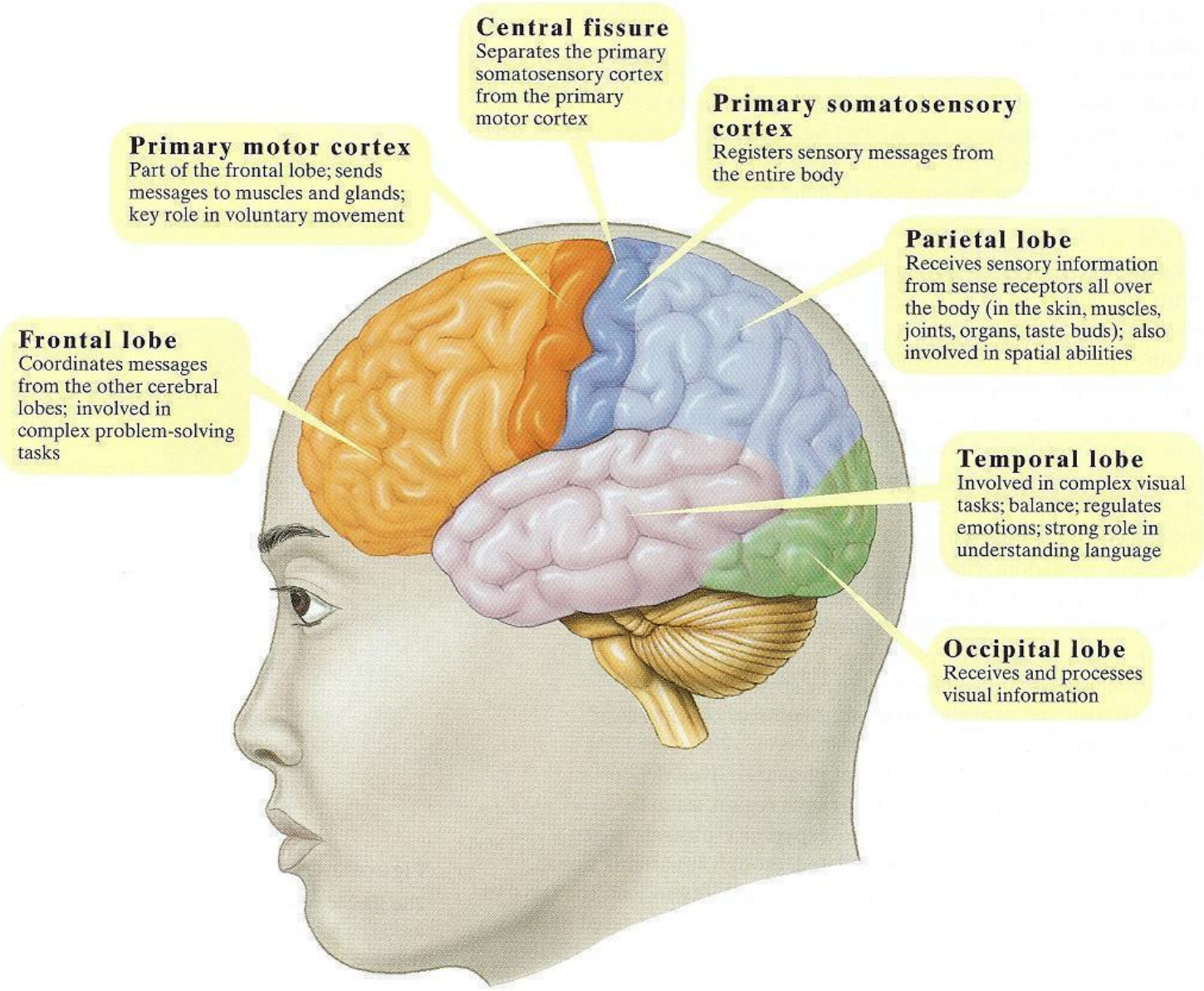
midbrain Region between the hindbrain and the forebrain; it is important for hearing and sight, and it is one of several places in the brain where pain is registered.

The *cerebrum*, the outermost and most massive part of the brain, comprises the rest of the forebrain. It is divided into two symmetrical hemispheres that are connected by the corpus callosum, which provides a communication link between them. Women have more nerve fibers in the corpus callosum than men, allowing for faster exchange of information and better communication between hemispheres. This may have a bearing on the greater intuitive capacity often demonstrated by women.

The surface of the cerebrum, the cortex, is convoluted and folded in on itself so as to maximize the surface area. The *cerebral cortex* is the primary site of higher mental functioning. This is where the majority of advanced information processing occurs. And compared to other creatures only a small proportion of the human cortex is devoted to direct sensory input and motor control. The remaining area is involved in higher level processing.

There are four lobes (frontal, temporal, parietal, occipital) to each cerebral hemisphere. The cortical lobes are critical to high-level processes, and carry out specific functions. The *occipital lobe* is responsible for visual processing. The *parietal lobe* is responsible for bodily sensory input, visual/spatial abilities, and associative functions. The *temporal lobe* is responsible for auditory processing, language (Wernicke's area), musical ability and comprehension, balance and equilibrium, spatial orientation skills (map reading), facial recognition, and smell. And the *frontal lobe* is responsible for goal-directed behavior, decision making, concentration, abstract thought, reason, emotional control, temperament, personality characteristics, voluntary movement, fine motor control, and speech production (Broca's area).





The four lobes of the cerebral cortex. Deep fissures in the cortex separate these areas or lobes. Also shown are the primary somatosensory and motor areas.

cerebral cortex The outer surface of the two cerebral hemispheres that regulates most complex behavior.

association areas Areas of the cerebral cortex where incoming messages from the separate senses are combined into meaningful impressions and outgoing messages from the motor areas are integrated.

frontal lobe Part of the cerebral cortex that is responsible for voluntary movement; it is also important for attention, goal-directed behavior, and appropriate emotional experiences.

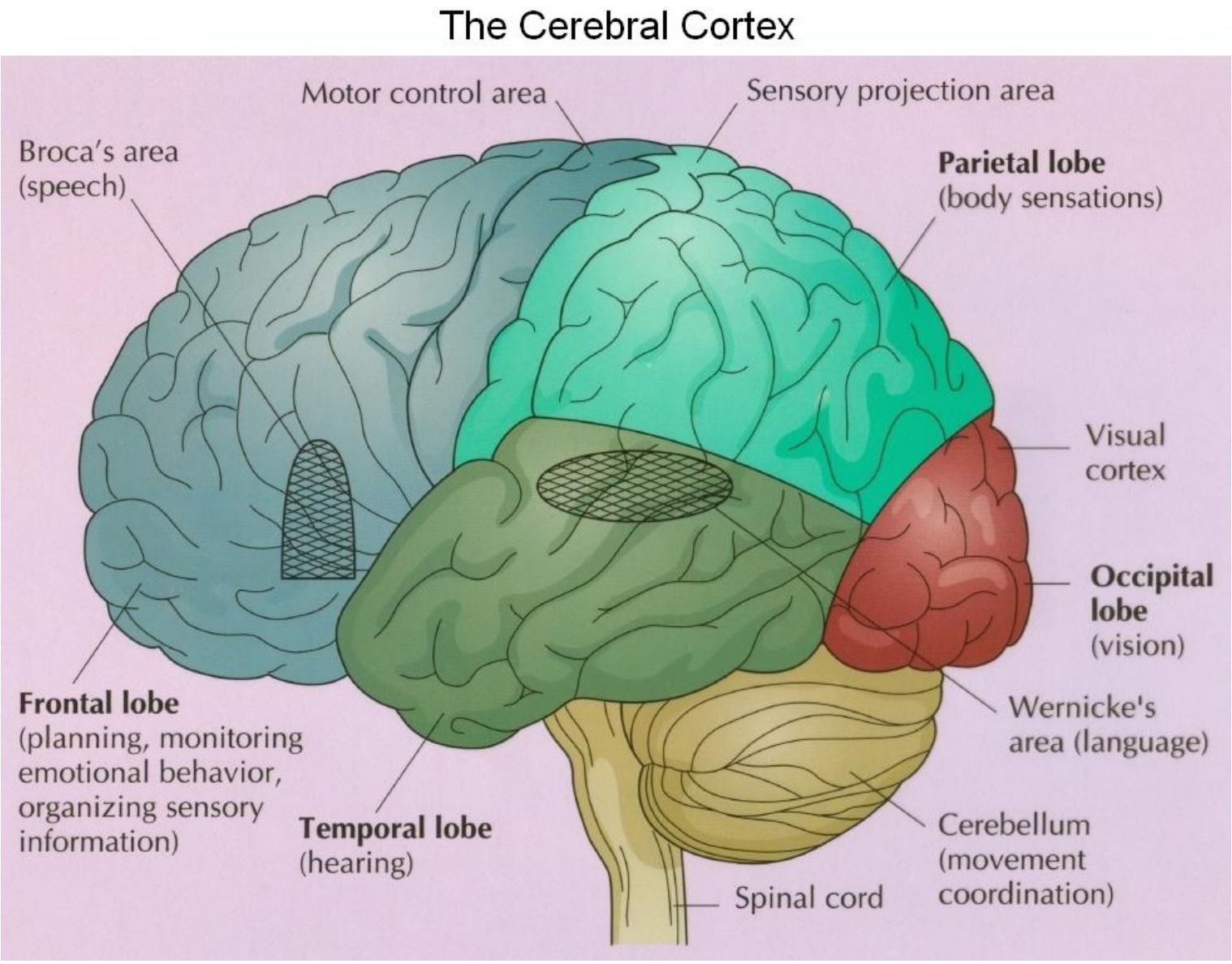
primary motor cortex The section of each frontal lobe responsible for voluntary movement.

primary somatosensory cortex Area of the parietal lobe where messages from the sense receptors are registered.

parietal lobe Part of the cerebral cortex that receives sensory information from throughout the body.

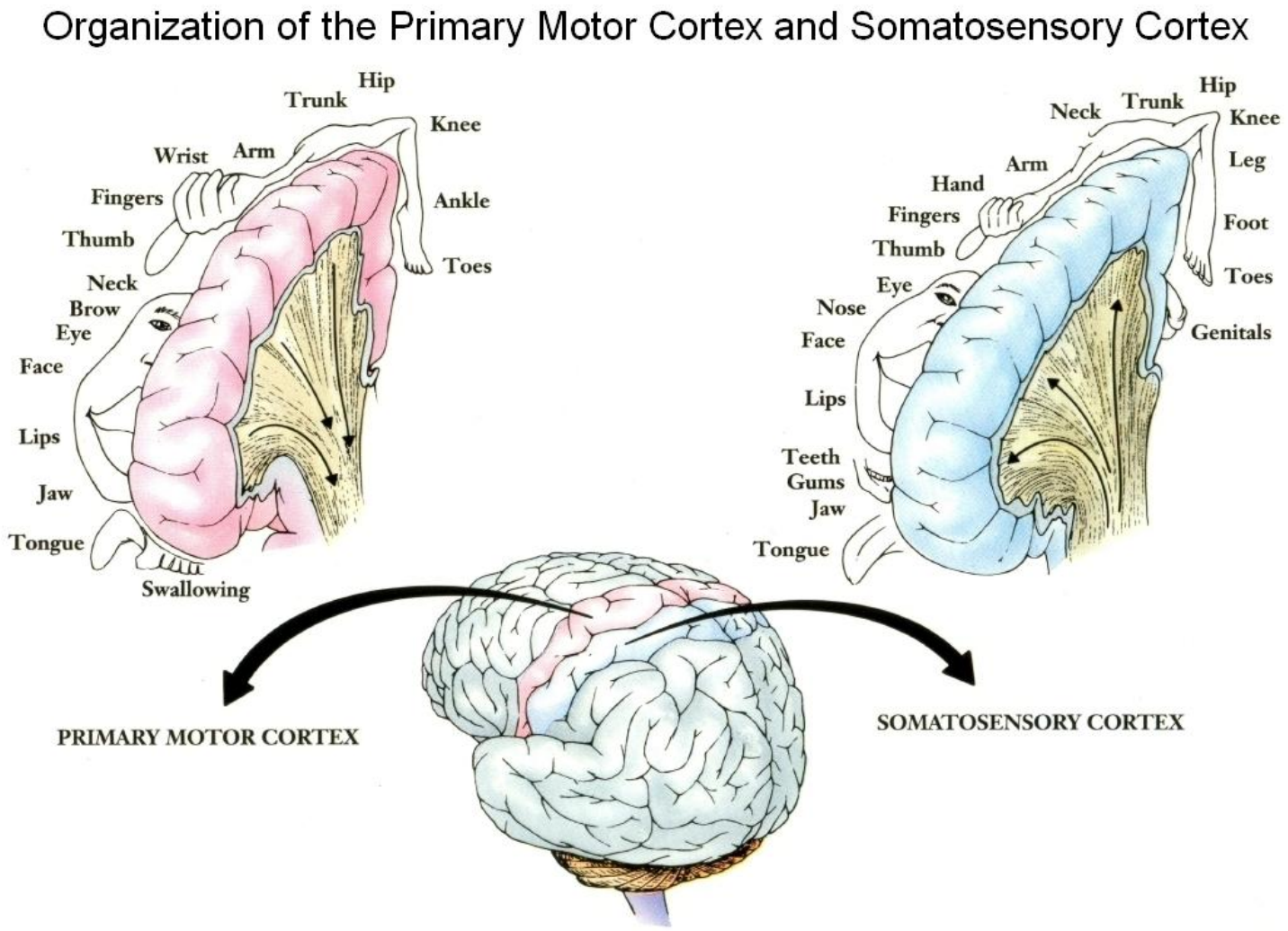
temporal lobe Part of the cerebral hemisphere that helps regulate hearing, balance and equilibrium, and certain emotions and motivations.

occipital lobe Part of the cerebral hemisphere that receives and interprets visual information.



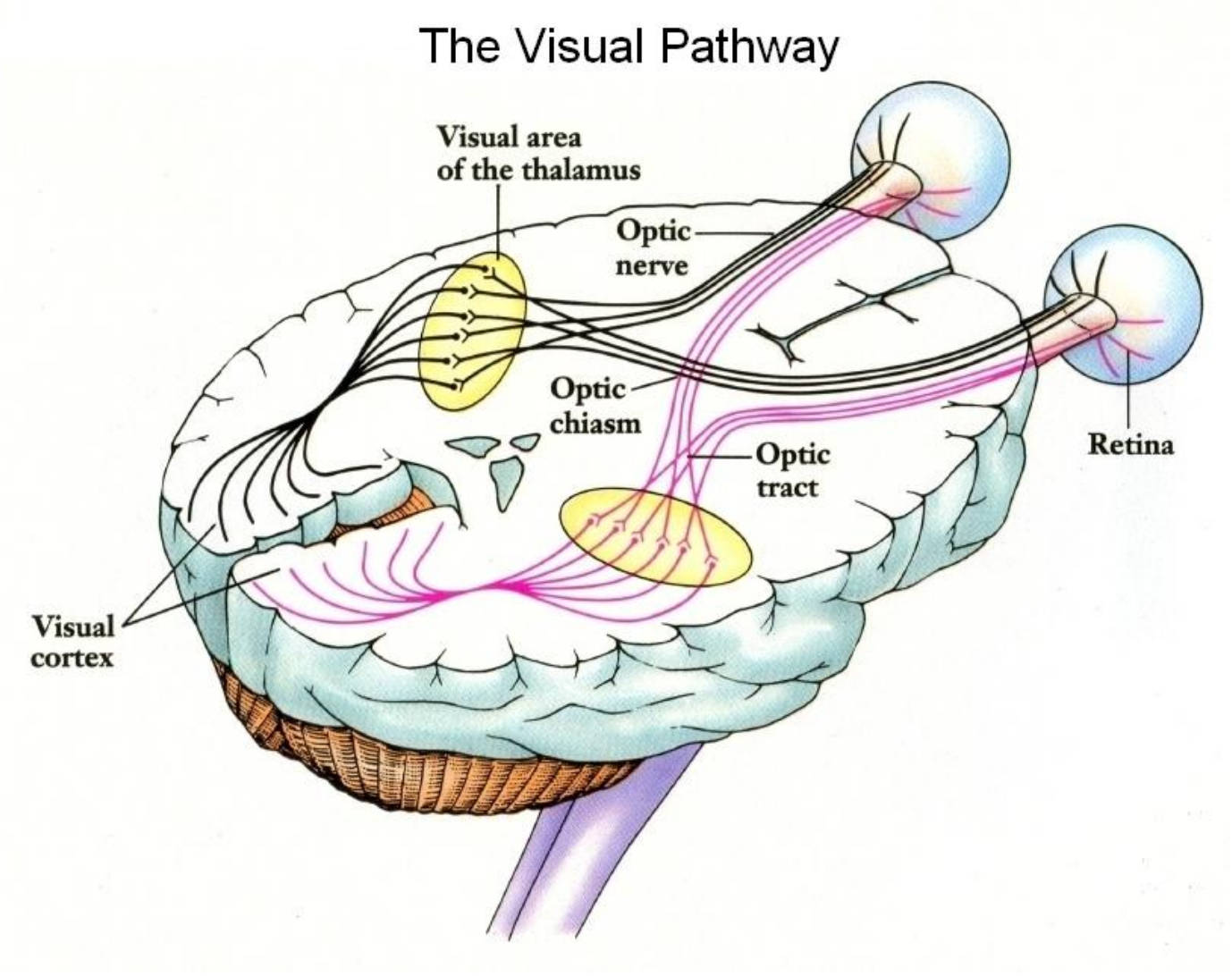
There is also *lateralization of function*, hemispheric differences in how the levels of the brain process information and what aspects of the information are attended to and processed. For most people the left hemisphere is responsible for analytical and reasoning abilities. It carries out linear functions such as logic (arguments and progressions), mathematical calculations, and language (reading, writing, and speech). Even the majority of left-handed people still have language control in the left hemisphere. The right hemisphere handles primarily non-verbal tasks such as the processing of things like music, art, and spatial analysis (the ability to mentally manipulate and comprehend spatial relationships). The right hemisphere does play some role in language comprehension, in the interpretation of facial expression, body language, and other subtle cues. As women are better able to exchange information between the cerebral hemispheres (thicker corpus callosum, more connecting fibers) they may be able to better utilize this information to interpret language, and perhaps detect lying.

Sensory input and motor control are also lateralized. Bodily sensations from one side of the body go to the contralateral (opposite side) hemisphere of the brain, the somatosensory cortex of the parietal lobe. So the left hemisphere of the brain processes sensations from the right side of the body. Motor control works the same way. The left motor cortex of the frontal lobe controls the right side of the body. This crossing over of somatosensory and motor control information occurs in the medulla oblongata. The body is also mapped out on the somatosensory and motor cortices. However, the size of a particular part of the body has little bearing on the size of the corresponding areas on the cortex. The layout and size of the cortical areas assigned represent the need for greater sensitivity and control over certain parts of the body, as well as the need to coordinate activities. And there is also another area of the cortex that acts as a center for directing motor functions. The location of this center differs between men and women. For women it is closer to the frontal cortical areas (closer to the motor cortex), giving them generally superior fine motor control. For men it is closer to the rear cortical areas (closer to the visual cortex), giving them generally superior targeting ability. Beyond all of this is handedness. Most creatures have a dominate side of the body, this is particularly manifested in humans by which hand is preferred for tasks such as throwing and writing (the majority are right handed).

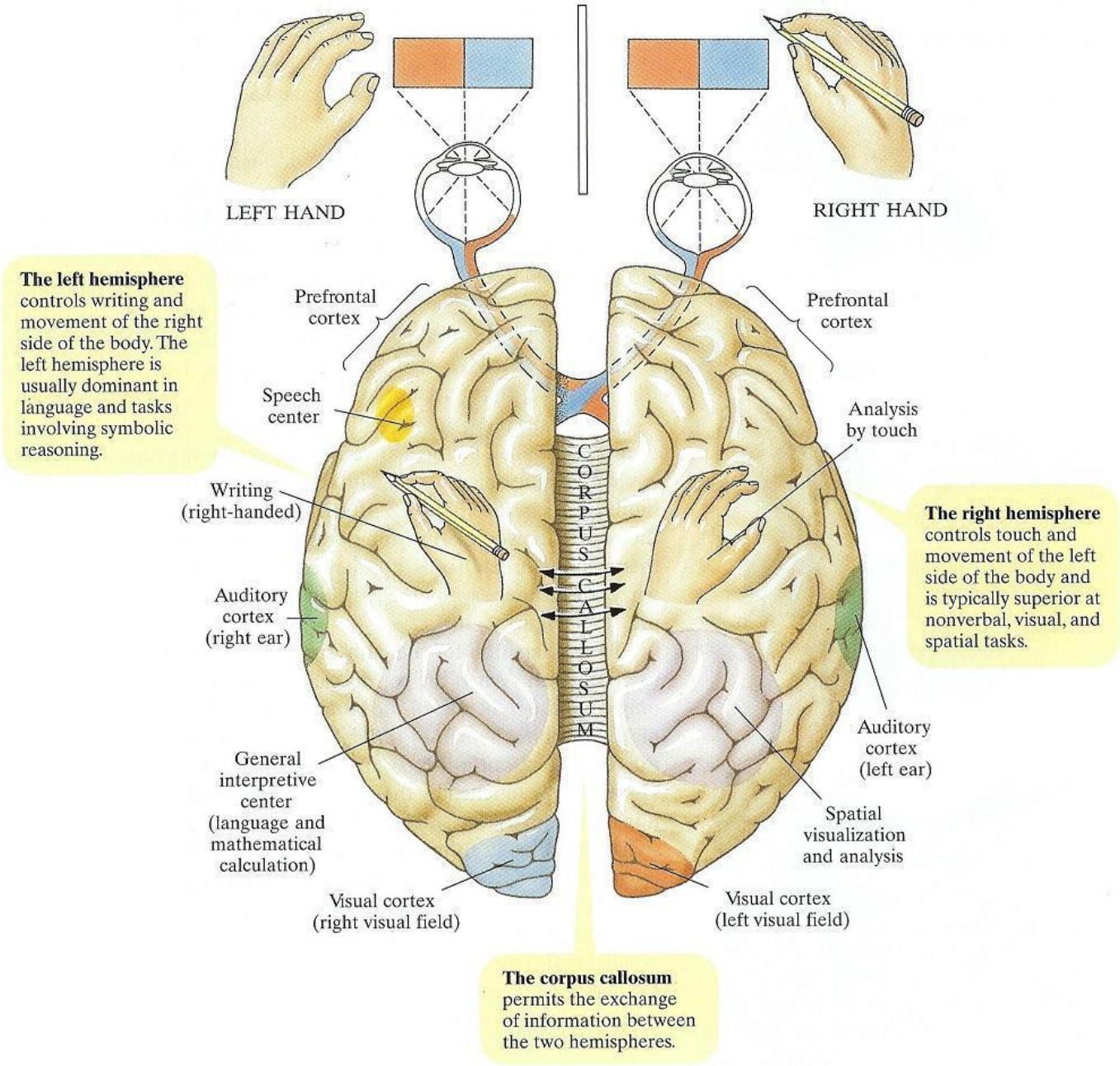


Most of the auditory information we receive from each ear goes to the contralateral temporal cortex. So sound coming from the right side is registered in the left hemisphere. This makes sense, in that sounds coming from one side of the body are then processed by the same hemisphere that controls that side of the body so we can efficiently orientate toward the source.

Visual information is handled in a special way in humans and other creatures that have eyes closely spaced on the front of the head. The visual field viewed by each eye is split in two parts, right and left. Half of that information is sent to the contralateral visual cortex of the occipital lobe, the other half to the ipsilateral (same side) visual cortex. This crossing over of half the information occurs at the optic chiasm. So all of the information from the right side of the visual field is sent to the left visual cortex, while that from the left side of the visual field goes to the right visual cortex.



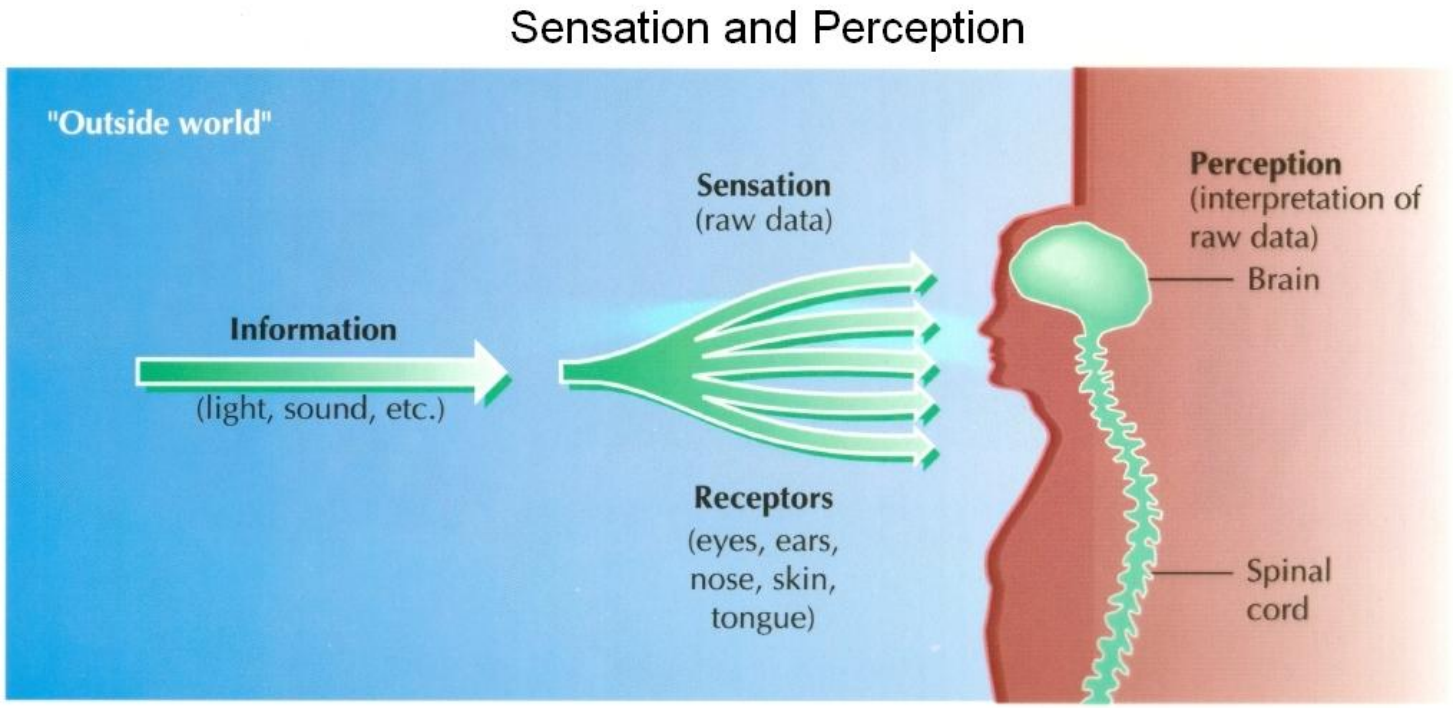
The end result of all this is that everything you need to know about what's going on relative to one side of your body (touch, voluntary movement, sound, visual information) all goes to the same hemisphere of the brain, the one contralateral to that particular side of the body. This helps to properly localize these stimuli, attend to them, and respond to them. Taste (right and left side of the tongue) and smell (left and right nostril), by the way, both go to the ipsilateral brain hemisphere as these aren't generally localized to the right or left anyway.



corpus callosum A thick band of nerve fibers connecting the left and right cerebral cortex.

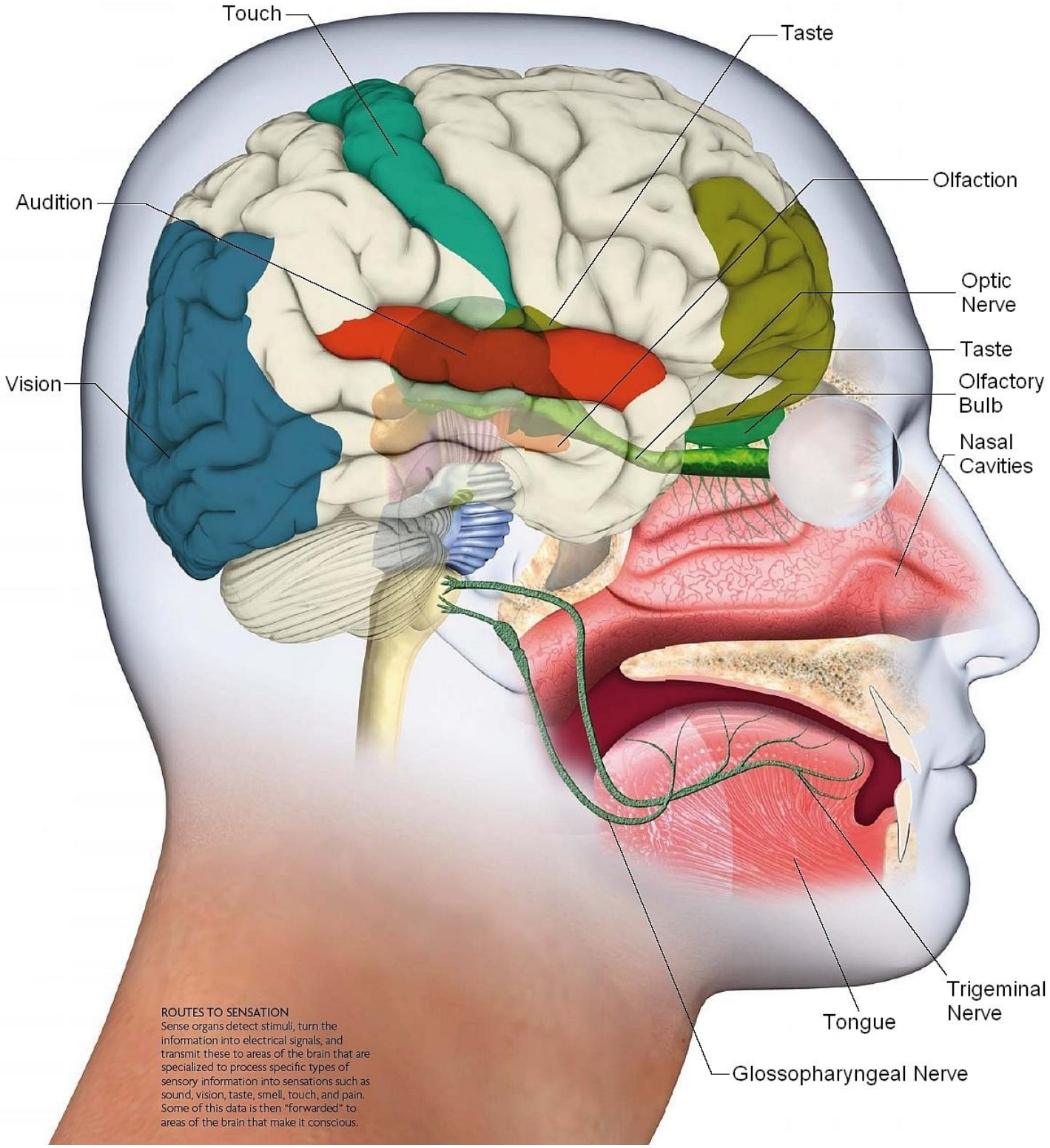
Sensation and Perception

Sensation: Sensation is the process whereby a physical stimulus produces physiological reactions that eventually lead to a subjective, psychological experience. Sensation is the raw, unanalyzed experience, before perceptual processes that interpret the experience are evoked. All of our sensory systems require *receptors*. These are unique neural structures that react to particular forms of physical stimulation. As the entire nervous system is derived from the skin during the course of fetal development, the receptor mechanisms often employ modified hair cells. *Transduction* is the general term for the various methods employed to transform physiological reactions to external physical stimuli into neuronal impulses. All forms of transduction involve responding to a physical stimulus with bioelectrical changes that can trigger neural impulses. Sensory neurons carry sensory information from these receptors to the central nervous system. Once there other cells process the sensory information in particular ways. The processes common to all of our senses include transduction, coding (preserving information about the stimulus in patterns of neural activity), and adaptation (altering sensitivity to a stimulus with continued stimulation or lack of stimulation).



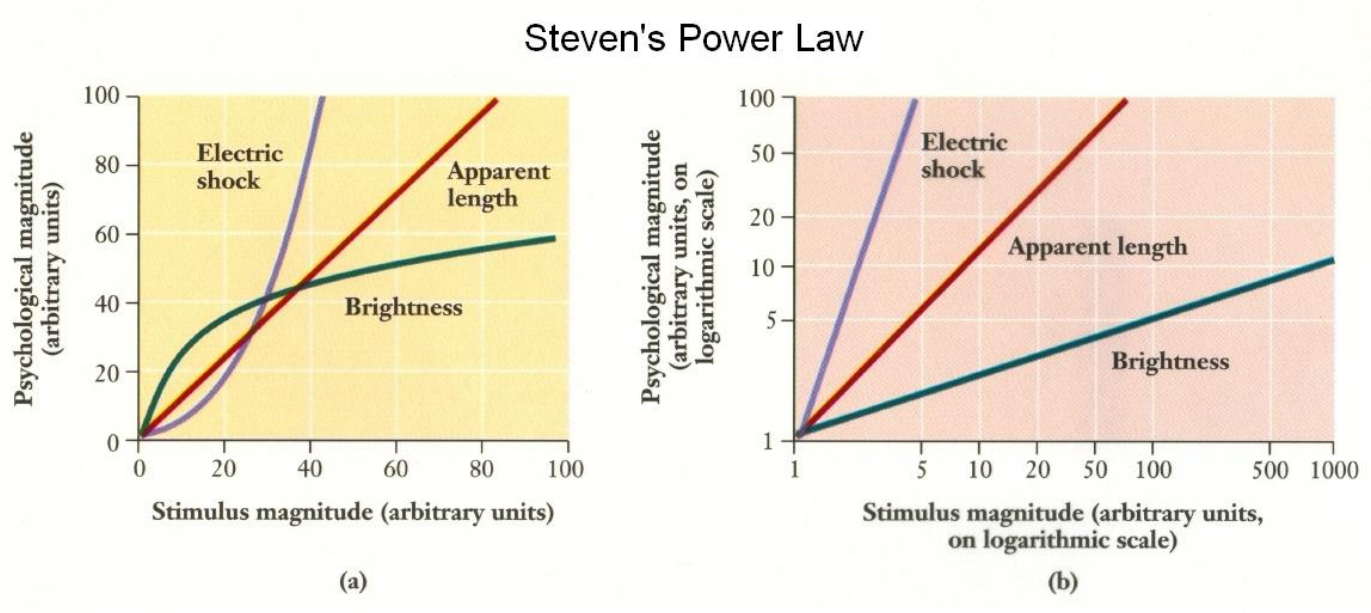
There are a number of different sensations that we commonly experience, at least a dozen distinct modes. These include sights, sounds, smells, tastes, chemically produced sensations of hot and cool (spices and menthol), tactile sensations, kinesthetic position and movement, a number of internal sensations (including hunger, thirst, and gastric distress), and a sense of the passage of time. They provide information about the external world and our own bodies. This information allows us to deal effectively with the world.

Sensory information must reach the more advanced cortical areas of the brain for perception to occur. Although we may react at a rudimentary level as sensory information is passed along from receptors to neurons to lower brain centers (such as the thalamus) true perception does not occur until we are consciously aware of the incoming sensory information. Perception involves not only that conscious awareness, but also interpreting the sensory information in order to determine what it represents and ascertaining its relevance.

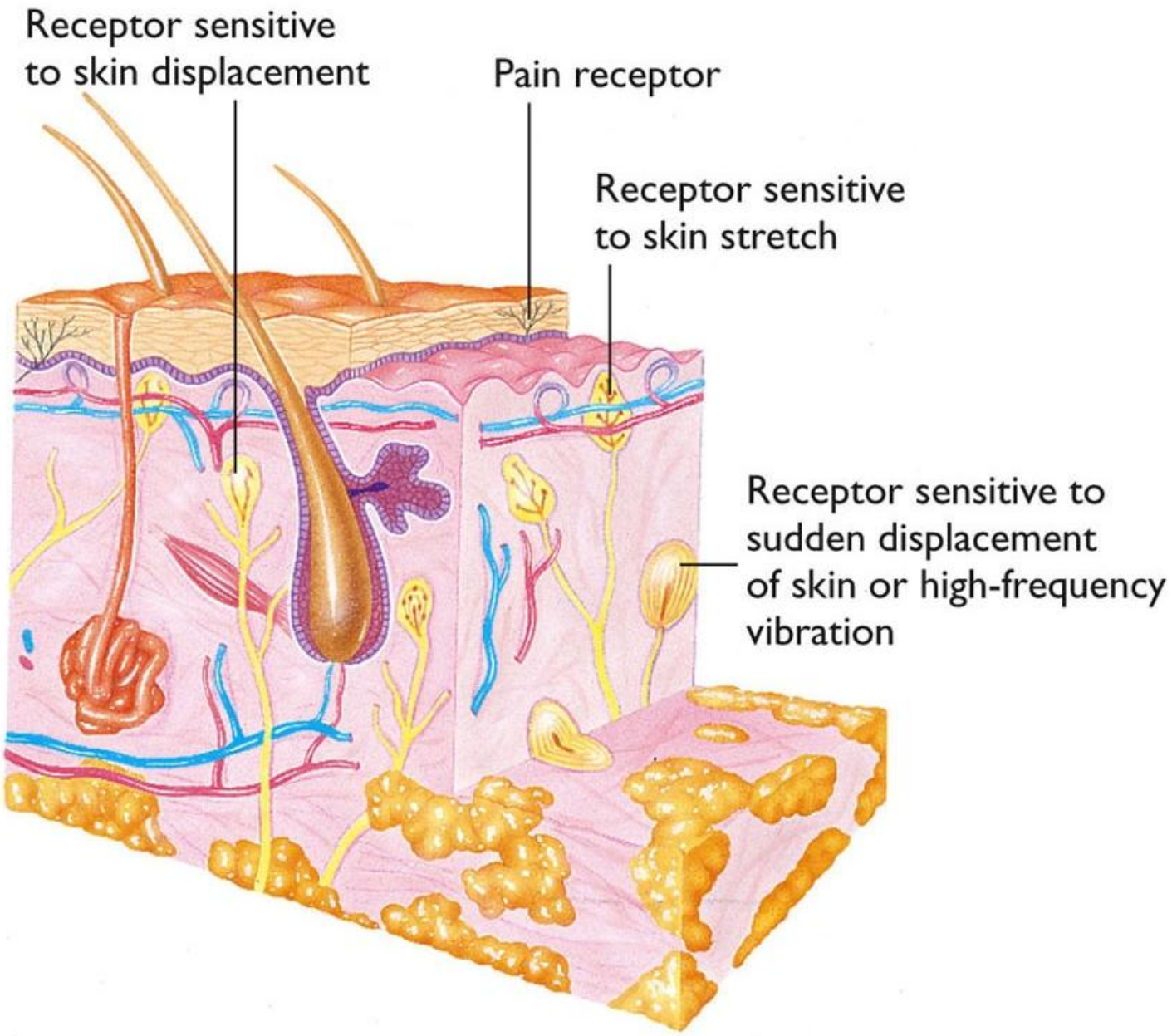


ROUTES TO SENSATION
Sense organs detect stimuli, turn the information into electrical signals, and transmit these to areas of the brain that are specialized to process specific types of sensory information into sensations such as sound, vision, taste, smell, touch, and pain. Some of this data is then "forwarded" to areas of the brain that make it conscious.

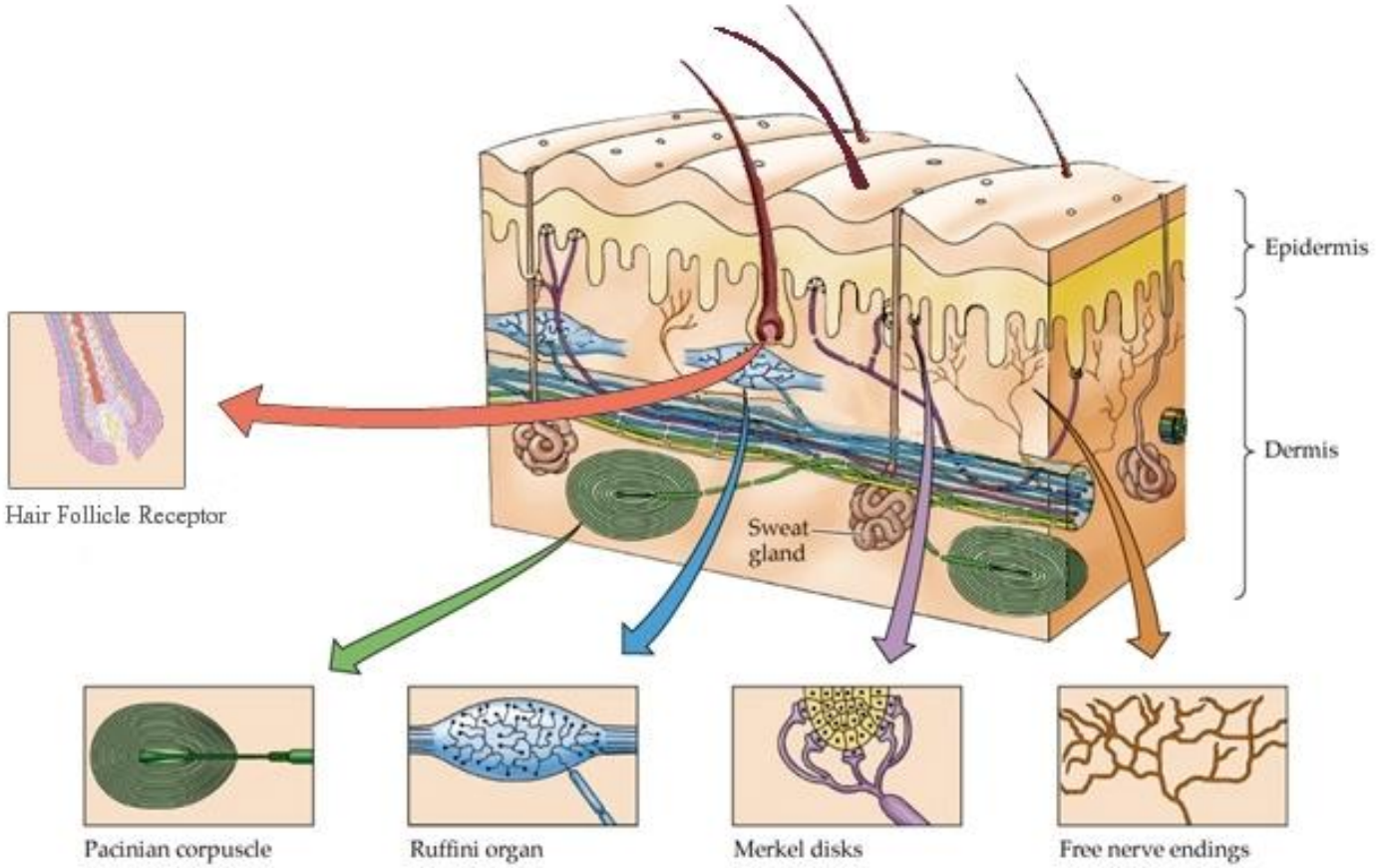
Psychophysics: Attempts to relate characteristics of the stimulus to aspects of the resulting subjective experience. One question is: How weak can a stimulus be and still be detected? This question concerns the so-called absolute threshold. A second question is: How different do two stimuli have to be before we notice the difference? This is known as the just noticeable difference (jnd). A third question is: How is the strength of the stimulus related to the strength of the sensation? For example, how does loudness change as we vary the physical intensity of a sound? In most cases a power function is involved, so the strength of physical stimulus must be more than doubled to provide the sensation of being twice as intense.



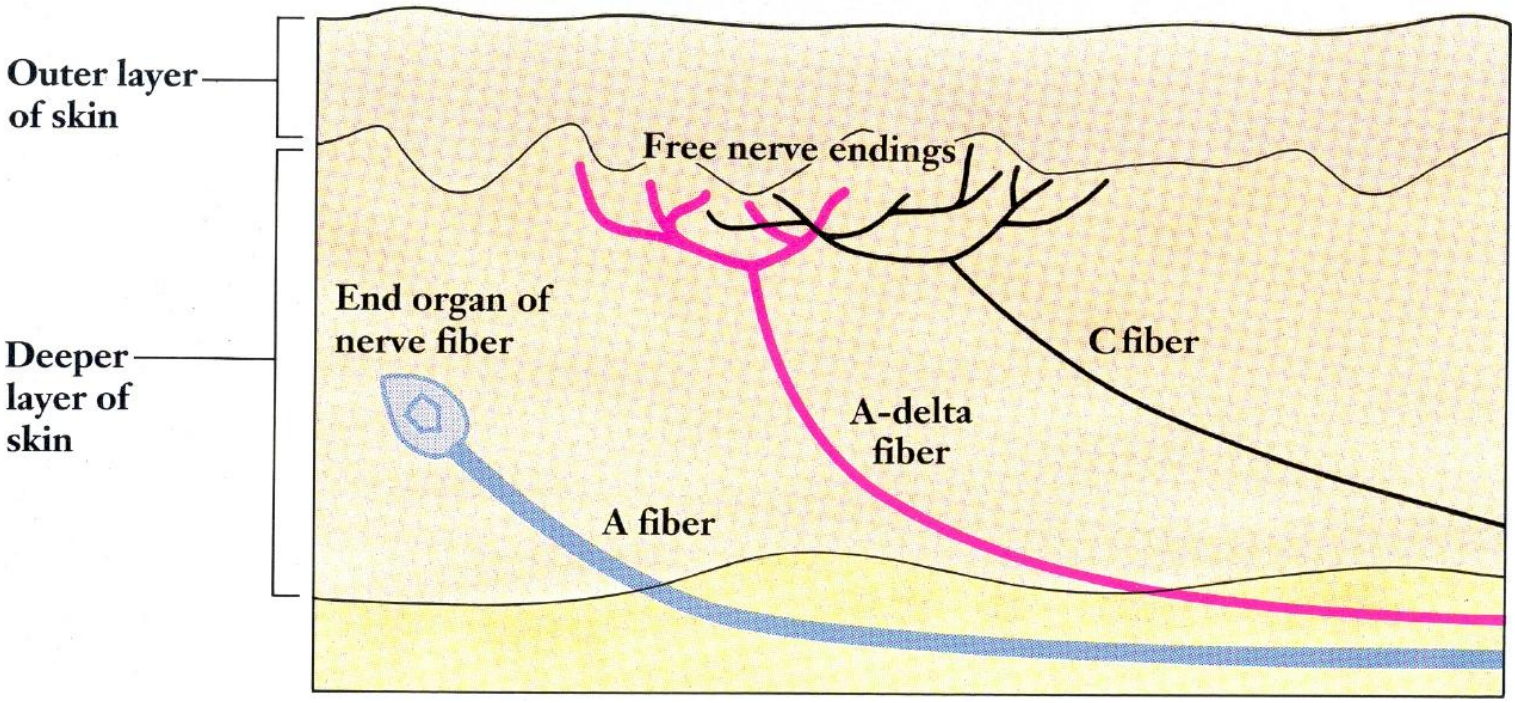
Tactile Sensations: These come from a variety of receptors located in the skin and bones, and muscles. Often the receptors are little more than *raw sensory neurons* (nerve endings). Temperature is conveyed by special receptors for warm and cold in the skin. The sensation of hot is the result of intense stimulation that activates both the warm and cold receptors simultaneously. Light pressure is detected at the surface of the skin, by free nerve endings and the bending of hair cells. Deep pressure is detected by receptors deeper in the skin and muscles. Pain, though sometimes undesirable, has great survival value by often preventing serious tissue damage. There are two subsystems of pain, a slow one mediated by neurons called *C fibers* and a fast one mediated by faster neurons called *A-delta fibers*. Each subsystem has its own neural pathways and results in its own type of subjective experience. The gate-control theory helps to explain pain and its inhibition. Pain relief may come from a number of natural sources, including endorphins, acute stress, and even our beliefs.



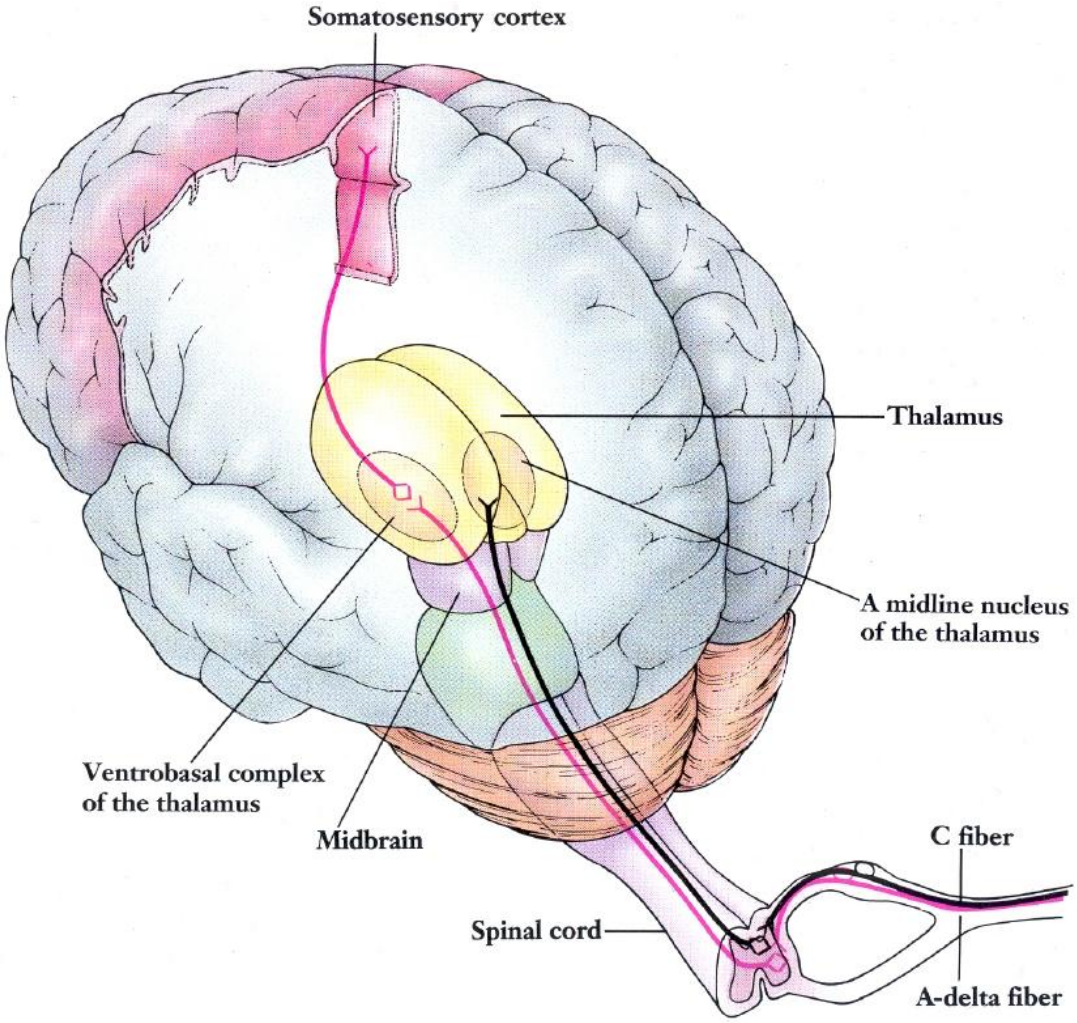
Mechanoreceptors of the Skin



Pain Receptors in the Skin

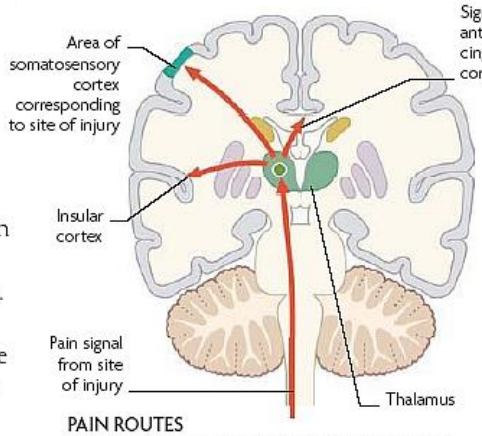


Pain pathways

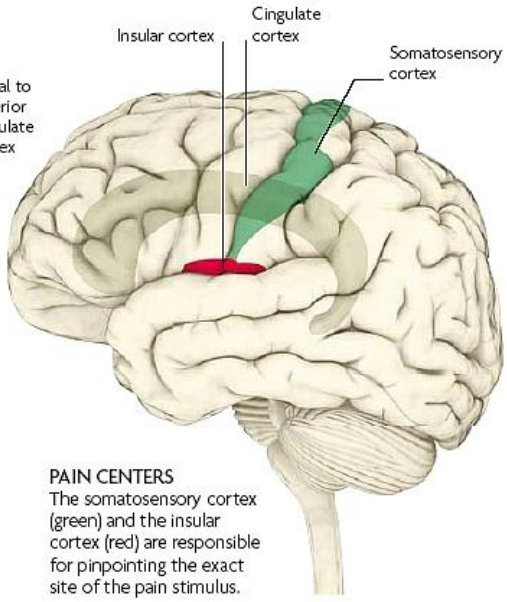


PATHWAY OF PAIN

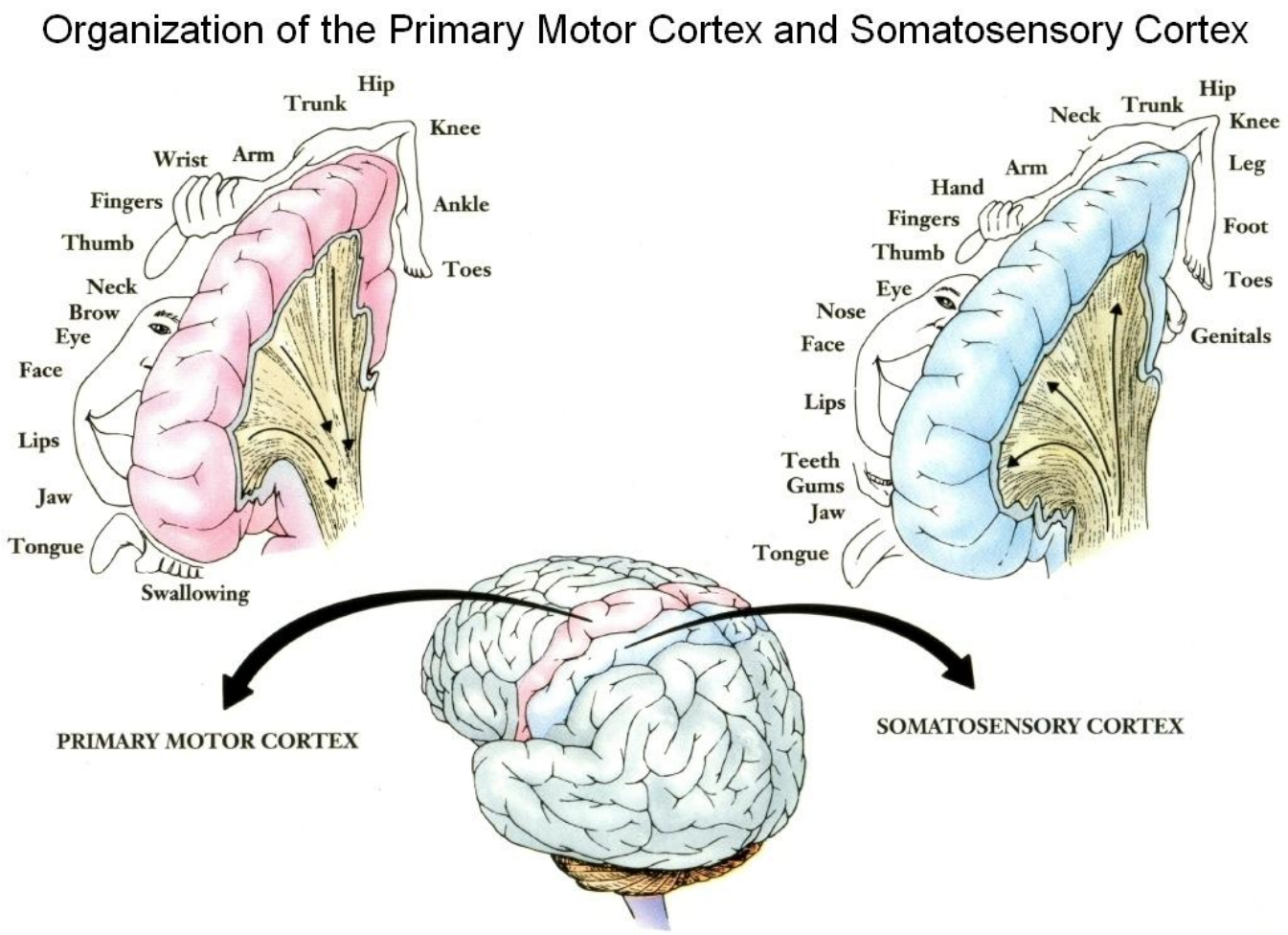
Pain signals are transmitted to several areas of the cortex, where they activate neurons that monitor the state of the body. Two such areas are the somatosensory cortex, which lets the brain know which part of the body the pain stems from, and the insular cortex–the deep fold that divides the temporal and frontal lobes. The other cortical site associated with pain experience is the anterior (front) of the cingulate cortex (ACC), which lies in the groove between the hemispheres. The ACC seems to be particularly concerned with the emotional significance of pain and with determining how much attention an injury should command.



PAIN ROUTES
Pain signals from the body ascend to the brain via the spinal cord, then rise through the brainstem to the thalamus. Thereafter, they are distributed to various cortical areas for processing.



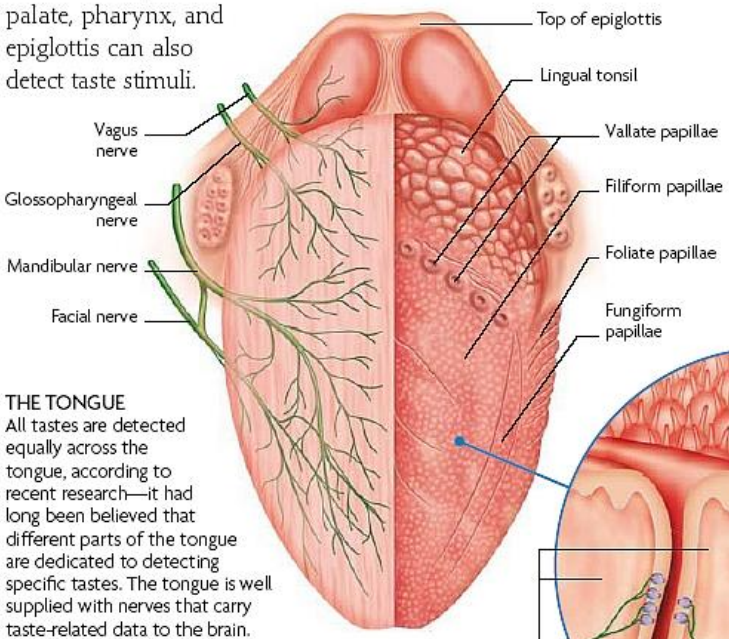
PAIN CENTERS
The somatosensory cortex (green) and the insular cortex (red) are responsible for pinpointing the exact site of the pain stimulus.



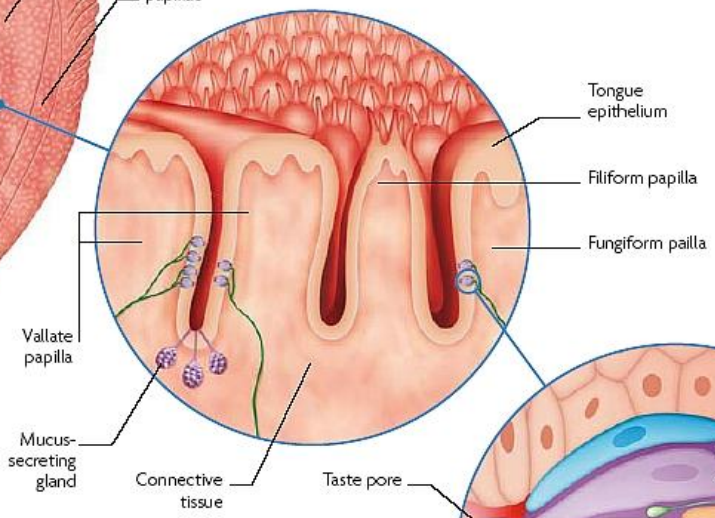
Taste and Smell: These are the chemical senses. Both require molecules of a particular substance to be dissolved in either saliva or mucous, and then bind to the receptor cells. Five basic tastes have been confirmed. Those are sweet (sugars), sour (acidic), salty (salts), bitter (alkaloid), and umami (savory, detection of high protein concentrations). Flavor enhancers such as MSG also activate umami receptors. There may also be receptors for both fat and calcium. The receptors are housed in structures called *taste buds*, located on different parts of the tongue and palate. Traditionally it has been taught that there are specific areas of the tongue sensitive to specific tastes. However, each of the receptor types is actually distributed over most of the tongue and palate. There may be higher concentrations of particular receptors at certain locations, but overall any part of the tongue can detect any of the five basic tastes. In addition, there is sensitivity to the chemical sensations of hot and cool (spices and menthol). These aren't tastes in the same sense. They're the result of a form of irritation to the membranes of the mouth and throat. For olfaction, or smell, there are thought to be at least 200, and perhaps as many as 1,000 different receptors. Specific receptors are activated by molecules having particular three-dimensional shapes. Alone or in combination these receptors allow us to distinguish some 20,000 different odors. The combined sensations of taste, smell, and hot or cool give us the overall experience of flavor. When we exhale while eating molecules of the food enter the nasal epithelium activating olfactory receptors there in conjunction with the basic taste receptors on the tongue.

THE TONGUE

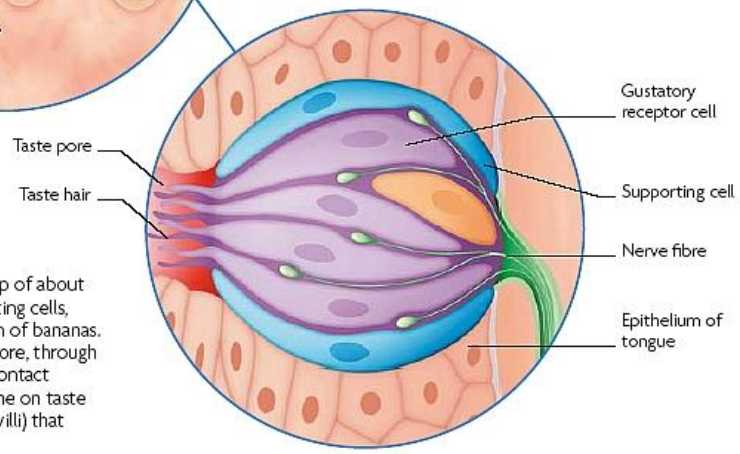
The tongue is the main sensory organ for taste detection. It is the body's most flexible muscular organ, as revealed by its work in both nutrition and communication. It has three interior muscles and three pairs of muscles connecting it to the mouth and throat. Its surface is dotted with tiny, pimplelike structures called papillae. Other parts of the mouth, such as the palate, pharynx, and epiglottis can also detect taste stimuli.



THE TONGUE
All tastes are detected equally across the tongue, according to recent research—it had long been believed that different parts of the tongue are dedicated to detecting specific tastes. The tongue is well supplied with nerves that carry taste-related data to the brain.



PAPILLAE
Papillae contain taste buds and are distributed across the tongue. Four types of papillae have been distinguished—vallate, filiform, foliate, and fungiform. Each type bears a different amount of taste buds. Fungiform and filiform are the smallest papillae, and vallate are the largest, and together form a V-shape across the rear of the tongue.

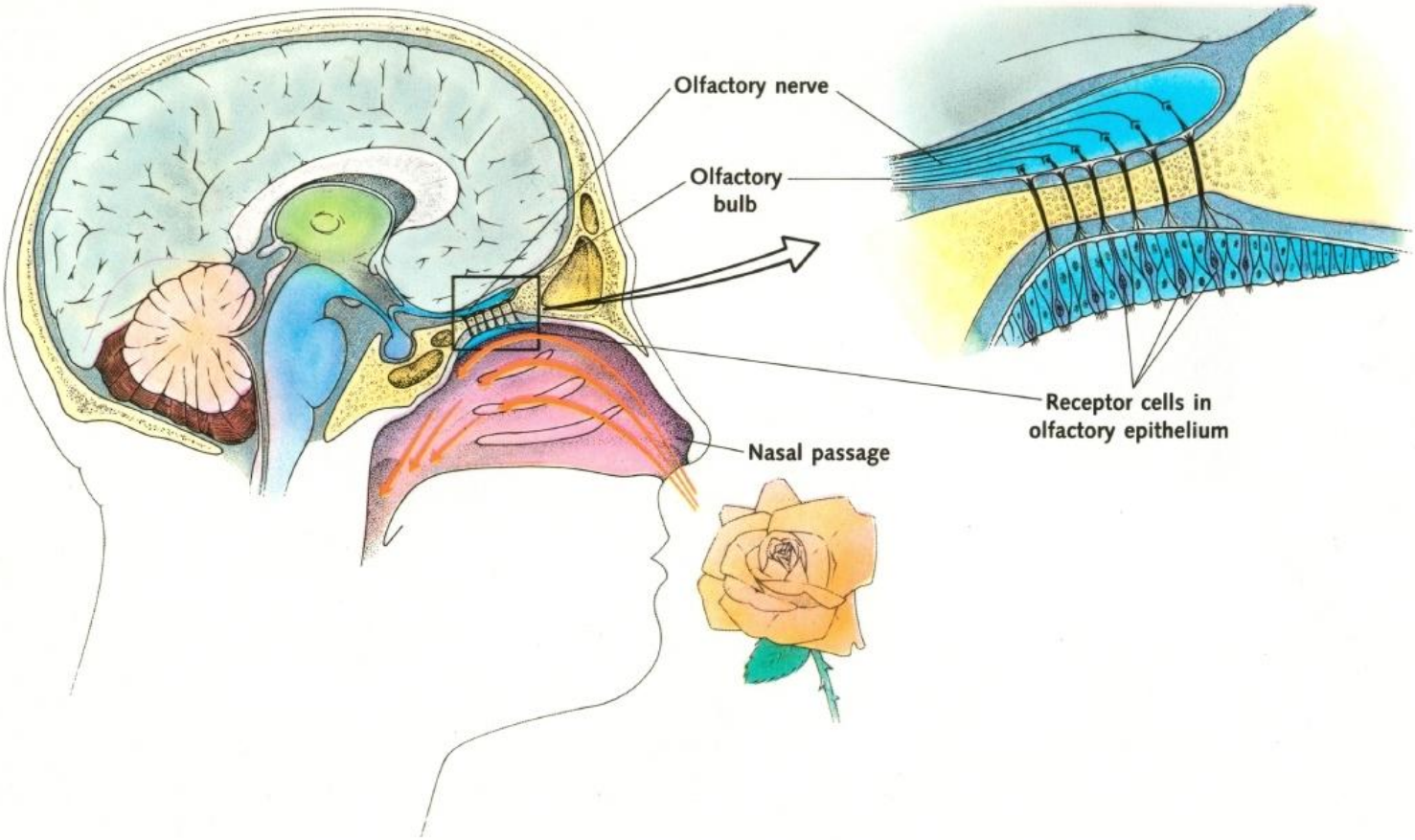


TASTE BUDS
A taste bud is composed of a group of about 25 receptor cells alongside supporting cells, layered together much like a bunch of bananas. The tips of the cells form a small pore, through which taste molecules enter and contact receptor molecules. These are borne on taste hairs (tiny projections called microvilli) that extend into the pore.

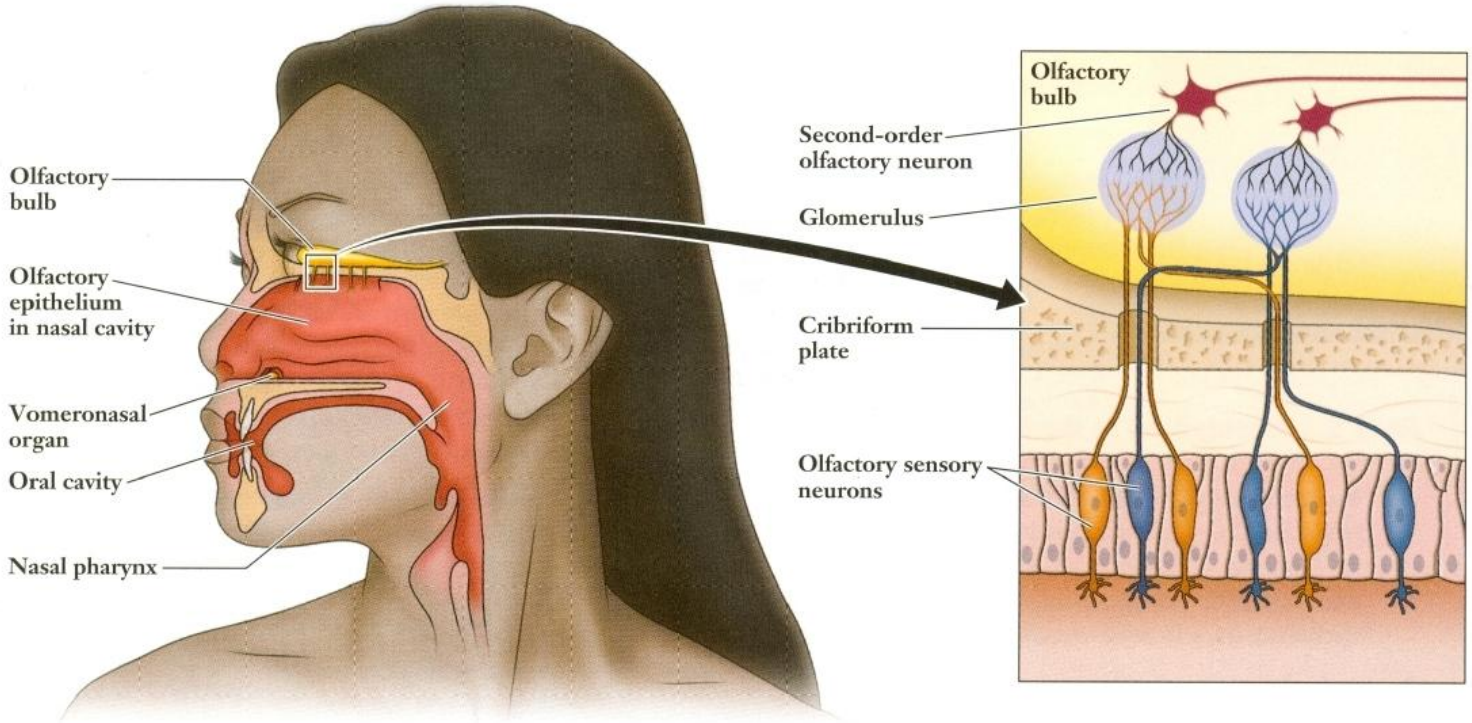
THE FIVE BASIC FLAVORS

NAME	DESCRIPTION
Sweet	Often linked to energy-rich, high-calorie foods.
Sour	May be a danger sign, signaling unripe or "off" foods.
Salty	Most chemical salts, including sodium chloride, taste salty.
Bitter	May be linked to natural toxins, and is best avoided.
Unami	Savory ("unami" means "delicious" in Japanese).

Olfaction: The Sense of Smell

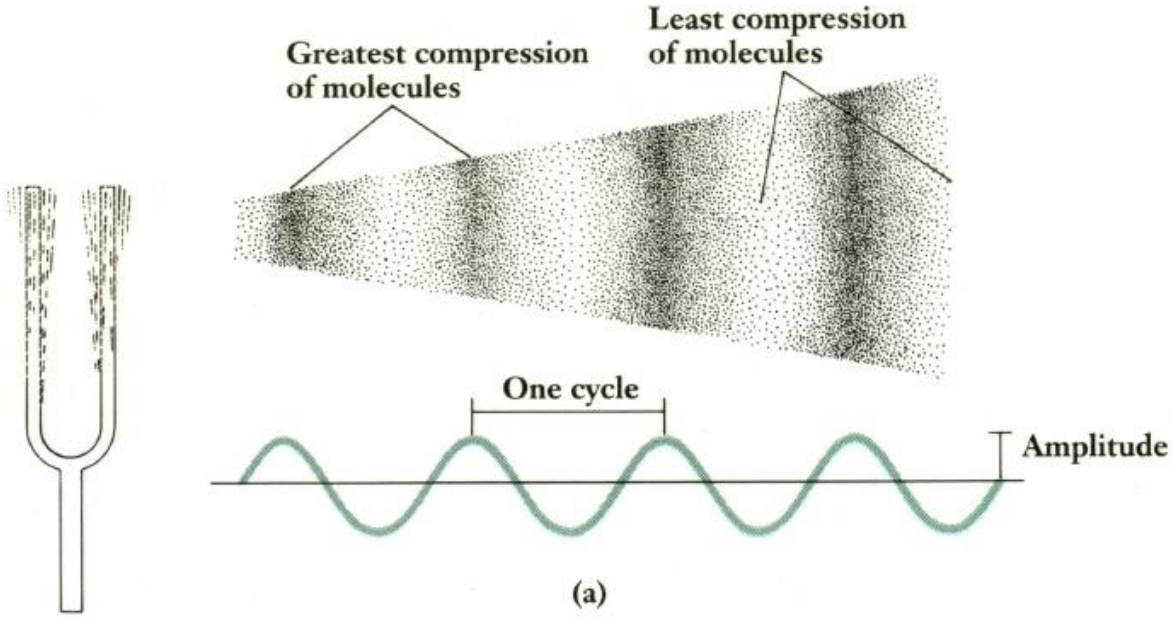


Olfaction: The Sense of Smell

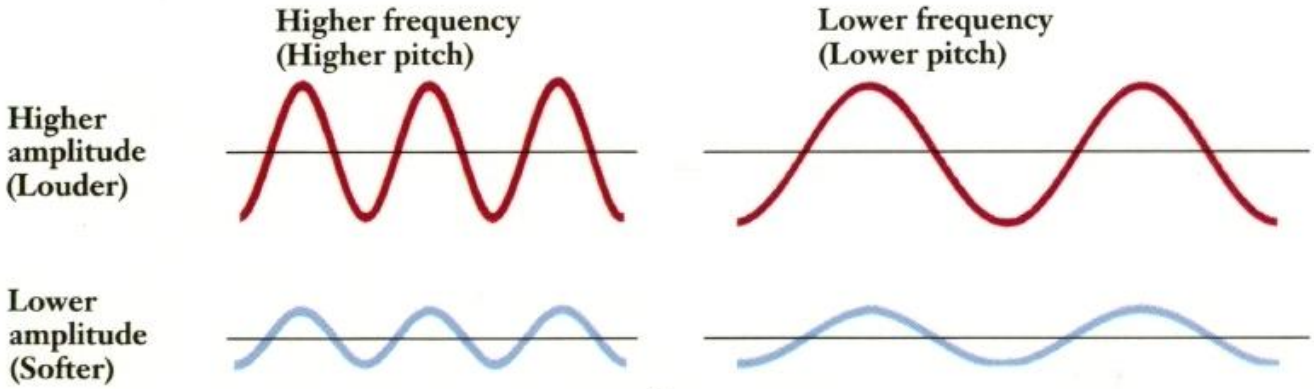


Audition or Hearing: Sound waves (vibrations in the air or some other medium) are the stimuli that initiate responses in the ear. Humans are sensitive to frequencies between 20 and 20,000 *Hertz* (cycles per second). These frequencies are experienced as different pitches. The pinna and ear canal comprise the outer ear. The pinna gathers in the vibrations producing sound, and helps us localize the sound source. The ear canal acts as a resonating tube to amplify frequencies between 2000 and 4000 Hz, the normal range of adult human voices. The *tympanic membrane* (ear drum) separates the outer ear from the middle ear and vibrates with the incoming frequency. In the middle ear there are three tiny bones (hammer, anvil, and stirrup) called the *ossicles*. The mechanical vibration of the ossicles now carries the sound information, and through leverage there is a 17% increase in the strength of the signal. The *cochlea* has a coiled shape and is the primary structure of the inner ear. The stirrup taps on the oval window of the cochlea, and this induces vibration of the fluid within. It is in the cochlea that transduction takes place. The *tectorial membrane* is deflected by the wave form generated in the fluid. In turn, it presses on the hair cells of the *basilar membrane*. As these hair cells are bent, they trigger neuronal impulses. The timing and pattern induced by the bending of particular hair cells is ultimately translated into the frequencies of sound (different pitches) we experience. There are two types of deafness--conduction (or conductive) deafness and sensorineural (or nerve) deafness. Each results from a different type of malfunction in the ear. Also note that the vestibular canals are located near the cochlea, and are of similar design. However, they provide kinesthetic information (body position and balance).

Physics of Sound

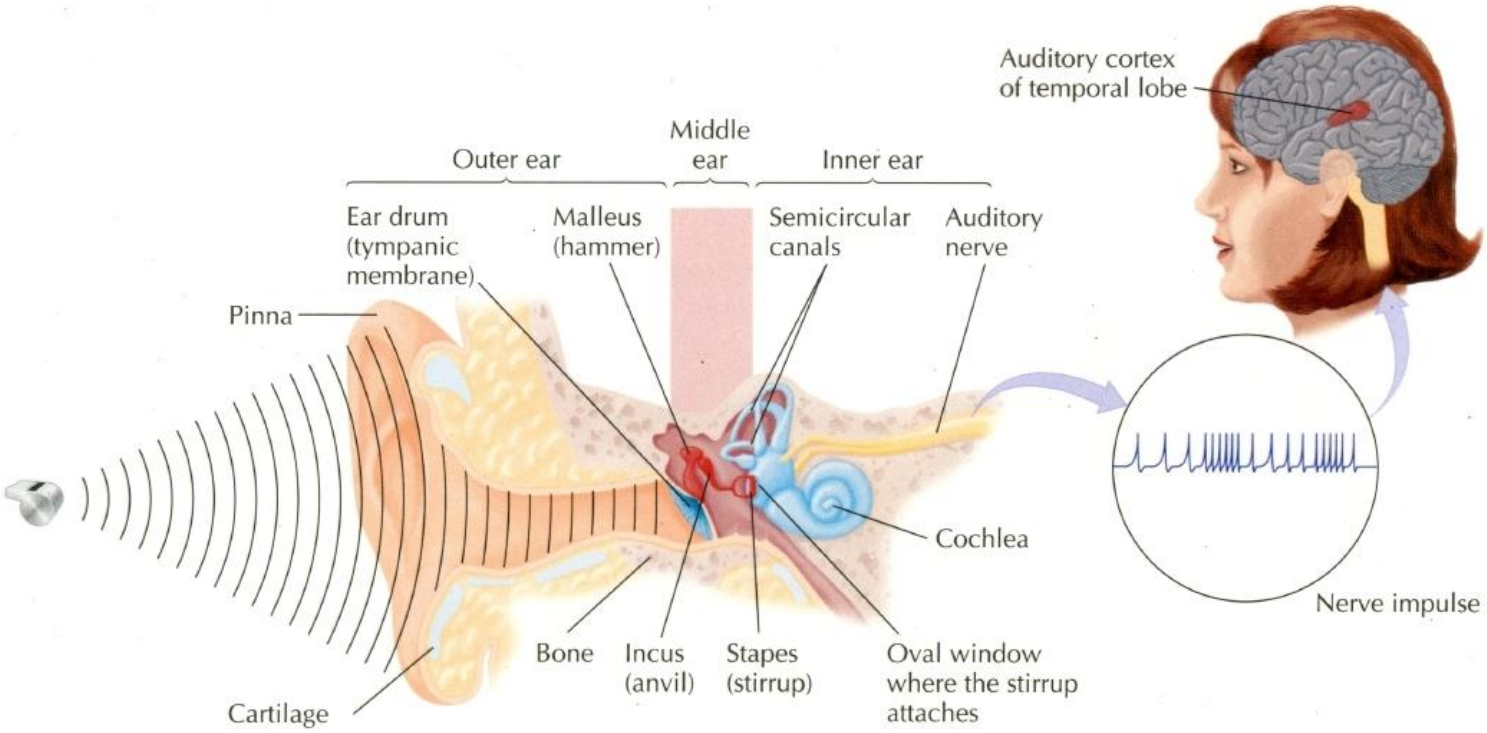


(a)

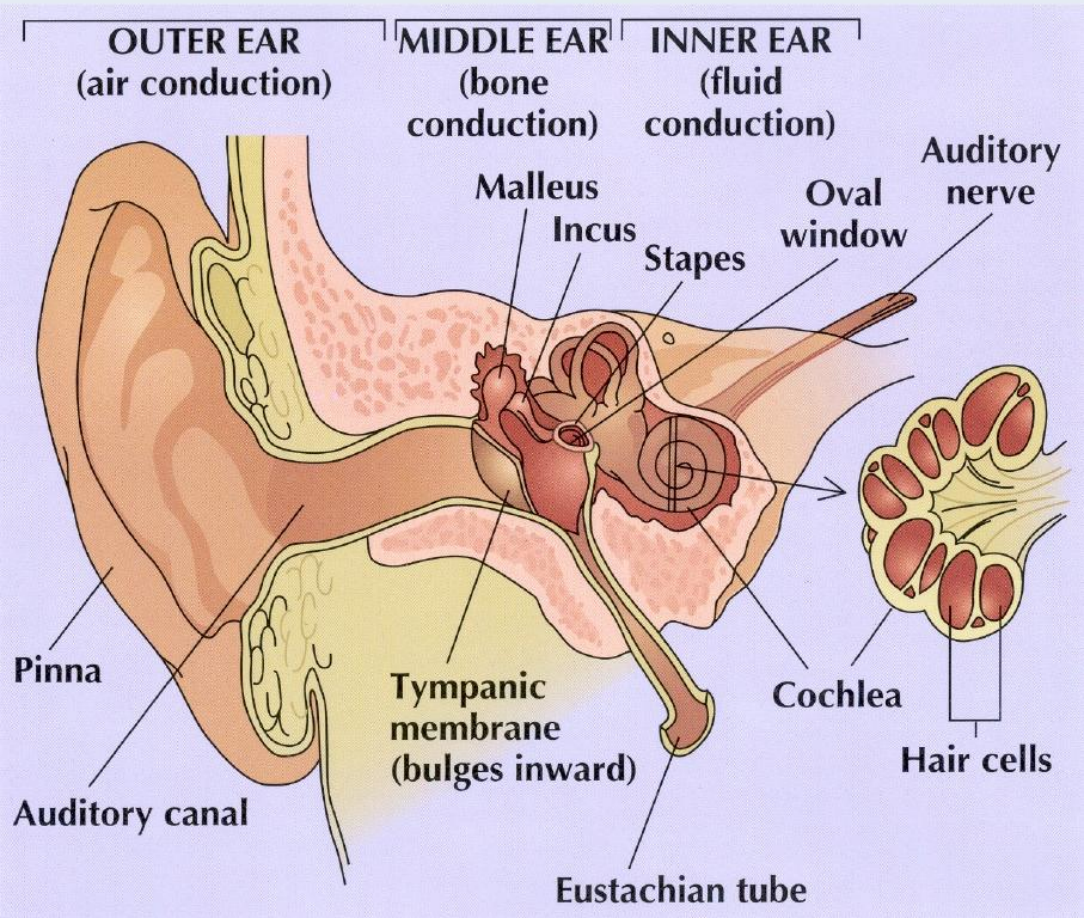


(b)

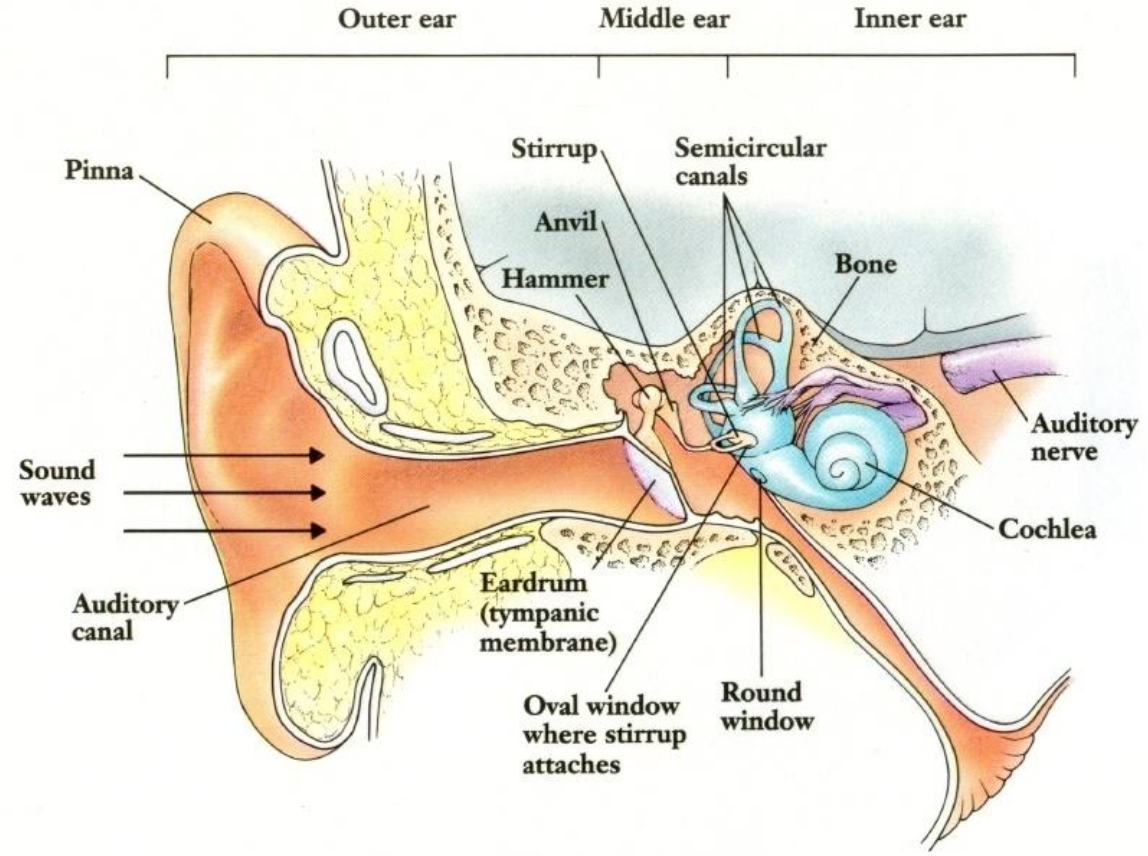
Human Hearing



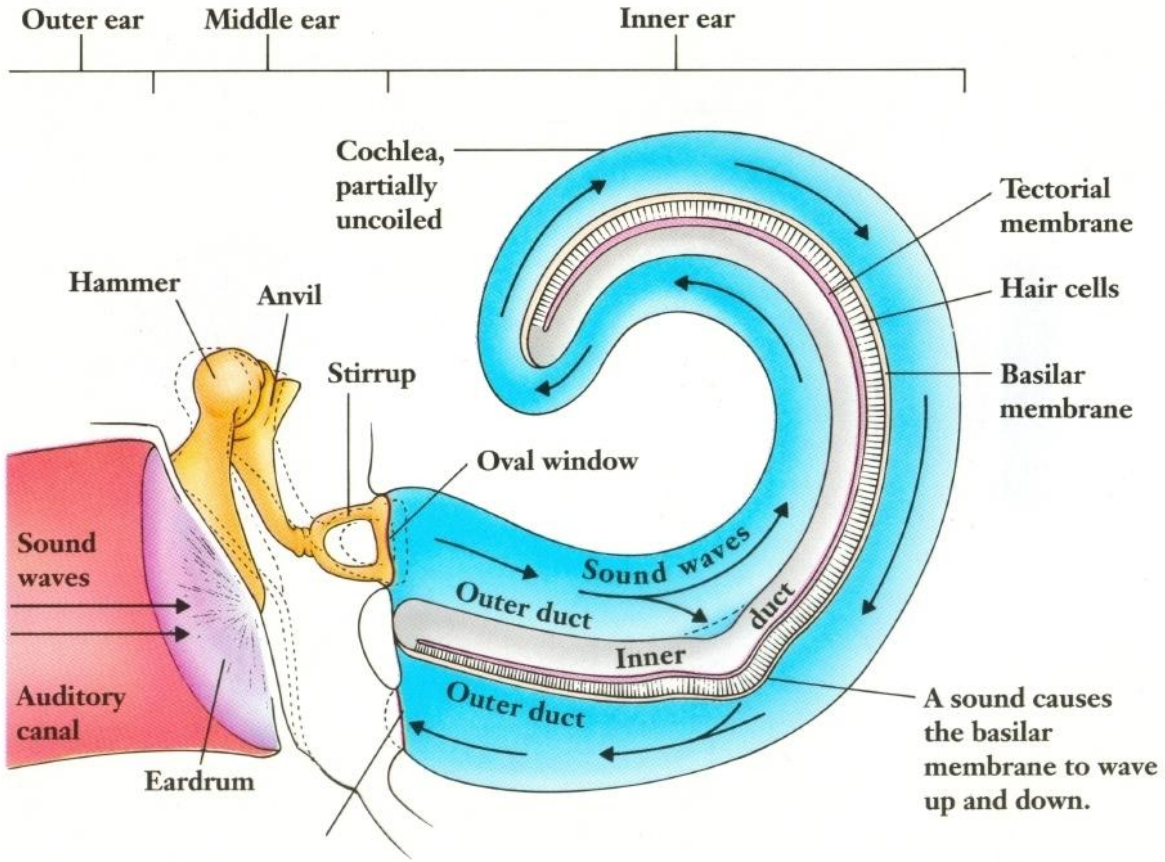
The Human Ear



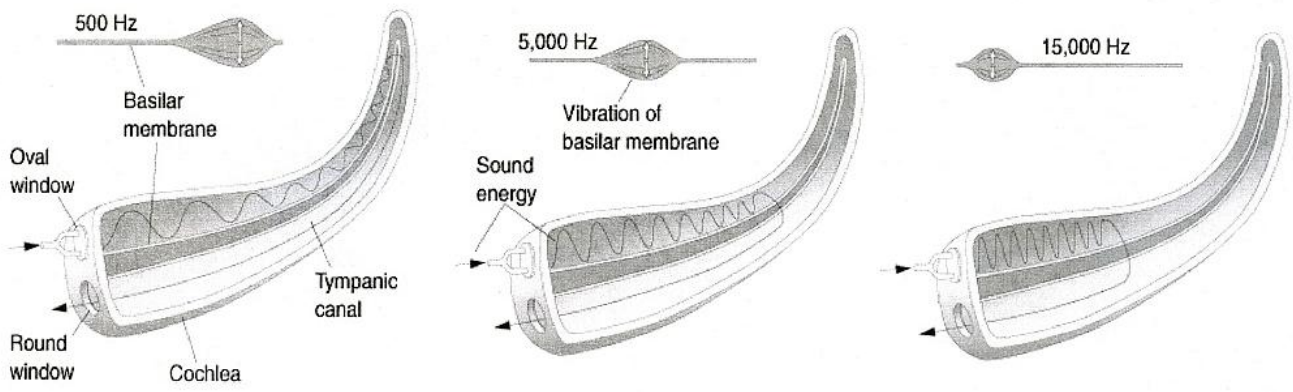
The Human Ear



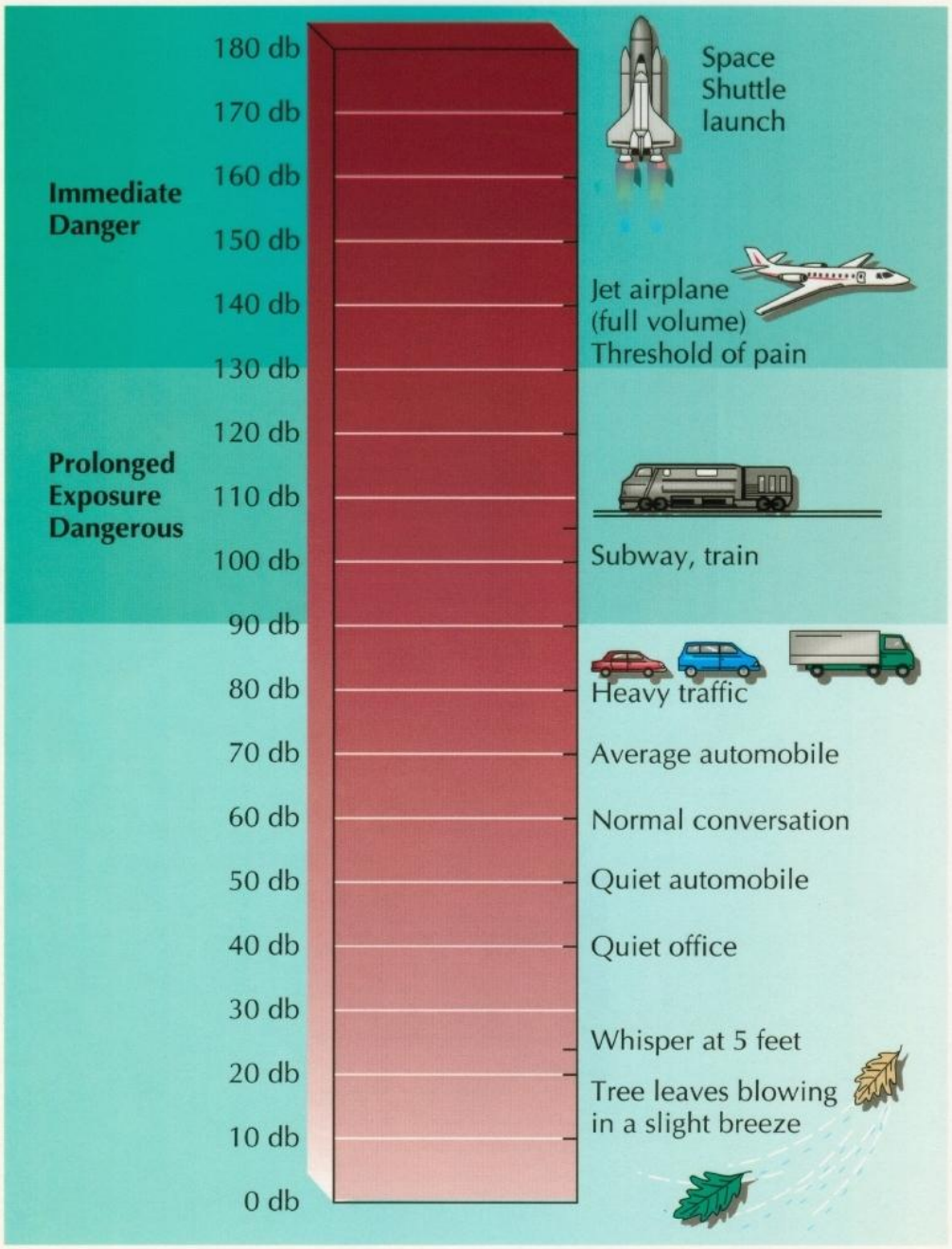
Auditory Transduction



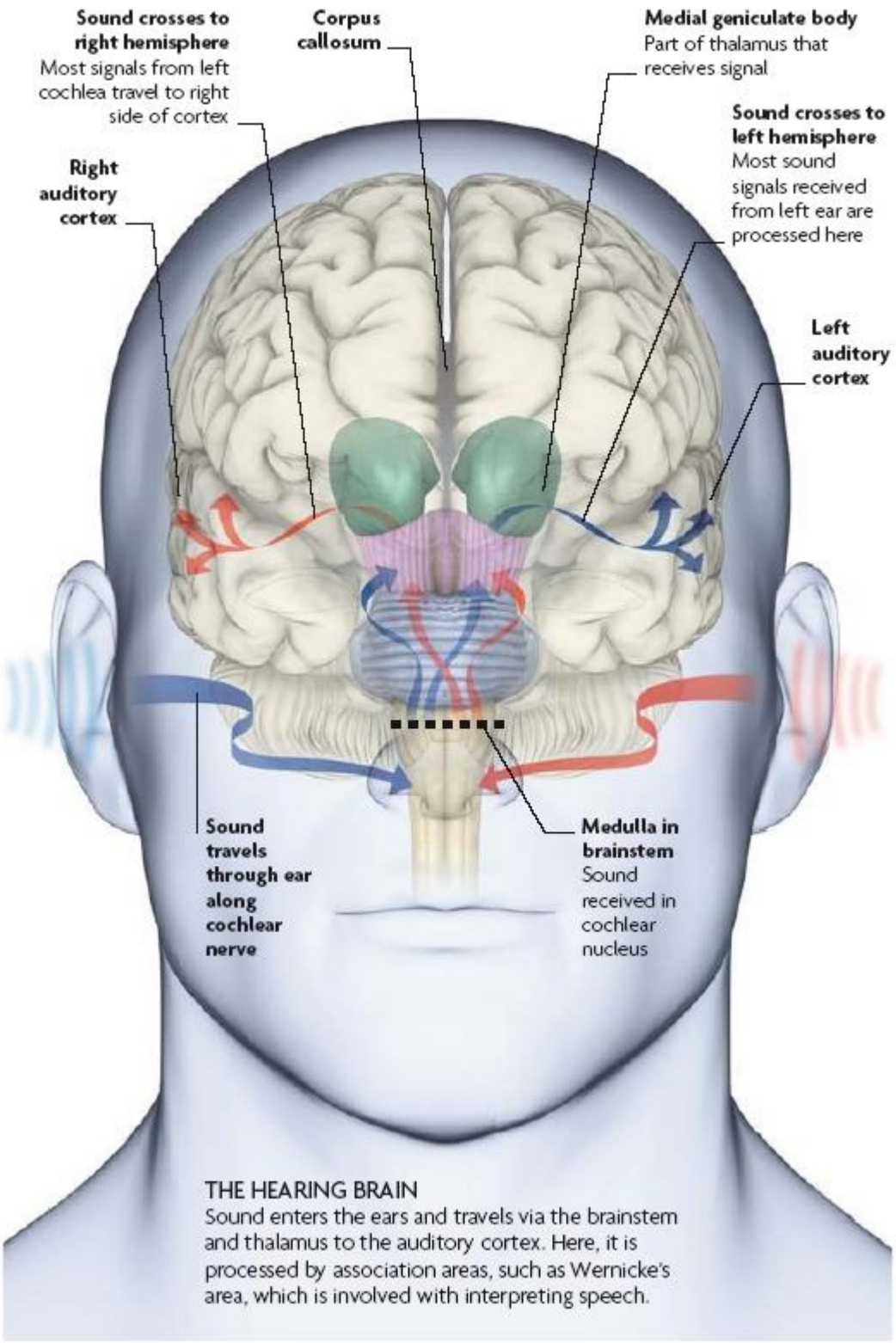
Cochlear Vibration to Different Frequencies



Sound Intensity Levels: The Decibel Scale

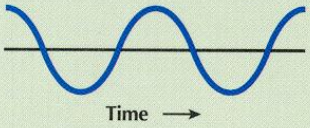
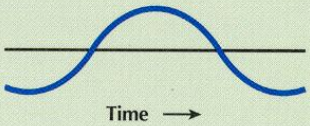
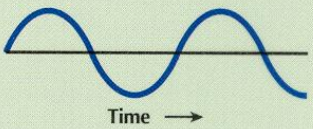
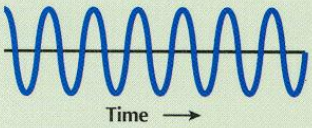
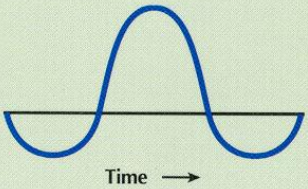
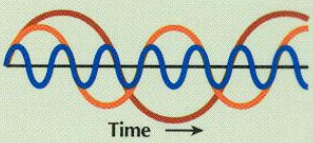


Auditory Pathway

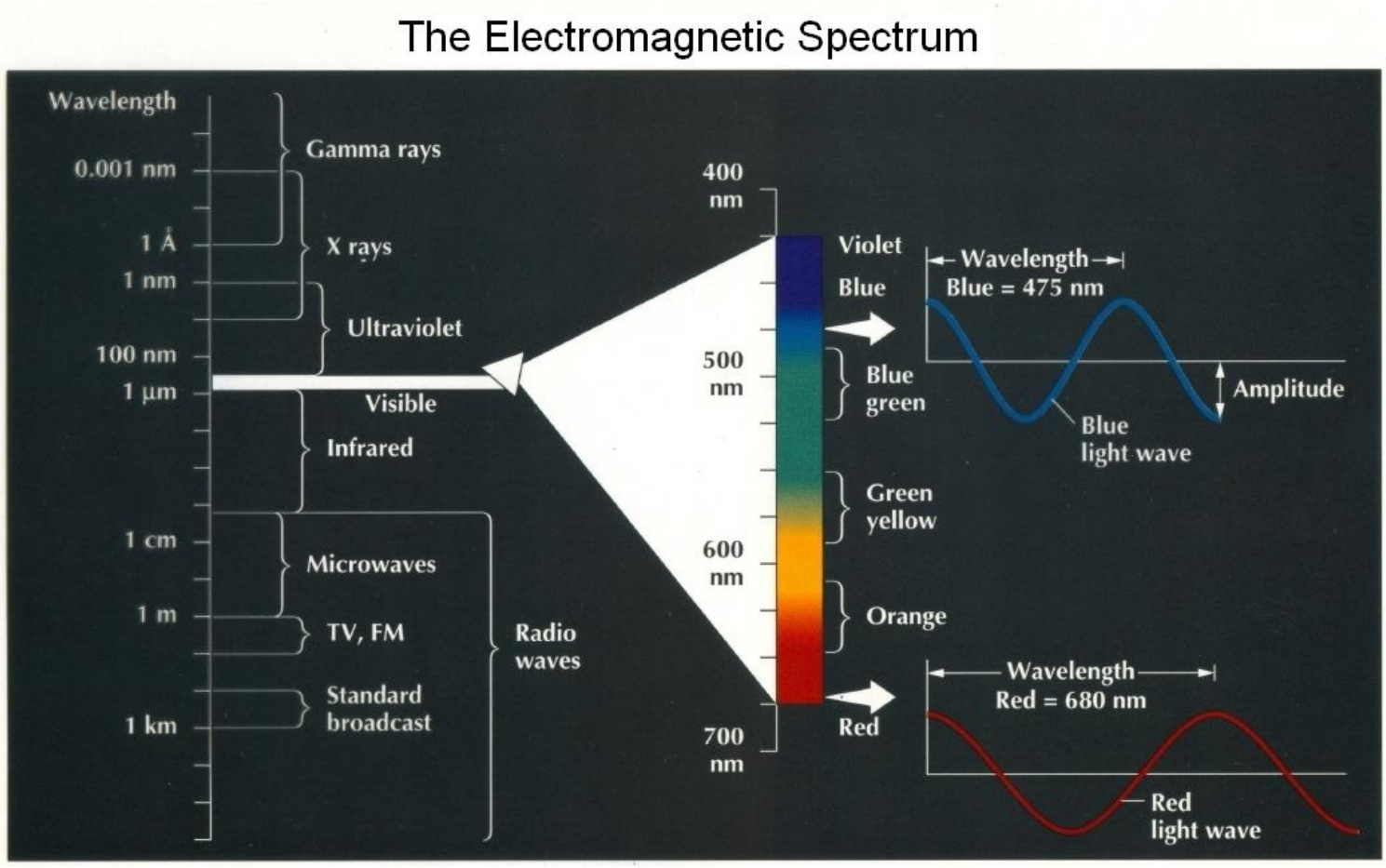


THE HEARING BRAIN
Sound enters the ears and travels via the brainstem and thalamus to the auditory cortex. Here, it is processed by association areas, such as Wernicke's area, which is involved with interpreting speech.

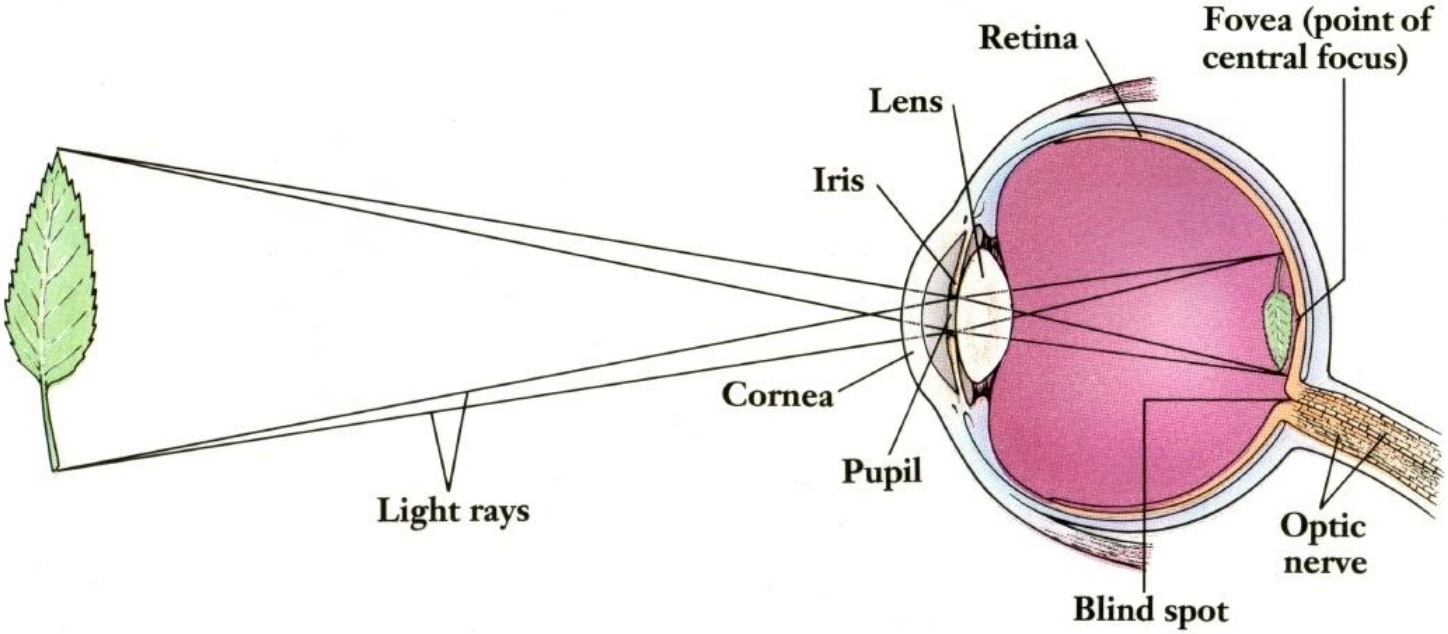
TABLE 4.1 PROPERTIES OF VISION AND HEARING

Physical properties	**Wavelength:** The distance between successive peaks.	**Wave Amplitude:** The height from peak to trough.	**Range of Wavelengths:** The mixture of waves.
			
	Long wavelength/low frequency	*Low amplitude/low intensity*	*Low range/low complexity*
			
	Short wavelength/ high frequency	*High amplitude/ high intensity*	*High range/high complexity*
VISION (Light Waves)	**Hue:** Short wave lengths produce higher frequency and bluish colors; long wavelengths produce lower frequency and reddish colors.	**Brightness:** Great amplitude produces more intensity and bright colors; small amplitude produces less intensity and dim colors.	**Saturation:** Wider range produces more complex color; narrow range produces less complex color.
AUDITION (Sound Waves)	**Pitch:** Shorter wavelengths produce higher frequency and high pitched sounds; long wavelengths produce lower frequency and low-pitched sounds.	**Loudness:** Great amplitude produces loud sounds; small amplitude produces soft sounds.	**Timbre:** Pure tones produce only one frequency; complex tones produce multiple frequencies.

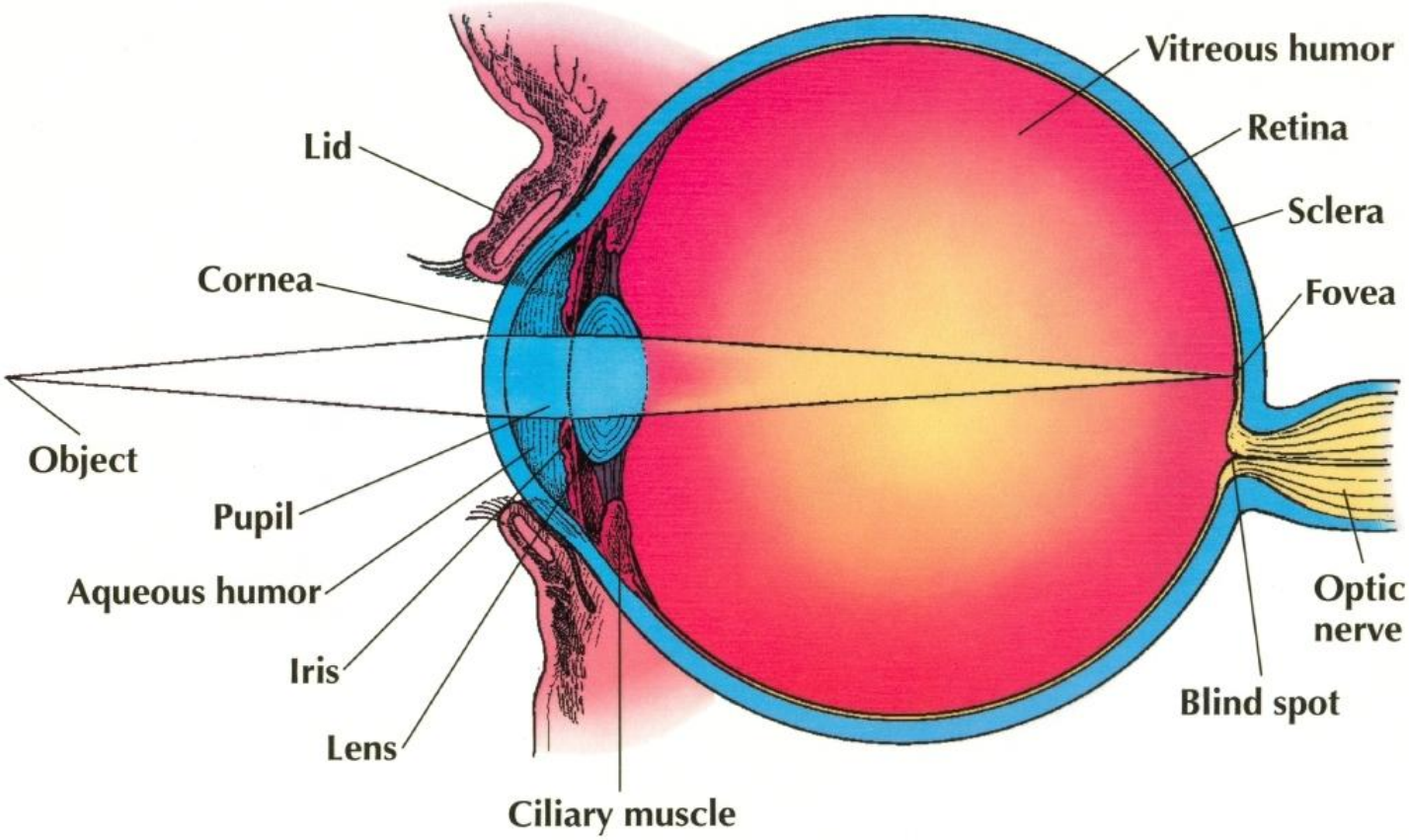
Vision or Sight: The nature of the sensory stimulus is light, which is captured by the eye. Light reflected off of objects in the environment results in perceptible patterns that we the use to identify those objects and their relative locations. The *retina* is the part of the eye that includes the receptor cells capable of responding to light. There are two types of visual receptors referred to as the *rods and cones*. Both types of receptor underlie specific visual subsystems with particular strengths and weaknesses. The rods enable us to see in very dim light, as they have the greater *sensitivity*. But the rods only allow us to see shades of blue and grey. We must rely on the cones to see color and fine detail, as they have the greater *acuity*. Color vision involves neural mechanisms in the retina and higher up in the nervous system that code information provided by the light stimulus. The visual system is able to enhance contrast for sharper vision. The brain processes information about visual features (such as edges, intersections, and movement) in the visual association areas of the occipital lobe.

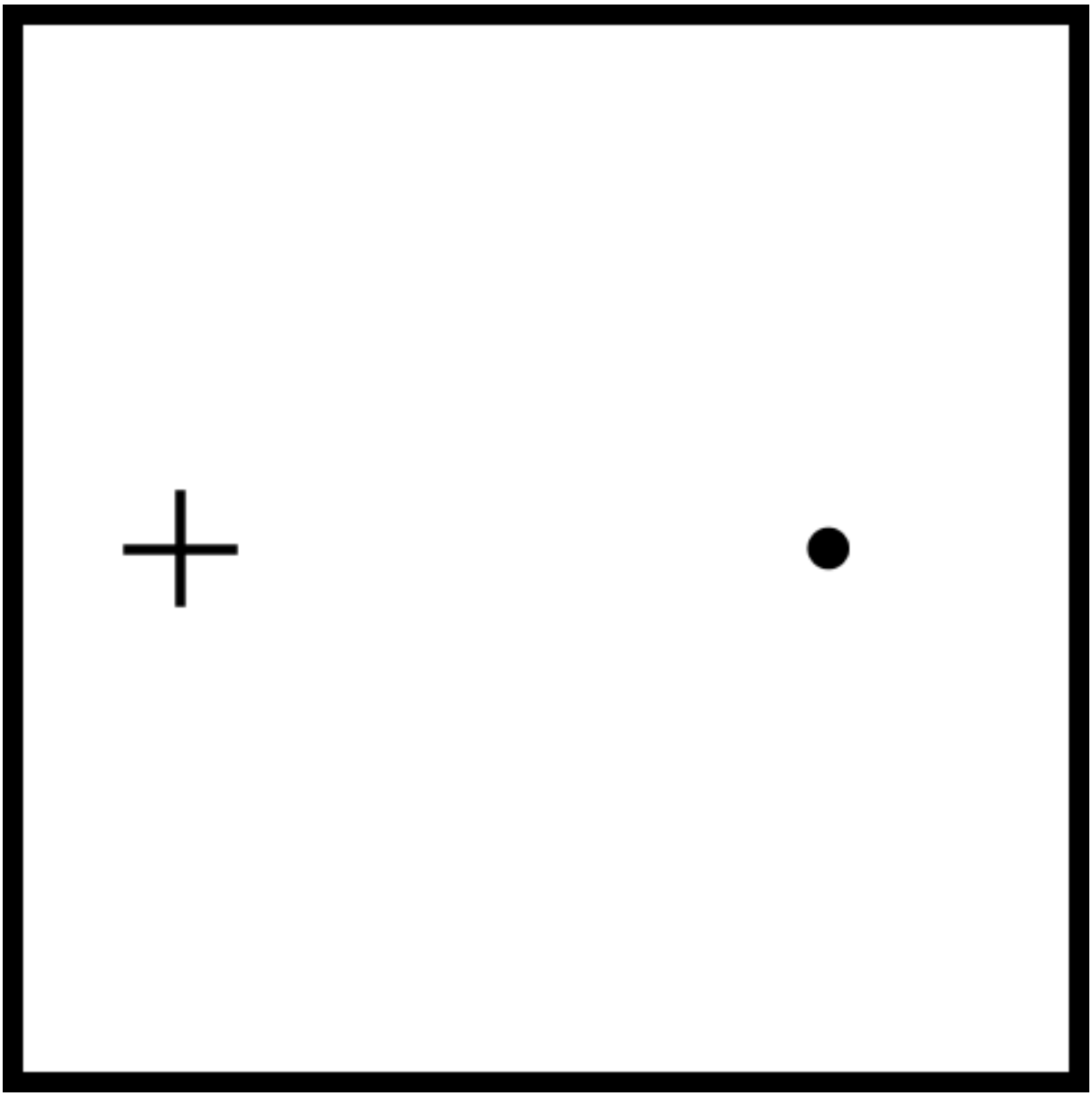


The Human Eye



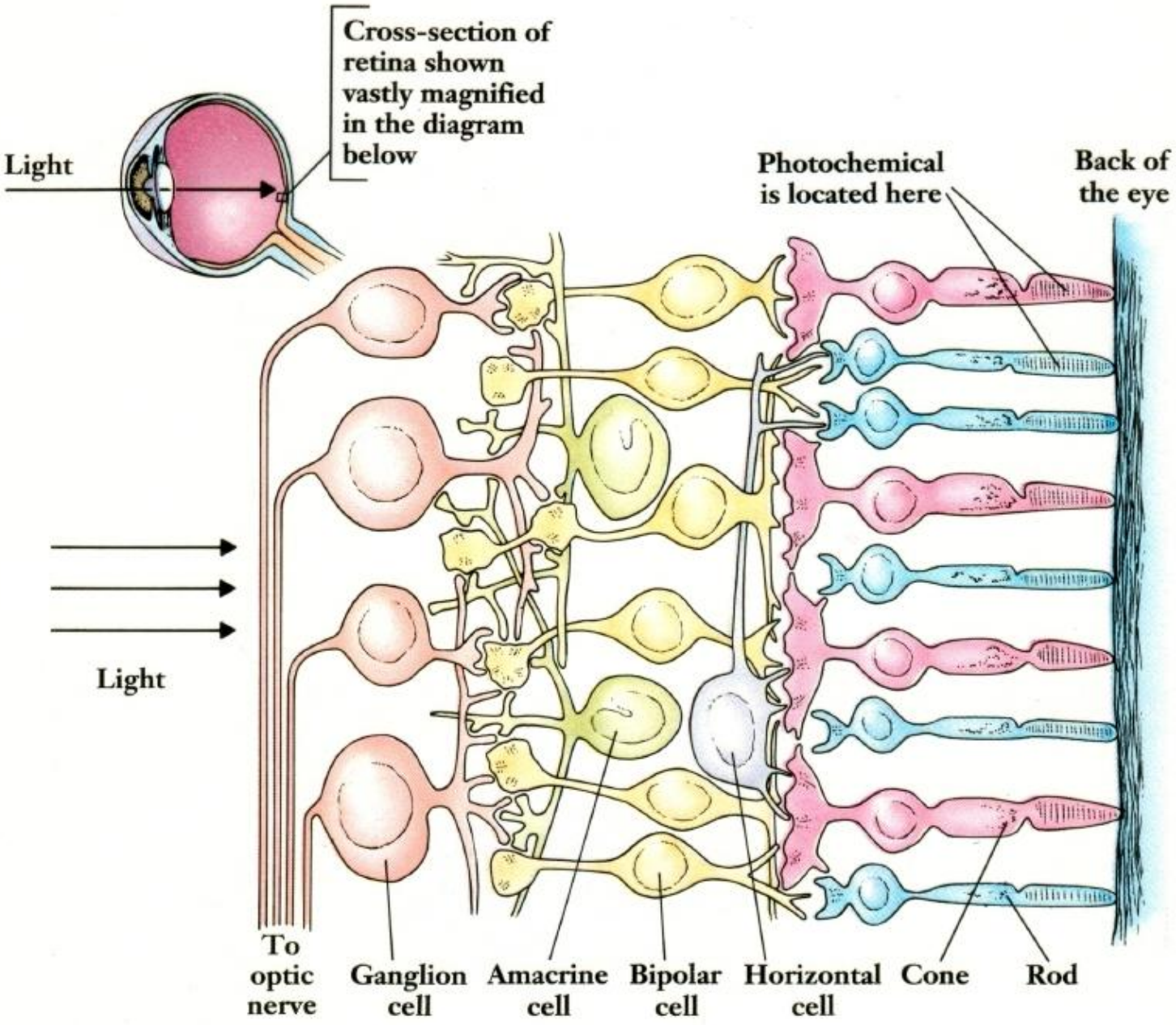
The Human Eye



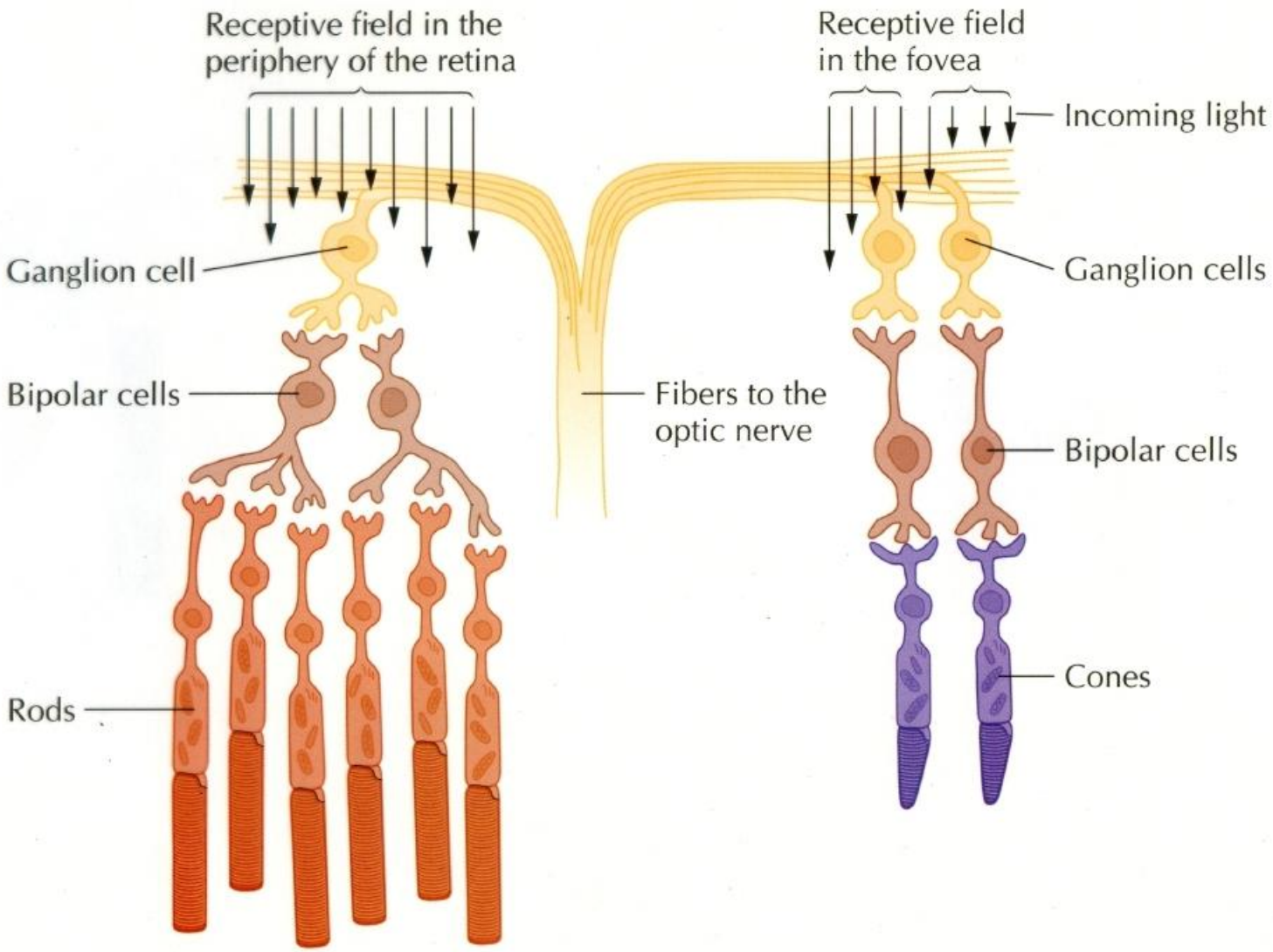


Blind Spot Demonstration: Hold the diagram about 18 inches from your face while covering your left eye. Focus on the '+' with your right eye. Move the paper towards you. At some point (approximately 10-12 inches) the dot to the right will disappear. Its image is now falling on your right eye's blind spot. If you continue to move the paper toward you it will reappear once its image no longer falls on your right eye's blind spot. Also note that while the dot is in your right eye's blind spot uncovering your left eye will cause it to reappear, as it's not in that eye's blind spot. If you flip the paper over, cover your right eye, and repeat the procedure you'll find your left eye's blind spot. The demonstration will also work for your right eye on the computer by covering your left eye and moving your head towards the display, but it's much harder to flip over the screen to test your left eye. Normally we don't notice these blind spots for three reasons. First, within each eye the visual system fills in the blind spot area with appropriate background extrapolated from the immediately surrounding area. So if this page were printed on colored paper, that color would fill in the blind spot area. That would even be the case with a simple background pattern. Secondly, our eyes are usually moving around so any specific area of the visual field only falls on the blind spot of one of your eyes briefly. And the third reason we don't normally notice these blind spots is that when something is in one eye's blind spot it's not in that of the other, so the two eyes compensate for each other's blind spots.

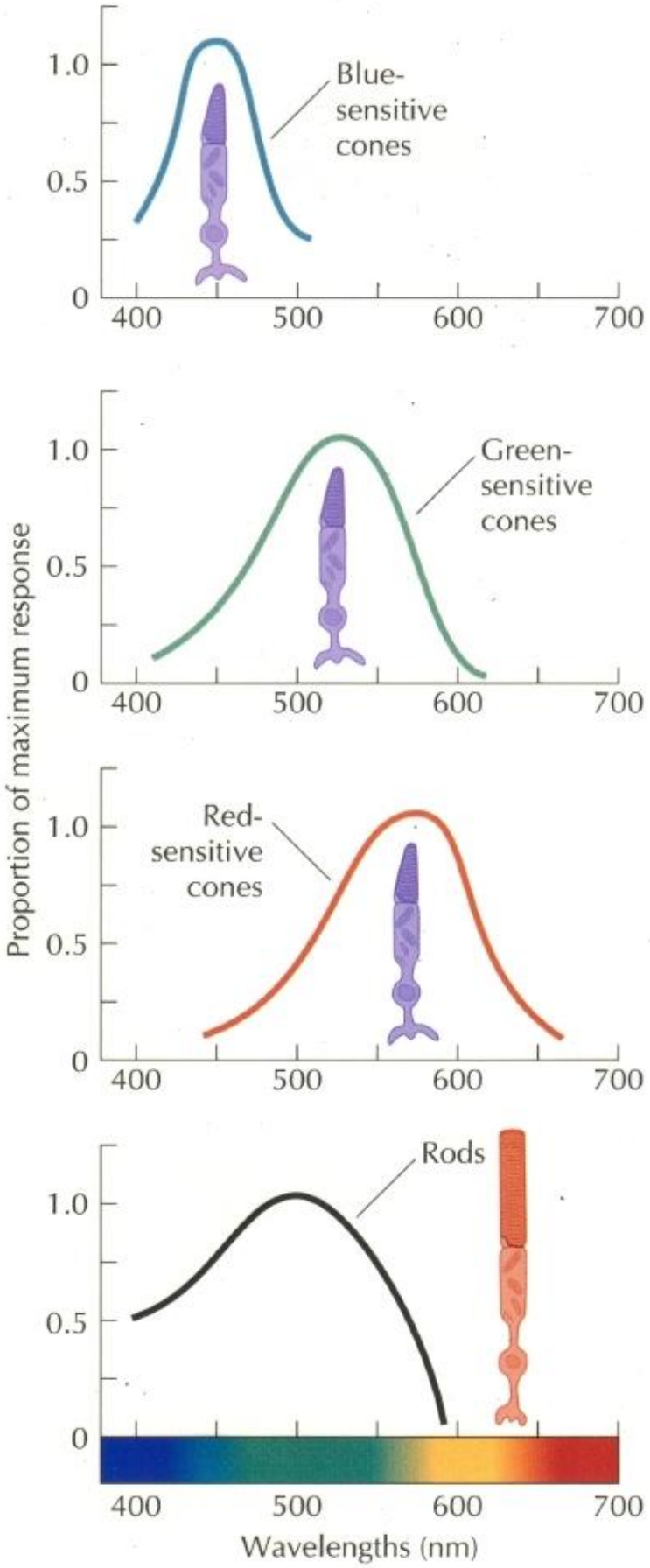
Arrangement of Cells in the Retina



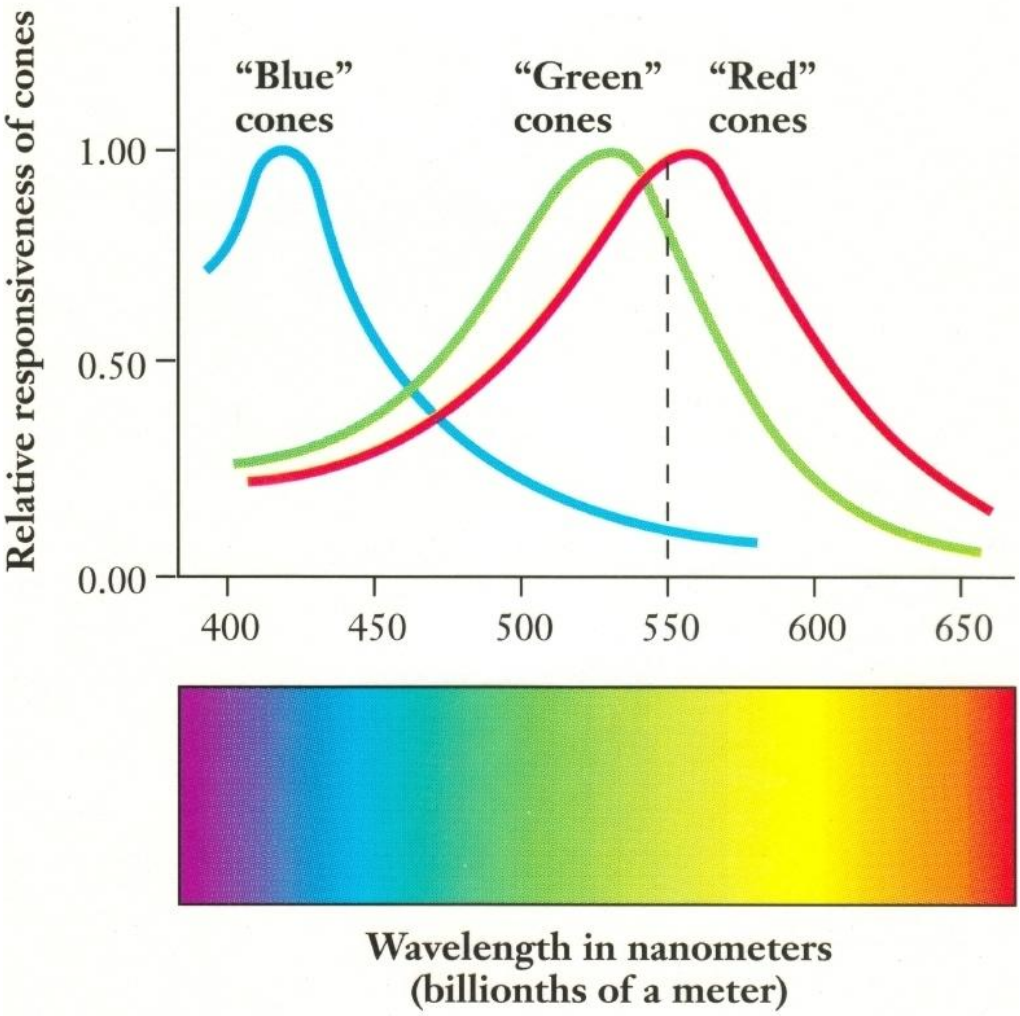
Receptive Fields of Rods and Cones



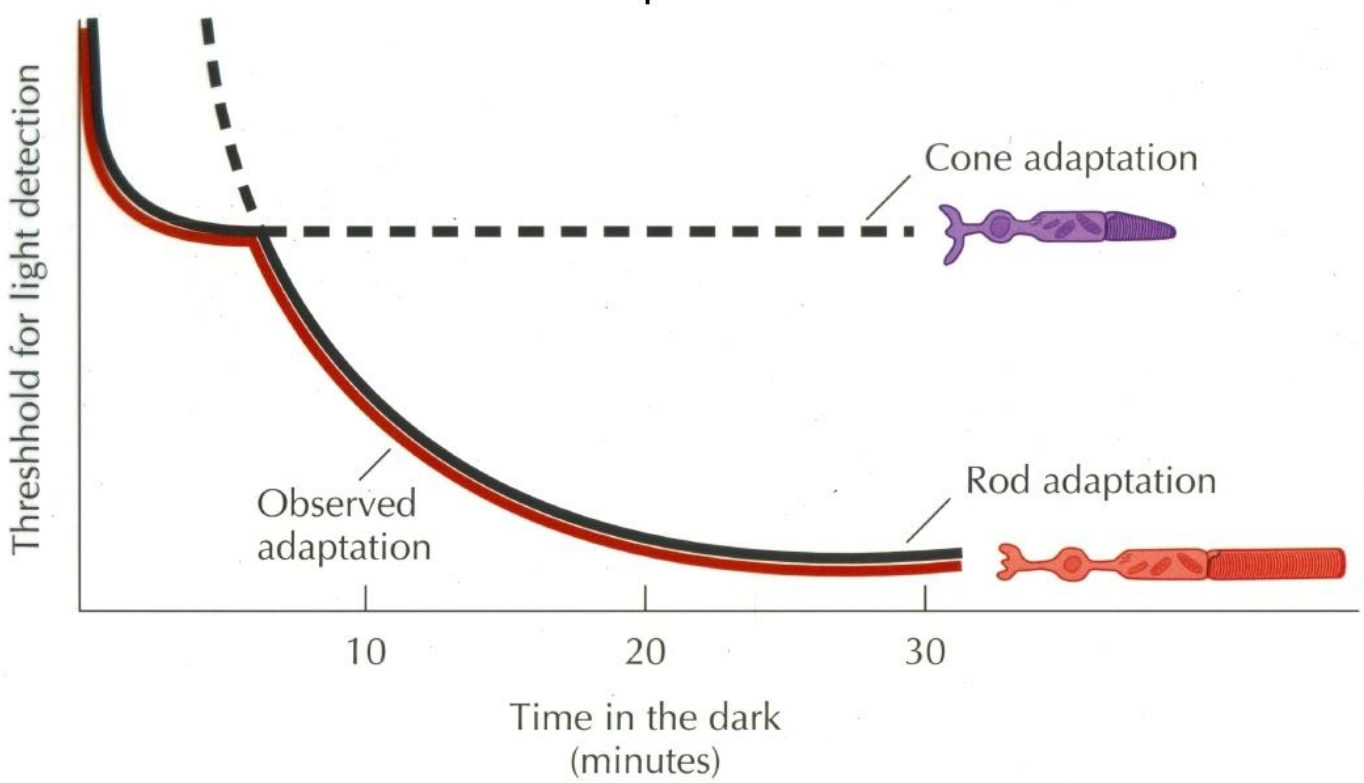
Receptor Sensitivity Curves

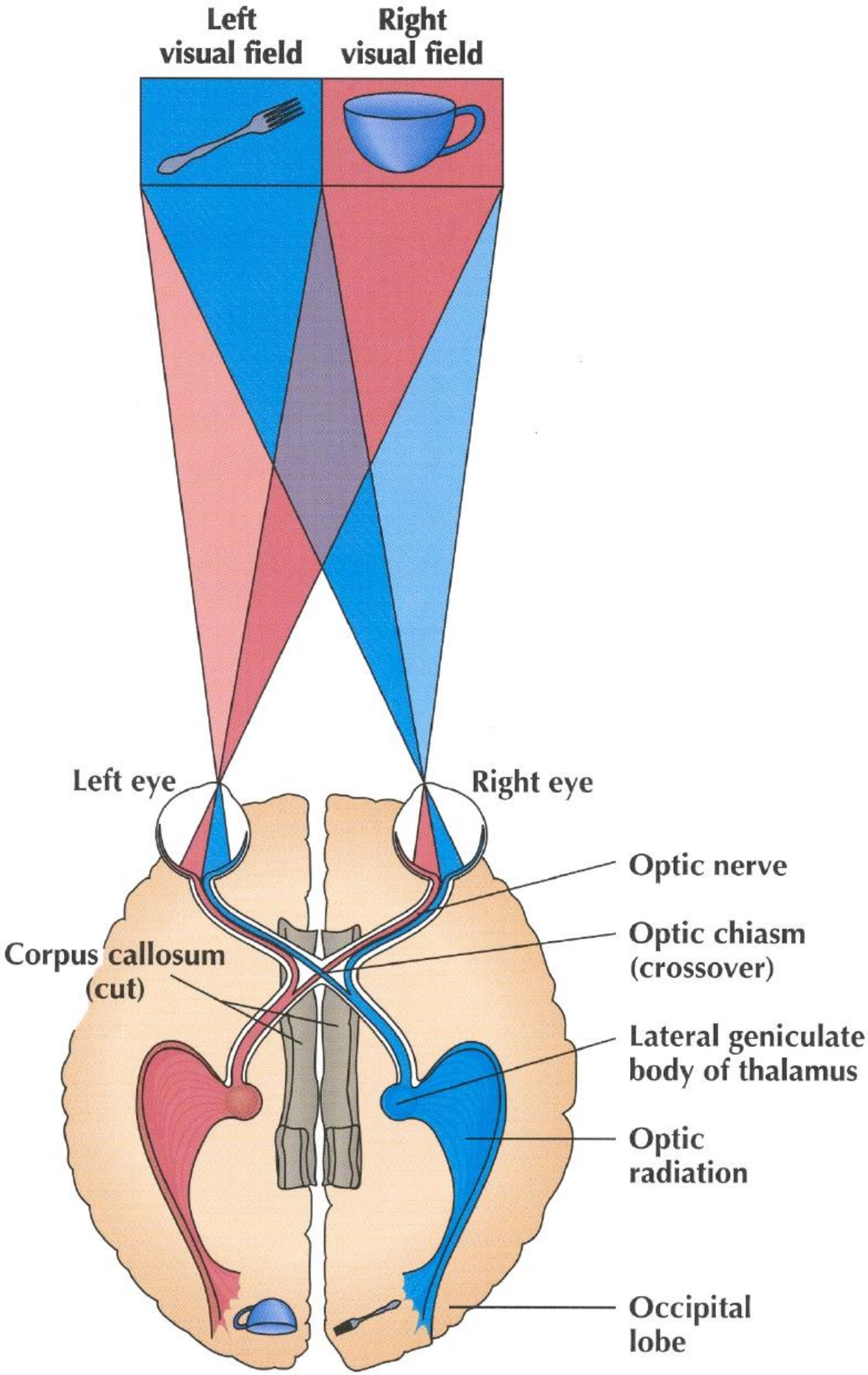


Retinal Cone Sensitivities



Dark Adaptation Curves

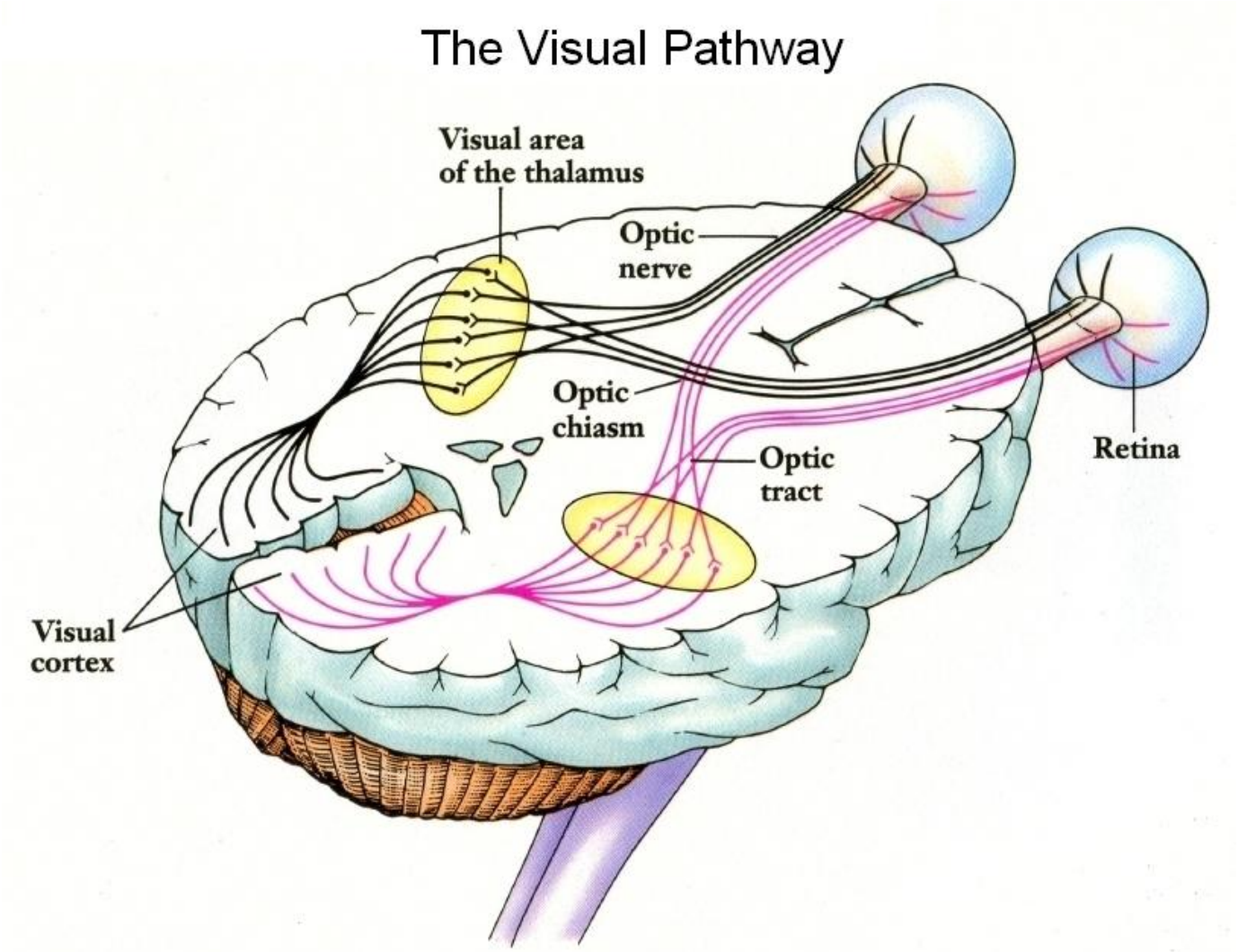



Left visual field
Right visual field
Left eye
Right eye
Optic nerve
Optic chiasm (crossover)
Corpus callosum (cut)
Lateral geniculate body of thalamus
Optic radiation
Occipital lobe

Getting Your Fiber Optics Crossed: The retina is a concave mirror representation of the incoming panorama known as one's current visual field. As a result of the optics involved the incoming image is flipped vertically (up and down) and horizontally (left and right). The left half of the visual field is mapped onto the right half of each eye (retina). The right half of the visual field is mapped onto the left half of each eye (retina). So each eye's retinal image has information pertaining to each half of the visual field.

Now the brain is concerned with discerning locations and coordinating movements in the world, or in other words, within the visual field. It is of little use to coordinate by way of which eye (retina) that information comes from specifically. And so it is at the optic chiasm that there is a separation of each eye's (retina's) view of the world into separate left and right visual field views. This is accomplished by the nasal (inner) portion of each eye's retinal image crossing over to the contralateral (opposite) side of the brain, while the temporal (outer) portion of each eye's retinal image goes directly back to the ipsilateral (same) side of the brain. The result is that each hemisphere's visual cortex receives information from both retinas, pertaining to one side (the contralateral side) of the visual field out there in the world. To restate, it's not the information from one eye (retina) that goes to the contralateral visual cortex; it's the information about one side of the visual field (from both retinas collectively) that goes to the contralateral visual cortex.

This arrangement ultimately makes it easier for the brain to locate things in the world relative to the body and to coordinate movements in relation to the visual field. The left hemisphere of the brain controls the right side of the body, and gets all the information about the right visual field. The right hemisphere of the brain controls the left side of the body, and gets all the information about the left visual field. Now if one eye is damaged, the remaining eye will still be transmitting information to both hemispheres of the brain, representing both halves of the visual field. As a result an individual with such an injury will not be totally blind on one side of the visual field. Ultimately the arrangement is very efficient, well coordinated, and has built in redundancy to help insure functionality even with loss. It's really quite cool.



Perception: Perception is the ability to extract meaning from the patterns of stimulation received by the sense organs. Perception involves the interpretation of our sensations, and the imposition of order or categorization. Based on our history of dealing with the world as we know it, there are certain expectations we assume to be true in all cases. We are not necessarily aware of these expectations, but they drive our perceptual experience. Helmholtz referred to this aspect of perception as *unconscious inference*.

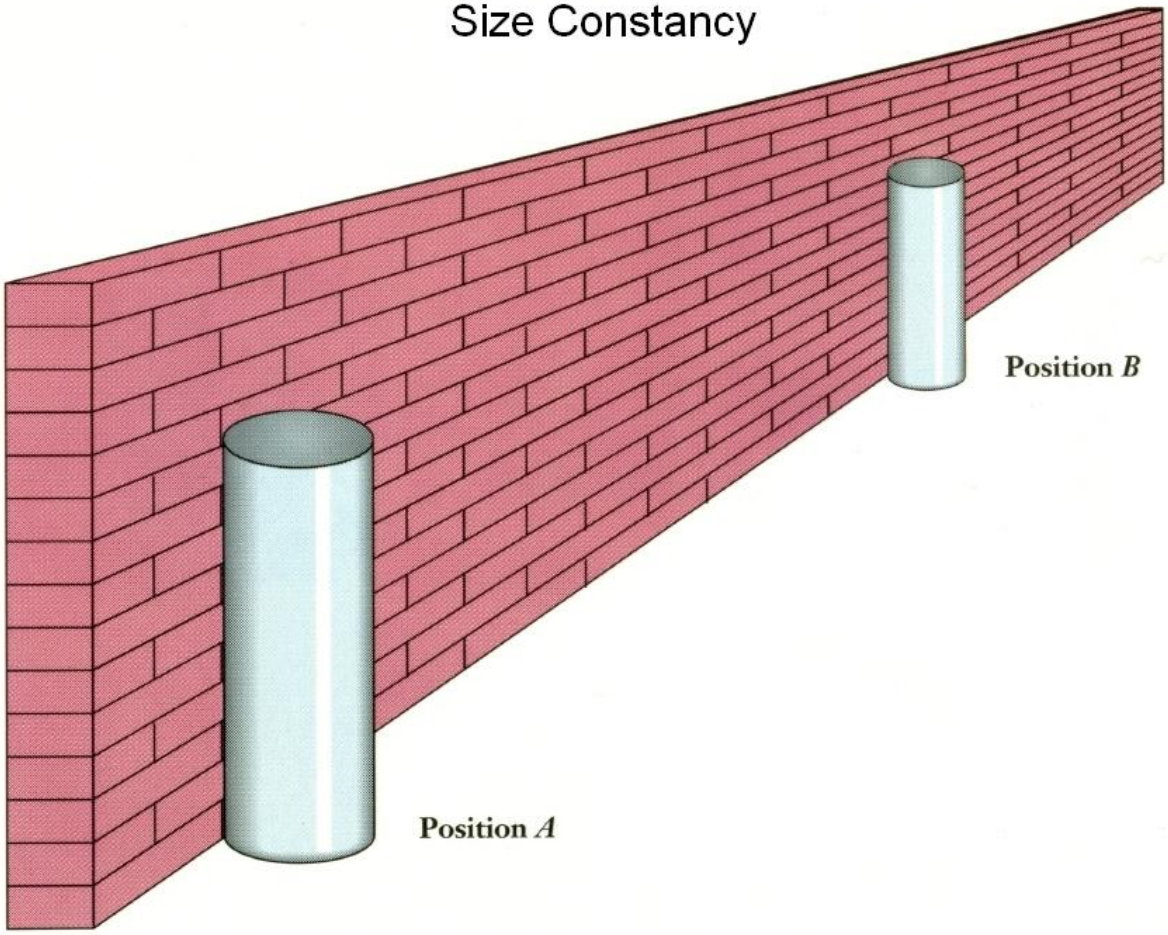
A vast array of stimuli are available to us at any given moment, yet we cannot perceive them all with equal clarity and completeness. How do we select what we perceive? Selective attention is our ability to focus on stimuli that are currently relevant. Theorists are interested not only in our ability to focus our attention selectively but also in our ability to divide attention over several different tasks simultaneously, within limits, of course. With practice, we can actually make some processes automatic. A number of theories have been proposed to explain attention. Although they differ in important ways, they generally contain these basic components: first, a large-capacity compartment that does an automatic preliminary analysis of sensory input; then a selection mechanism that determines which input goes on for further processing; and finally, a limited-capacity compartment in which input receives more thorough, effortful processing.

Visual Perception: Pattern perception and object recognition involve both top-down and bottom-up processing. In top-down processing, our knowledge helps us to interpret incoming information; it often involves utilizing information about the whole to help us interpret parts. In bottom-up processing, we begin with parts and construct from them a perception of the whole. At the most elementary level, these parts are called features. Although top-down and bottom-up processing may appear to be mutually exclusive, and although different theorists may emphasize one over the other, the perception of patterns and objects consists of a continuous interaction of top-down and bottom-up processing. The Gestalt school of psychology was the first to emphasize holistic perception, as demonstrated in their principles of grouping.

The spatial perception of objects: The physical world and the objects in it (distal stimuli) are three-dimensional. However, our retinal image of these things (proximal stimuli) is two-dimensional. In the primary visual cortex this information is coded into three-dimensional Cartesian coordinates. Ultimately we experience the reality of a three-dimensional world. We use various cues to help us make determinations about depth, size, and motion.

The monocular cues include the following: Accommodation, where the brain monitors the activity of the ciliary muscles that alter the shape of the lens to focus on objects at various distances. Size and shape constancy are based on experience, as we know the relative sizes and shapes of certain objects. Shadowing helps to gauge size and relative location. Interposition is when closer objects partially obscure more distant objects. Accessible detail as more detail can be detected for closer objects. Texture gradient as regularly spaced aspects of a scene appear closer together with distance. Linear perspective is the perception of parallel lines appearing to converge in the distance. Aerial perspective has to do with objects that are quite distant taking on a bluish hue. This is due to the fact that the gases making up the atmosphere are not entirely transparent. Motion parallax functions while we are moving, with closer objects passing by quickly in a blur while more distant objects pass by more slowly and remain in focus.

Size Constancy

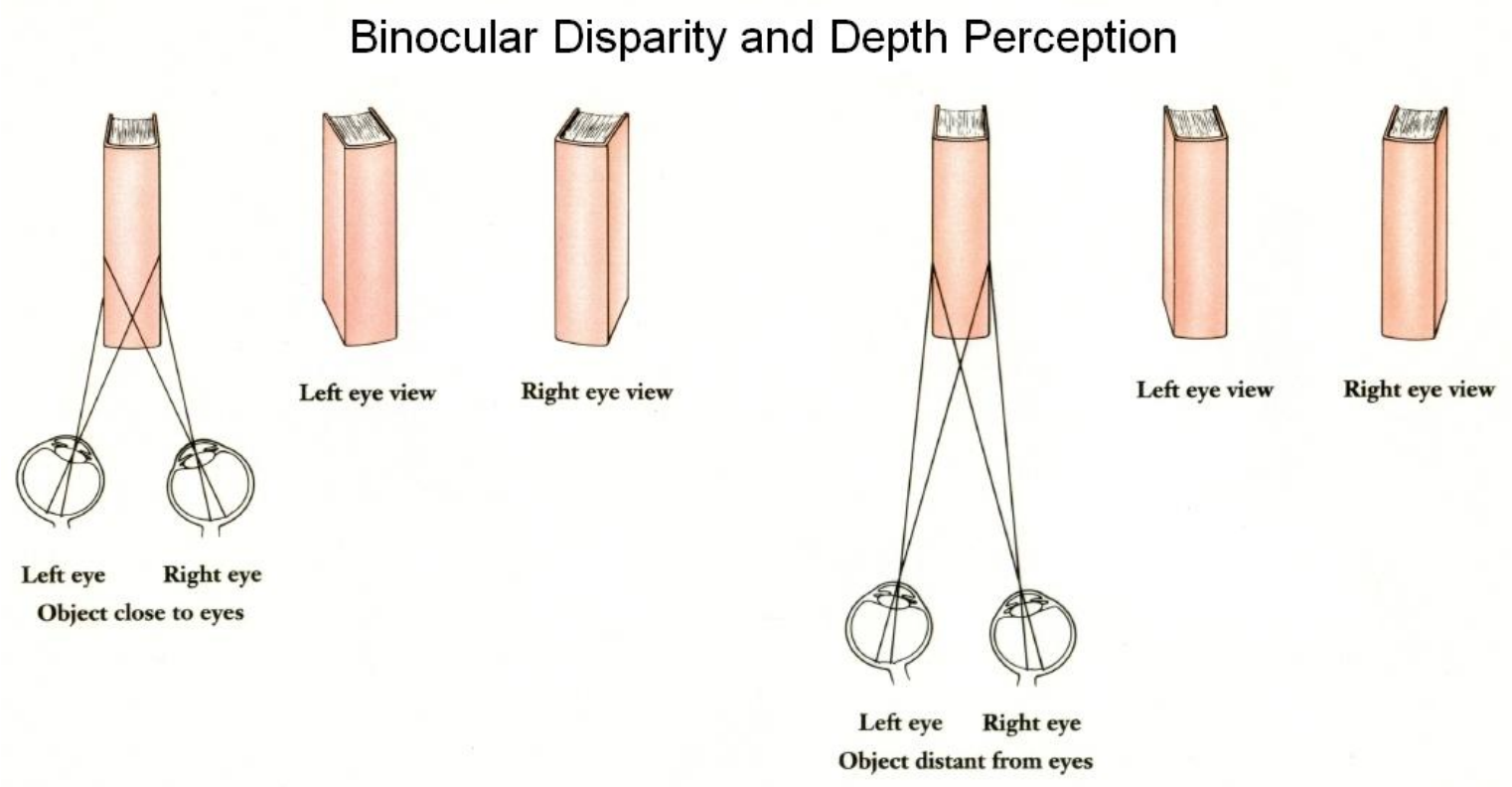


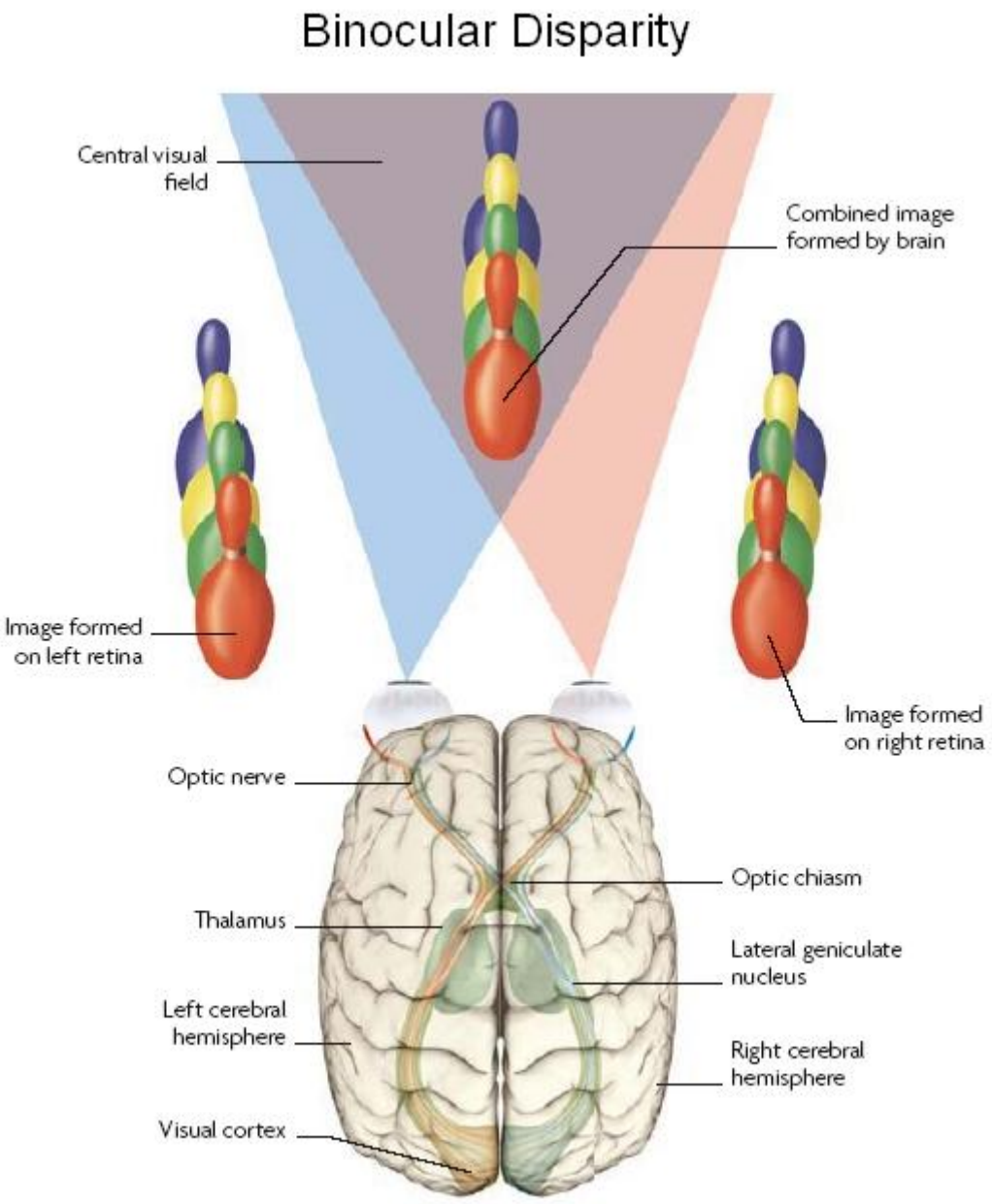
Shape Constancy

Photograph by Fritz Hoffmann

The Road Ahead
National Geographic, May 2008

However, the most striking cues for depth are binocular. Because the eyes are approximately six centimeters apart they receive slightly different views. This is termed binocular disparity and it is a major cue to depth. Generally, the closer an object is, the more different the two views will appear to be. In conjunction with that is convergence, the degree to which the eyes turn in to observe a close object. The brain registers the muscle tension needed to move the eyes this way, and uses the information as a cue to the distance of the object. However, if binocular disparity is such a major depth cue, why we don't have three or four eyes. Wouldn't the differences between each of those views further enhance our perception of depth? Yes, probably it would, but not by that much. The big leap comes from going from one to two eyes. Additional eyes would only provide a minimal enhancement in depth perception, which would not offset the biological cost of maintaining them. Two seems to be the right number, it provides a good sense of depth, and still allows for adequate vision if one eye is injured.

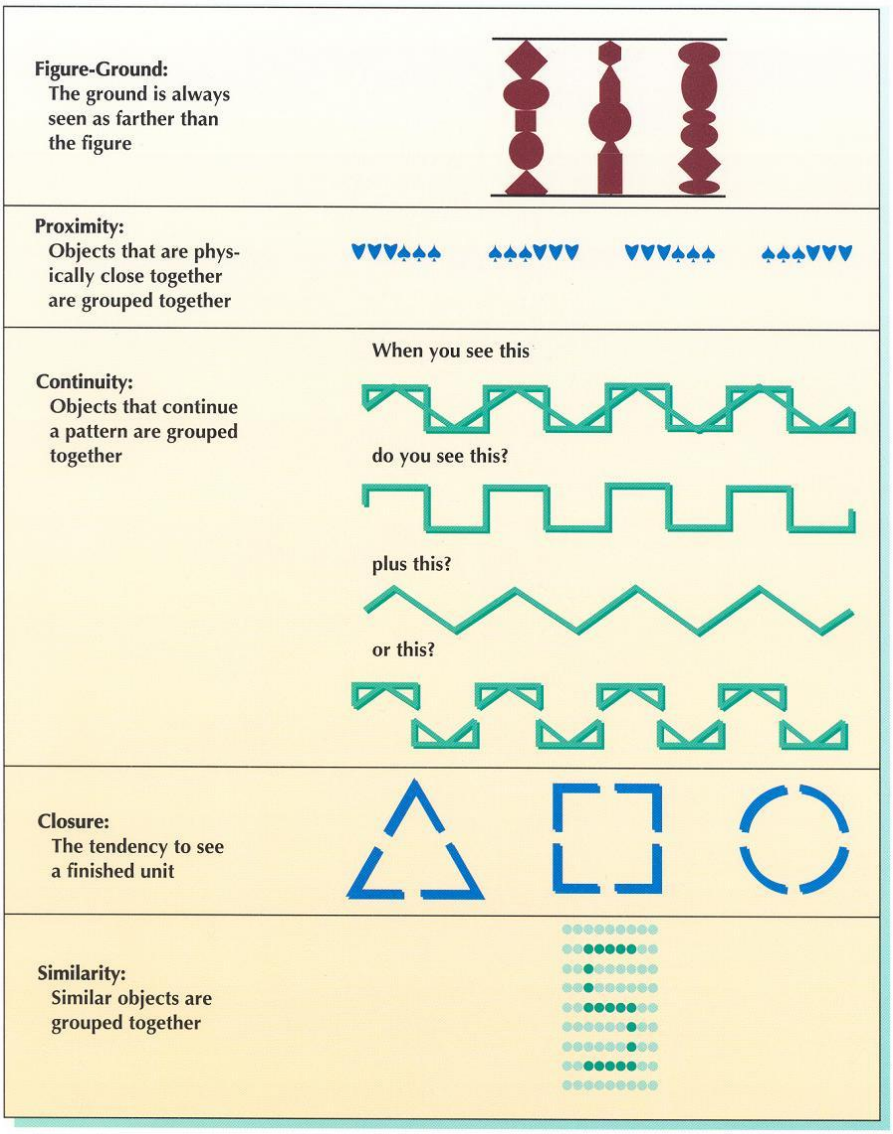




Note that in many cases the study of the spatial aspects of perception has progressed through the development of techniques of perspective used in art and the study of visual illusions. Our eyes are employing these same techniques in order to use our two-dimension retinal images to perceive a three-dimensional world. The difference is that for visual perception these various cues are automatically employed and interpreted, in art they are consciously and purposely used to convey the effect of depth. And psychologists have also gained a better understanding of how we perceive size and depth by studying errors in judgment. There are various forms of visual illusions, which tell us a great deal about how the perceptual system normally works. There are color illusions, where the same shade appears different due to surroundings. Relative size illusions occur when objects we'd normally perceive as being the same size are presented in such a way that they appear quite different in size. A related phenomenon is the moon illusion, in which the moon looks much larger near the horizon than high in the sky, even though the size of the retinal image cast by the moon remains the same. Apparent motion illusions are the result of complex shading effects that induce a sense of motion from a still diagram or picture. Impossible figures are just that, objects that could not actually exist in the world. These often result from different parts of the figure inducing different perceptual interpretations. Ambiguous figures can be interpreted in more than one way, with the brain vacillating between the possible interpretations.

An underlying theme worth following carefully is the perceptual system's use of information about relationships among various aspects of a scene. For example, frames of reference are critical to motion perception. We perceive that something has moved if its position changes relative to the earth or some stationary object such as a building or a tree.

There are two views of the way we make use of relational information. The unconscious-inference theory hypothesizes that unconscious mental "calculation" is necessary. The direct-perception theory maintains that we are biologically designed to pick up such relational information effortlessly.



DIGGING DEEPER: Time Perception

Reprinted from Okun, B. F., Fried, J., & Okun, M. L. (1999). *Understanding diversity: A learning-as-practice primer*. Pacific Grove, CA: Brooks/Cole. (pp. 118-119)

Each culture has its own concept of time. Anthropologists, sociologists, and others have devised certain theories of time that divide temporal concepts into manageable categories. E. T. Hall (1971) devised one of the most well known theories. Hall divides time into polychronic and monochronic time. In polychronic time, people engage in many tasks at any given moment. People are highly involved in their tasks. Time is viewed holistically, with the emphasis being on the activity of the moment. Time is cyclical (Gudykunst & Ting-Toomey, 1988). It is not a tangible entity, but is rather unstructured. In polychronic time, people tend to be more spontaneous, and they view appointments as being breakable. One reason for this is that the emphasis is on people, not on schedules (Samovar & Porter, 1995). This is in sharp contrast with monochronic time, in which only one task is undertaken at any given moment. Time is viewed as fixed in nature (rather than cyclical), and as a manageable entity. It is linear, not cyclical (Gudykunst & Ting-Toomey, 1988). It is seen as something tangible that can be divided and wasted (Samovar & Porter, 1995). As a result, schedules take on great importance and appointments are sacred (Hall, 1966, p. 82). There tends to be a strong link between the type of time a culture subscribes to and other cultural features. Collectivistic cultures, such as Latin American, Middle Eastern, Mediterranean, Japanese, and French cultures, tend to favor polychronic time. Individualistic cultures, such as German, North European, and North American cultures, tend to favor monochronic time (Samovar & Porter, 1995; Gudykunst & Ting-Toomey, 1988; Hall, 1982). Time is also related to whether a culture is high-context or low-context. In high-context cultures most of the information transmitted is contained in the physical context (the setting) or is internalized in the people who are interacting. (In other words, the context gives the message its meaning.) As a result, very little information needs to be transmitted explicitly. In contrast, low-context cultures put most of their information into the explicit message. Most of the information is stated verbally. The United States tends to be low-context, whereas China, for example, is high-context (Hall, 1971). There is a strong correlation between high-context cultures and polychronic time and low-context cultures and monochronic time (Hall, 1971).

Gudykunst, W. B., & Ting-Toomey, S. (1988). *Culture and interpersonal communication*. Newbury park, CA: Sage.
Hall, E. T. (1966). *The silent language*. New York: Doubleday.
Hall, E. T. (1971). *Beyond culture*. New York: Anchor/Doubleday.
Hall, E. T. (1982). *The hidden dimension*. New York: Anchor/Doubleday.
Samovar, L. A., & Porter, R. E. (1995). *Communication between cultures*. Belmont, CA: Wadsworth.

States of Consciousness: Sleep, Meditation, and Hypnosis

We all normally experience different states of consciousness. Waking experience is just one of them. Sleep is another state of consciousness and is not the same as being unconscious. During episodes of meditation and while under hypnosis we're actually in a state similar to that of sleep onset. Sleep has a restorative function. During deep sleep (delta wave sleep) the body rests and repairs itself. During REM sleep the brain sorts through information. The brain is really quite active during certain stages of sleep, especially REM sleep.

Sleep Across Species: Periods of acquiescence are common to the vast majority of multicellular animals. The frequency, duration, and nature of these episodes differ from species to species, but for the most part they are regularly occurring periods of rest and restoration. And dreaming is part of sleep for animals as it is for humans. There doesn't appear to be any rule regarding the average amount of sleep particular creatures need. Neither predator versus prey relationships, diurnal versus nocturnal habits, size, nor metabolism are very good predictors of how much sleep a particular animal might need.

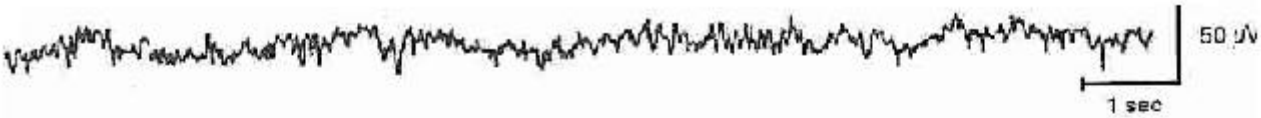
Amount of Sleep Needed: Research on humans has shown that the amount of sleep needed varies quite a bit between individuals and also decreases with age. However, regardless of the amount, we need to sleep on a regular basis. It's often cited that the average person needs eight hours of sleep per night. Although that's true, remember it's a statistic. It's also a cultural artifact as it divides up the day nicely into eight hours of work, eight hours of recreational time, and eight hours of sleep. The truth is some people can get by on only three to four hours sleep per night, others need as much as twelve. The necessary amount of sleep varies greatly, taking on the form of a bimodal distribution with the majority of people needing either seven and one half or nine hours of sleep. So although the average is eight hours, few would sleep eight hours if allowed to sleep as much as they felt like sleeping. Problems result from people being told that eight hours is the required amount of sleep they must have. Many people try to sleep eight hours, and only eight hours. So some aren't getting all the sleep they need, others think they have a problem because they have trouble sleeping that much. The right amount is that which causes you to feel refreshed when you get up, as well as alert and energetic throughout the day. There's no real benefit to sleeping more than you need to, but it's not good to sleep less than that. An individual must determine their own unique requirements. To do this, take a few days when you can sleep as long as you want. Over the first couple days you may sleep a lot, to make up for any deficits due to not having gotten enough sleep for awhile. After that you should start sleeping about the same amount of time from night to night. This is the amount of sleep you naturally need to get every night, and it's unique to you. It might only be six hours, it might be ten and one half. Whatever the amount, that's how much you need to get on a daily basis. Now for a number of reasons we tend to need less sleep as we get older, so you might want to recheck this every five to ten years.

Sleep Research: Before the mid-1950s little was known about the physiology of sleep. The electroencephalograph (EEG) amplifies and monitors patterns of electrical activity from various locations on the scalp that reflect patterns of electrical activity in the brain. Taken together these readings yield wave patterns that represent gross brain activity. And it was found that particular brain wave patterns are specific to different levels of consciousness as we descend into sleep.

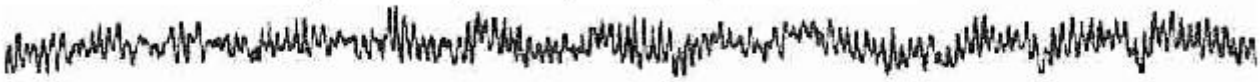
Stages of Sleep: We're not simply unconscious during sleep. We progress though a number of stages, some of which are marked by a good deal of brain activity. The easiest way to categorize the stages of sleep is by the characteristic brain wave activity occurring during each stage.

Stages of Sleep

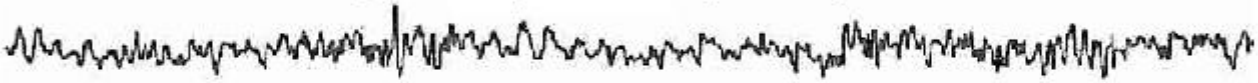
Beta Waves: Awake, High Frequency, Low Amplitude, Unsynchronized.



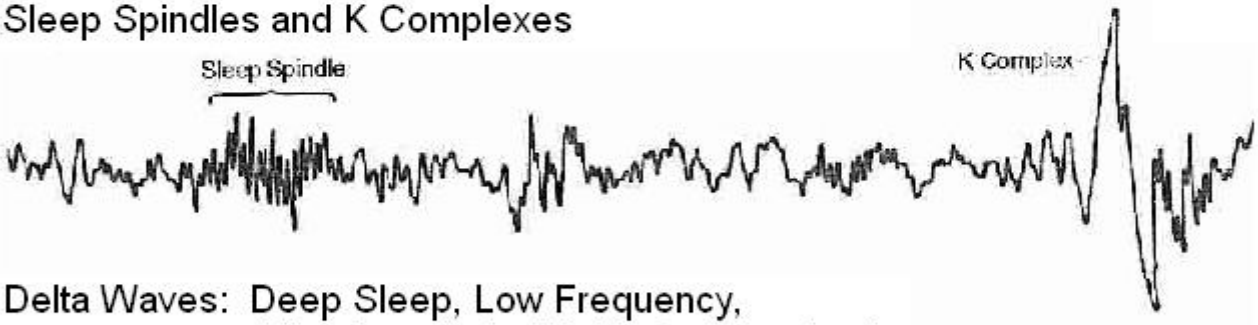
Alpha Waves: Very Relaxed, Lower Frequency, Higher Amplitude, More Synchronized.



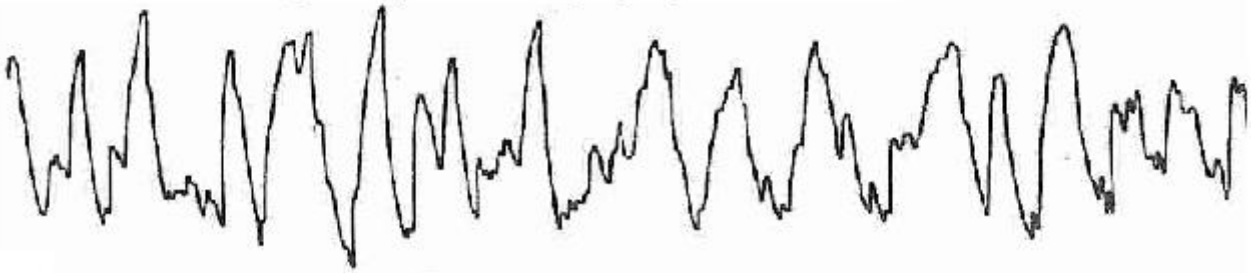
Theta Waves: Transitional, Lower Frequency, Little Change in Amplitude or Synchrony.



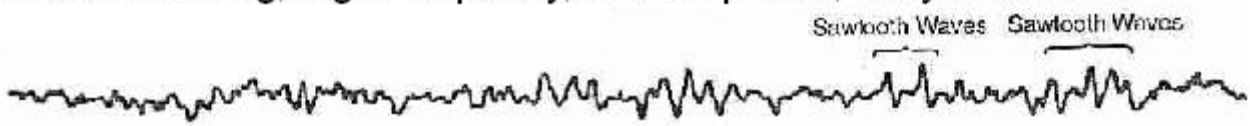
Sleep Spindles and K Complexes



Delta Waves: Deep Sleep, Low Frequency, High Amplitude, Highly Synchronized.



REM: Dreaming, High Frequency, Low Amplitude, Unsynchronized.



Beta Wave Activity - When awake our brains emit a pattern of high frequency, low amplitude, unsynchronized brain waves. Consider that various parts of the brain are all actively dealing with all sorts of information, there's a lot of activity (high frequency). Since the brain isn't really working in unison, the electrical activity varies from location to location over time (low amplitude). And much of this activity is independent, so the brain wave pattern is rather chaotic (unsynchronized).

Alpha Wave Activity - As we enter a state of deep relaxation, just prior to actually entering sleep, our brains emit a pattern of lower frequency (8-12 cps), higher amplitude, more synchronized brain waves. Usually, we reduce the amount of stimulation we receive when trying to go to sleep. We lie down with our eyes closed in a quite and darkened location. So there's less information for the brain to deal with, and fewer areas are active (lower frequency). There isn't as much disparate activity going on because of the smaller amount of information (higher amplitude). And the brain activity that is taking place is more focused and better coordinated (more synchronized). There is often a good deal of clarity of thought associated with alpha wave activity. This is when we clear our heads, and often those elusive answers to problems we've been working come to us when we're in this state. This is the state of consciousness people try to obtain during meditation, and that is induced by hypnosis. The use of mantras in meditation helps to further focus brain activity, as does the guiding used to induce hypnosis.

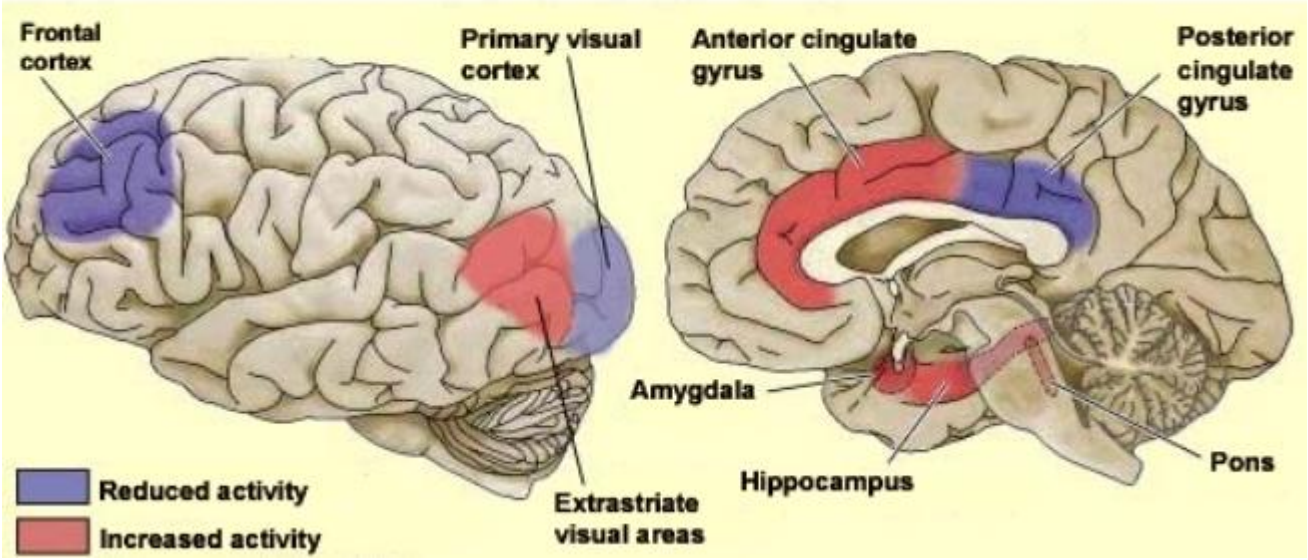
Theta Wave Activity - This represents the first stage of true sleep, but it is a transitional state. At this point our brains emit a pattern of even lower frequency brain waves (3-7 cps), but with no real change in amplitude. But there are occasional variations. Sleep spindles are brief periods of increased frequency (12-14 cps) perhaps due to the brain rousing back toward alpha or beta activity. There are also K Complex spikes having high amplitude, perhaps a precursor to the delta wave pattern that follows this stage.

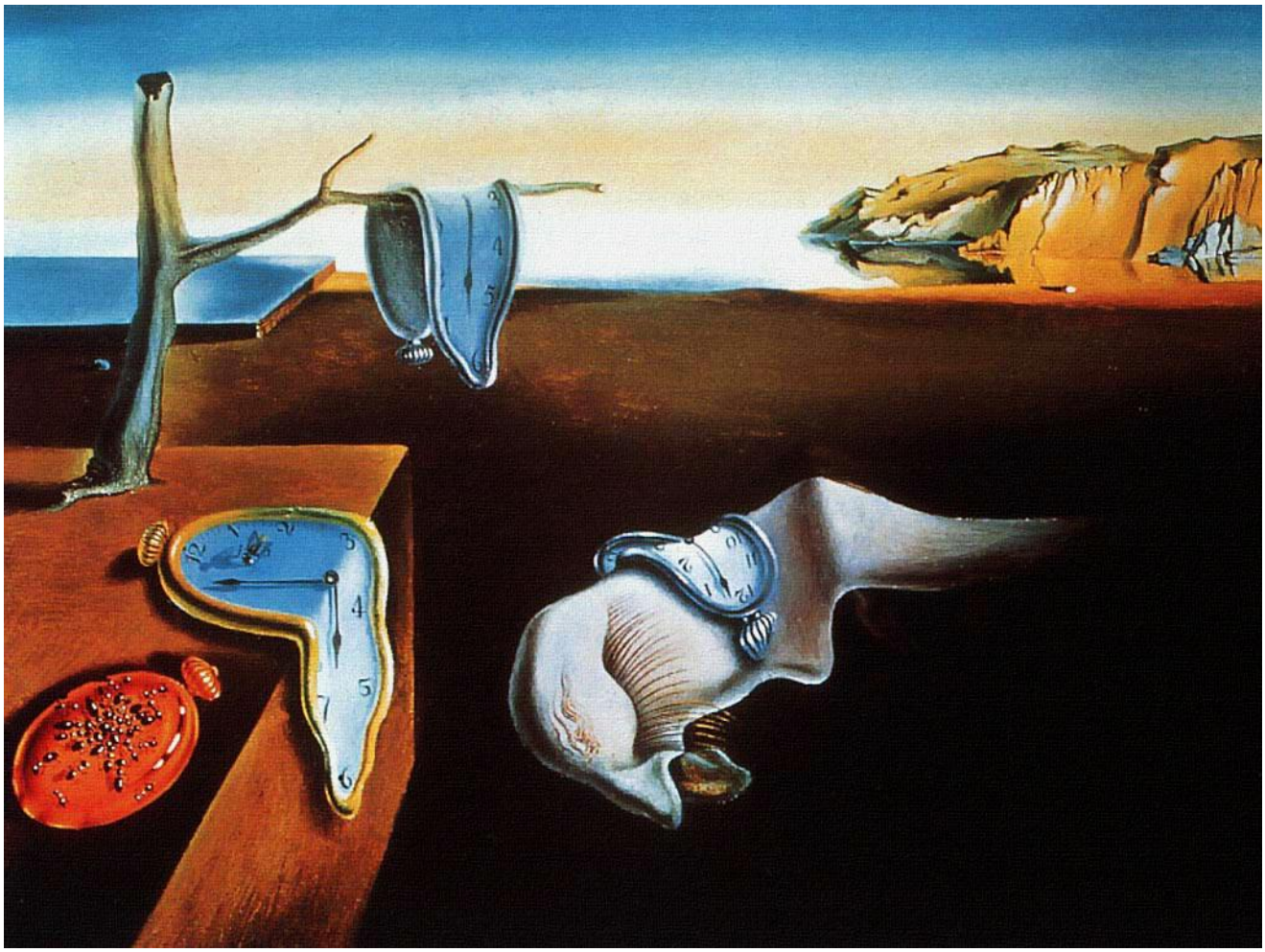
Delta Wave Activity - This is deep sleep and our brains emit a pattern of low frequency (1/2 to 2 cps), high amplitude, very synchronized brain waves. At this point very little information is being processed and there is little overall activity (low frequency). Much of the brain is more or less shut down, and the areas that are active are working in unison (high amplitude). The brain activity taking place is mostly devoted to governing basic life support, with the wave pattern corresponding to the general rhythm of respiration (highly synchronized). During this stage of sleep muscle tone is generally low as the body is performs restorative functions, tissue repaired, and some digestive activity takes place. People are difficult to awaken during this stage. And if aroused during this stage they feel sluggish, groggy, and disorientated.

It is also during delta wave sleep that people may experience night terrors or sleepwalk. Night terrors are not the same as nightmares. If we awaken from a nightmare we recall some of it and know why we are afraid. Those having night terrors usually wake up in a cold sweat and screaming, without having any idea as to what has terrified them so. Similarly, people who are awakened while sleepwalking are often scared, disoriented, and have no recollection of how they got to wherever they happen to be at. Both of these conditions most commonly occur in young males.

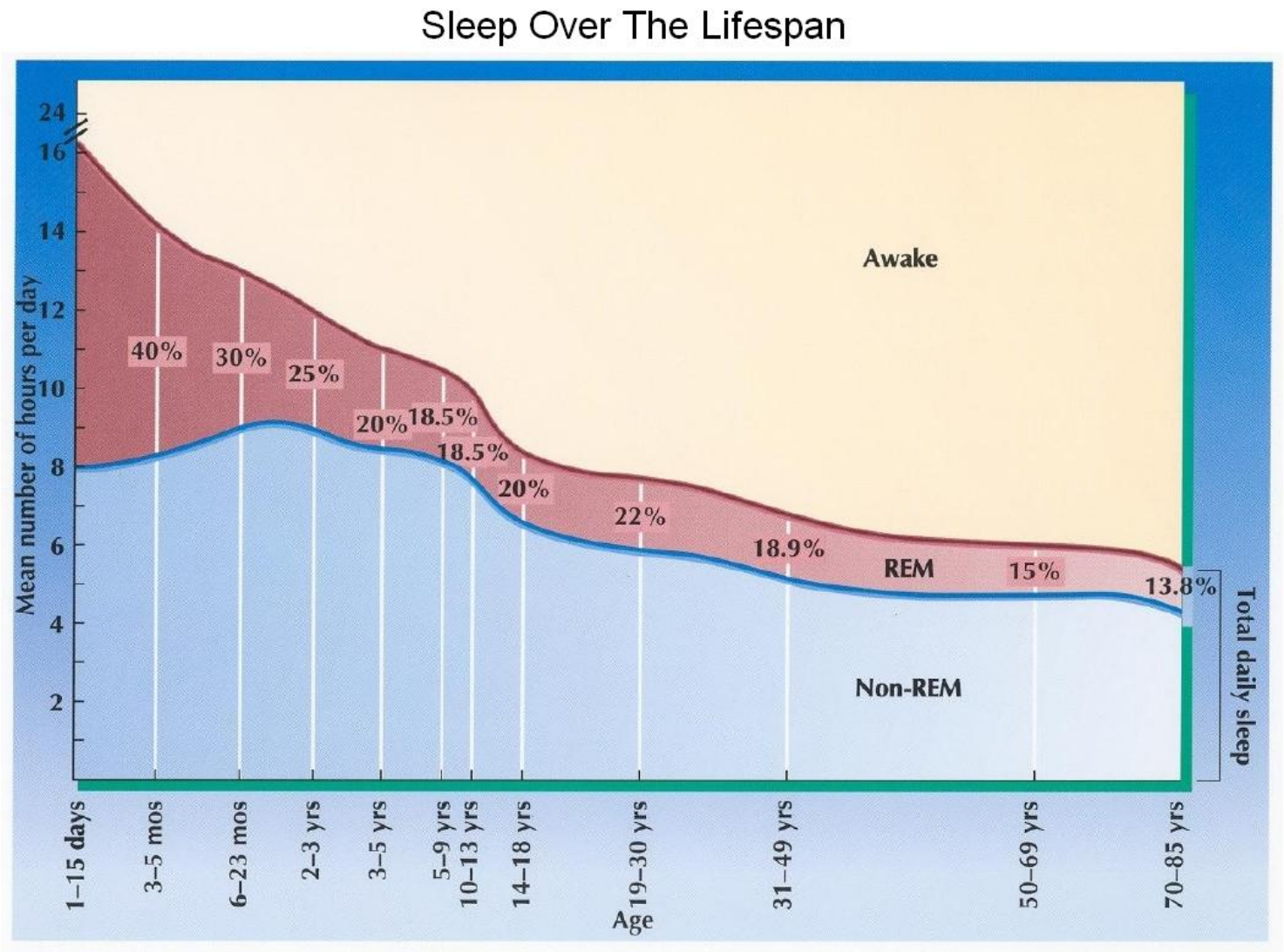
Rapid Eye Movement (REM) Activity - Also known as paradoxical sleep, there are a number of peculiar aspects to this stage of sleep. Our brains emit a pattern of high frequency, low amplitude, unsynchronized brain waves. This is quite similar to the beta waves emitted when we are awake. It is during REM sleep that we dream. Dreaming seems to involve a great deal of information processing as we attend to the subject matter of our dreams. As a result, various areas of the brain are active (high frequency) and independently processing different aspects of that information (low amplitude and unsynchronized). The hippocampus, the amygdala, and the visual association cortex are particularly active. The activity in the hippocampus indicates that dreaming is involved in memory, most likely in the consolidation of memories into long term storage. The activity of the amygdala reflects the emotional aspects of dreaming often reported. And this may be related to the activity of the hippocampus as associating strong emotions to information has been linked to better memory retention. The activity of the visual association cortex no doubt reflects our reliance on vision for much of the information we gather. The imagery in dreams is probably related to the processing of that information. Although the eyes move a great deal during this stage, there's no real evidence to suggest they're actually following the images in our dreams. Another area of the brain active during this stage is the pons. It sends out inhibitory signals to the muscles of the body, so that we're essentially paralyzed during REM sleep. This prevents us from getting up and acting out our dreams. Again, sleepwalking does not occur during this stage, but during delta wave sleep. It is also the case that we are functionally blind at this time, with input from the eyes being suppressed. A good number of people actually spend much of their time asleep with their eyes open.

Brain Activity During REM Sleep



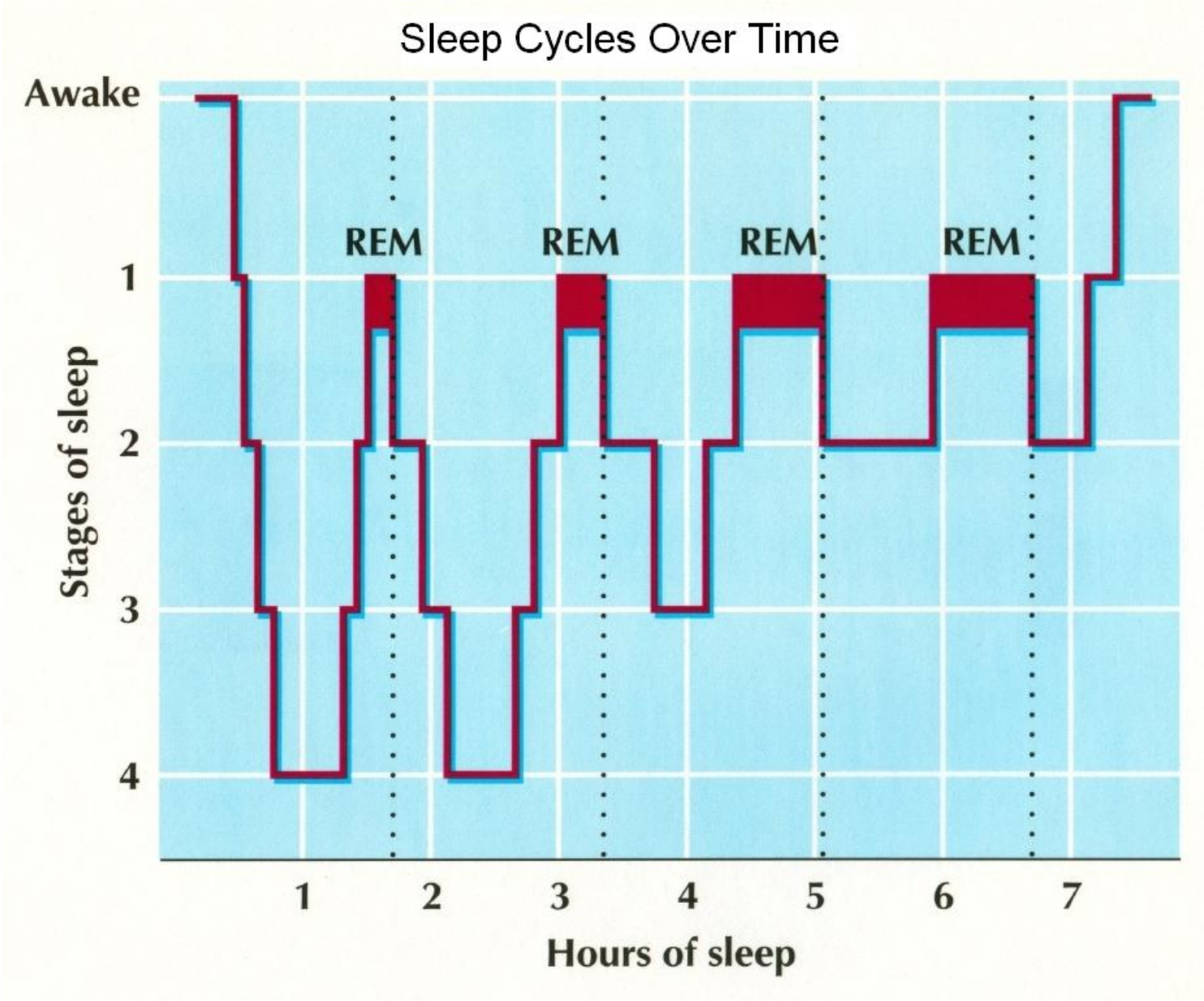


The nature of dreams, and their interpretation, has been an area of interest throughout human history. Dream interpretation and analysis is still practiced in clinical psychology. Dreams are believed to give insights into a person's unconscious thoughts. Most of this is based on the idea that dreams are symbolically coded. So once these symbols are decoded we can understand what our dreams mean. From there we may be able to determine underlying conflicts or problems that we're trying to deal with at an unconscious level. Of course, we only remember a fraction of our dreams. Often the details of those we do remember upon waking quickly fade. So therapists usually instruct patients to write down the details of their dreams immediately upon waking. However, it has also been proposed that dreaming plays a special role in memory. As we acquire new information we need to decide what is useful and what is not. Dreaming is believed to serve as a clearing house for recent information. We review that information one last time before either discarding it, or retaining it in long-term storage. Note that the very young spend a much greater proportion of sleep in REM compared to the elderly. And for the very young, everything is new. So there may be a lot more to sort through every night. On this view writing down your dreams would be counterproductive, as you'd then be trying to remember all the useless stuff your brain was trying to purge from the system.

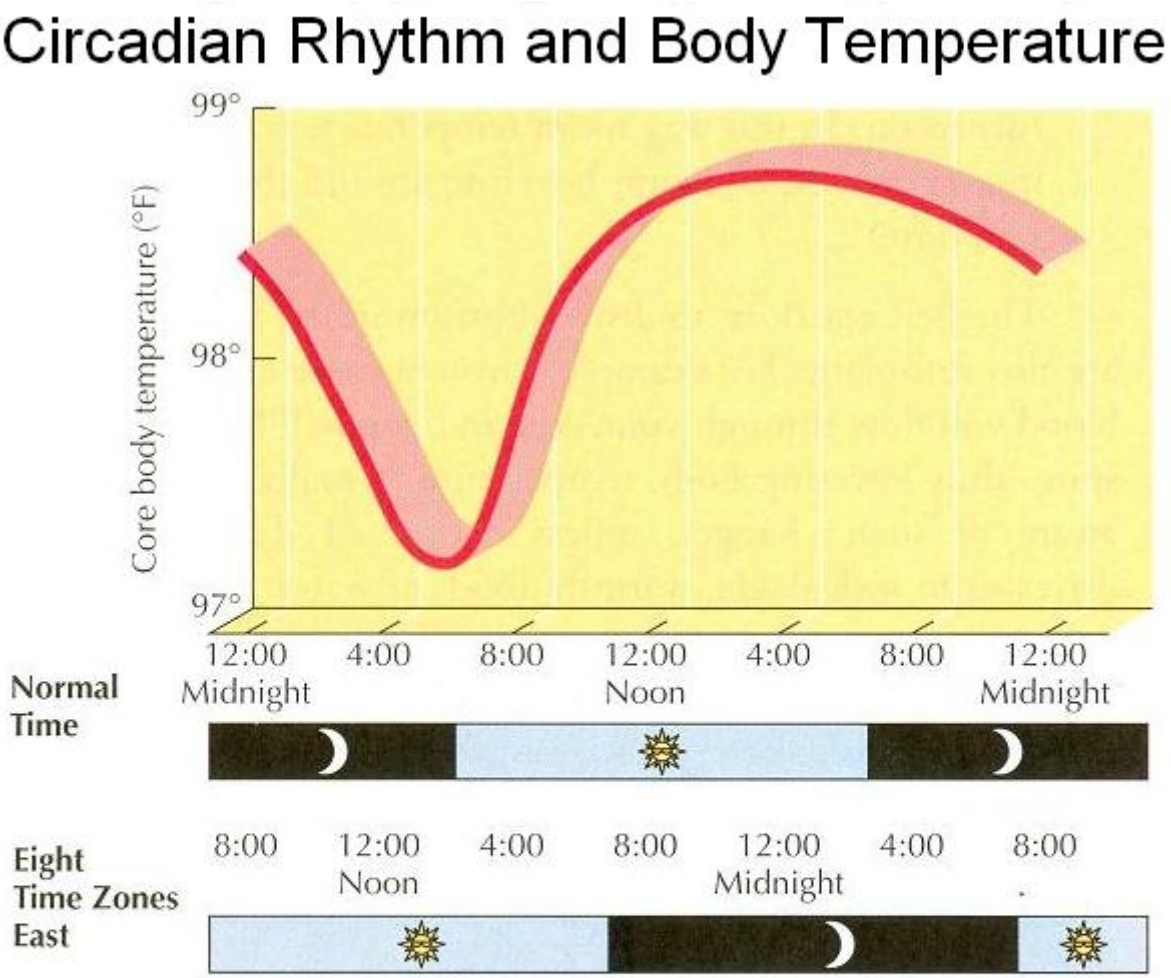


Nightmares are unpleasant, but not to be confused with the night terrors that occur during delta wave sleep. The emotions they generate may help in remembering some of the information they carry. Recurring dreams may simply be a form of state dependent learning, where being asleep serves as the cue for recalling the dream and replaying it. Lucid dreaming involves the realization that you are dreaming, then attempting to control and direct the events of the dream.

Sleep Cycles: After the initial episode of REM sleep about 90 minutes have elapsed. Then we drift back down through theta wave sleep to delta wave sleep. After that we go return to REM sleep. We continue to cycle through these stages of sleep for the rest of the night, each cycle lasting approximately 90 minutes. However, we spend progressively less time in delta wave sleep and more time in REM sleep as the night progresses. Presumably this is because after the first two or three episodes of delta wave sleep much of the needed physiological restoration of the body has been completed. So more time can be devoted to the psychological processes occurring during REM sleep. That's why the majority of people naturally sleep either seven and one half or nine hours, that translates into five or six 90 minute sleep cycles. Now if you're on a tight schedule you should plan your sleeping (and set your alarm clock) on the basis of 90 minute cycles, not hours. You want to wake up at the end of a REM period (brain waves similar to waking state), then you'll be fairly alert. If you wake up from a delta wave period you'll be groggy and listless. It's also better to most of your sleeping all at once. Short naps can be refreshing, but breaking up your sleep into three separate three hour rest periods during the day is not as good as sleeping nine hours straight through.

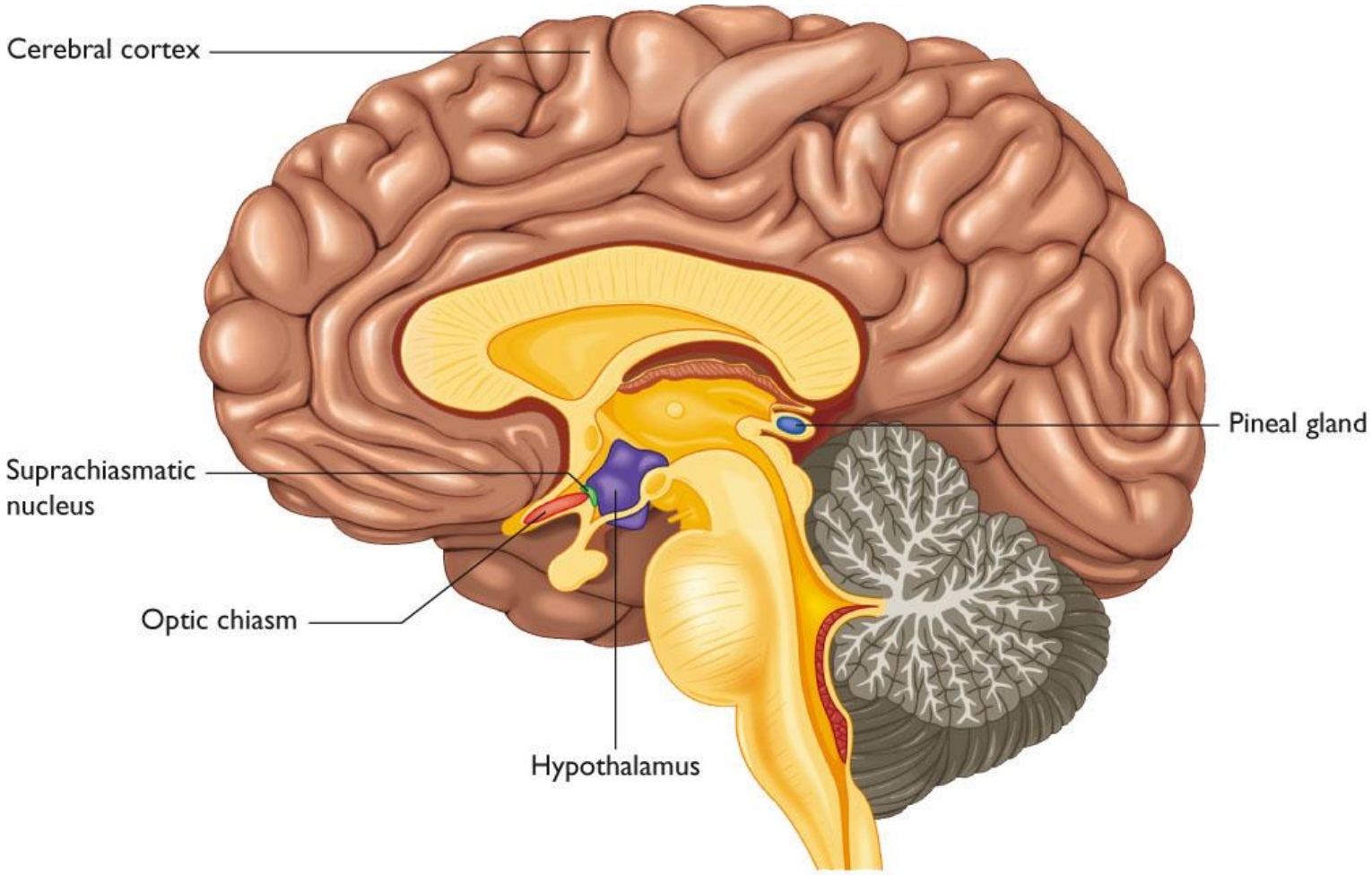


Circadian Rhythm: Our sleep is tied to an overall daily cycle. This internal clock is our circadian rhythm. Based on this, body temperature varies over the course of the day, as do performance levels. We're at our best midday, whatever that happens to be for a particular individual.



● **FIGURE 9.2** Core body temperature is a good indicator of a person's circadian rhythm. Most people reach a low point 2 to3 hours before their normal waking time. It's no wonder that both the Chernobyl and Three Mile Island nuclear power plant accidents occurred around 4 A.M. Rapid travel to a different time zone, shift work, depression, and illness can throw sleep and waking patterns out of synchronization with the body's core rhythm. Mismatches of this kind are very disruptive (Hauri & Linde, 1990).

Light, especially sunlight, helps to keep the circadian rhythm aligned with the 24 hour day. Jet lag is due to our internal clock becoming out of synch with the prevailing cycle of light and dark at our new location. It takes time to readjust the system. Experimental subjects that have been subjected to conditions of continuous light show a gradual drifting of their circadian rhythms. The suprachiasmatic nucleus governs the circadian rhythm. Its proximity to the optic chiasm allows it to monitor the amount of incoming light. Daily exposure to daylight facilitates the synchronization of our circadian rhythm to the prevailing conditions of light and darkness constituting day and night. Related to this may be the finding that lack of sunlight is linked to an increased incidence of depression. For people living in the northern hemisphere depression is more common during the winter months of December and January when the days are shortest. This can be a serious problem for people living near the artic circle during winter when there may be less than one half hour of daylight per day. It's speculated that this has something to do with limited opportunity to update and reset our internal clocks, so that we get out of alignment.



Sleep Deprivation: Going without sleep is not a good plan. It adds stress, taxes the body, and causes increased mental fatigue. Particularly problematic is the loss of REM sleep. If you go with only a few hours sleep per night you may get enough delta wave sleep to ward off physical exhaustion and keep going. However, without adequate REM sleep mental functioning and mood deteriorate. Attention, concentration, reaction time, motivation, perception, problem solving, decision making, and judgment progressively worsen with insufficient REM sleep. Coupled with these decreases in performance are increases in confusion, irritability, impulsivity, suggestibility, and often substance abuse (especially the use of stimulants to keep going). In extreme cases there have also been reports of hallucinations and paranoia. These effects can be particularly problematic when engages in activities that require one to be alert and thinking clearly such as driving. Indeed, the effects of sleep deprivation on driving seem to be quite similar to those attributed to alcohol intoxication. In the United States, from 1989-1993, driver drowsiness/fatigue was officially cited as the cause of an average of 56,000 accidents and 1544 fatalities per year. That's 3.6 percent of annual fatalities.

It should be noted that the effects of sleep deprivation, though progressively growing in severity with continued deprivation, are only short term. Once adequate sleep is obtained psychological functioning returns to normal. And those who have gone for prolonged periods without sleep, or with very little sleep, don't have to make up all the time they've missed once able to sleep for as long as needed. However, they do show REM rebound, sleeping a greater than normal proportion of the time asleep in REM sleep for the next few days. So REM sleep, and the psychological functions it serves, seems to be especially critical. By the way, Randy Gardner set the established record in 1965. He went 264 hours without sleep, about 11 days.

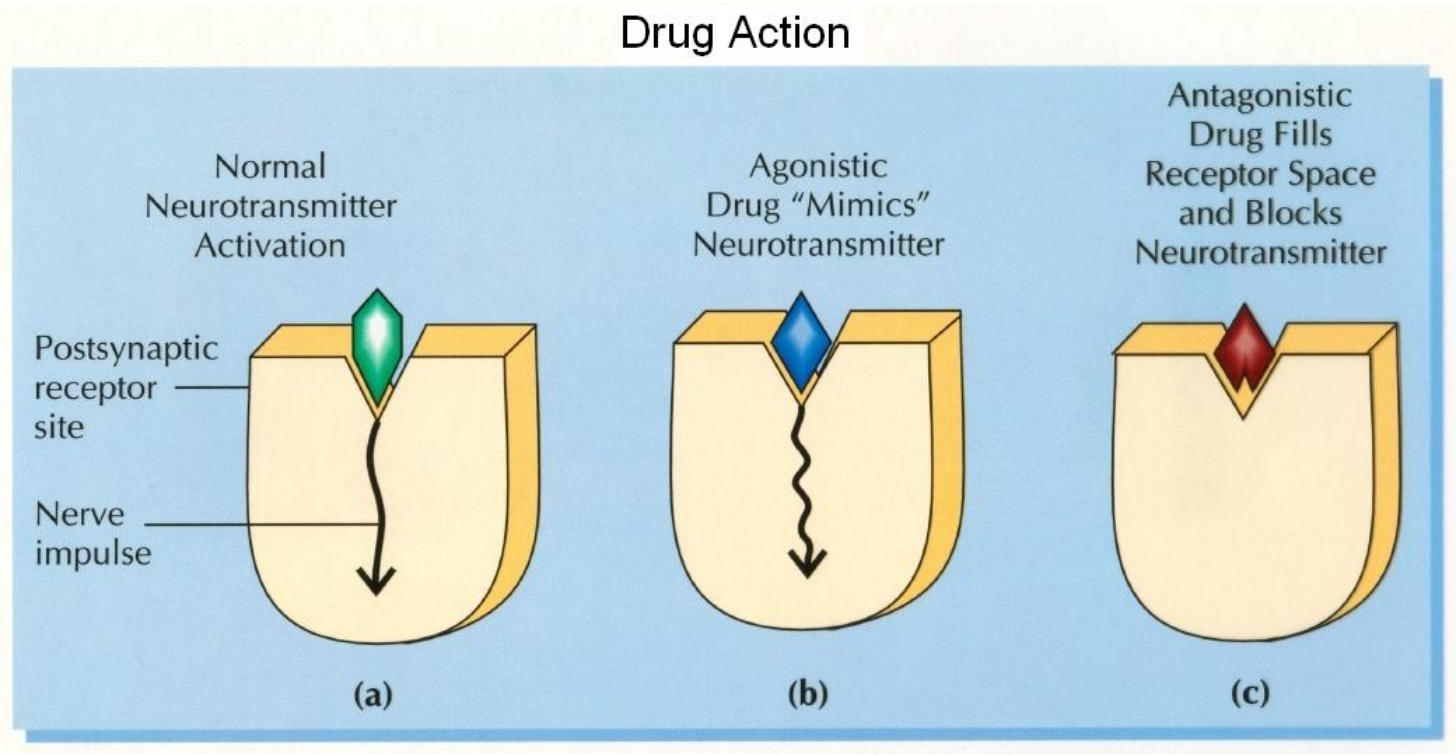
Sleep Disorders: Besides night terrors and sleepwalking there are a number of other sleep disorders. Two that have been extensively studied are sleep apnea and narcolepsy.

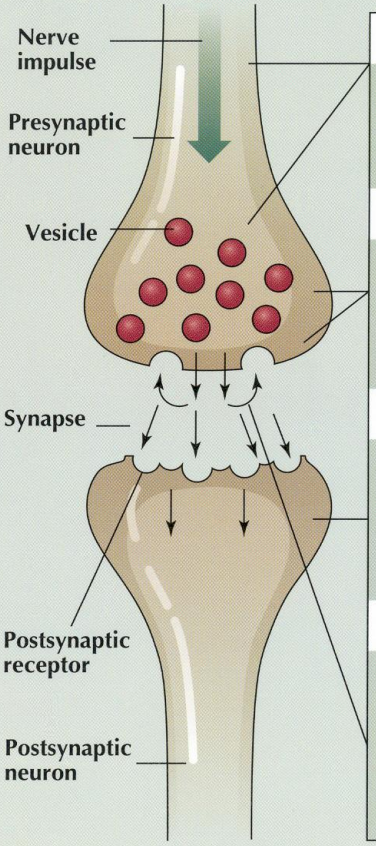
Sleep Apnea - This condition is the result of airway constriction during sleep. What happens is that the soft tissue at the back of the throat relaxes and droops down closing the airway, especially if the person is rather heavy set and sleeps on his or her back. Excessive snoring can be a symptom of this condition. But the real problem is that the restricted airflow results in a lack of oxygen. People with this condition repeatedly wake up gasping for breath, without any later recollection of those events. This can happen as many as 200 times a night, preventing a good night's sleep. So then the person feels tired and suffers from all the effects of sleep deprivation during the day.

Narcolepsy - This is a unique condition characterized by sudden attacks of sleepiness, and falling asleep and dreaming at any time. They may also experience related muscle weakness and paralysis. People with this disorder go right into REM sleep when this occurs. Research suggests that it may be due to a lower than normal number of neurons that produce the neurotransmitter orexin or receptors in the brain for orexin. Orexin normally helps keep people awake.

Psychoactive Drugs

A drug is any chemical substance that affects the body beyond merely providing nourishment or hydration. All manner of substances can act as drugs and it's actually quite difficult to definitively say what is and what is not a drug. Psychology is concerned with psychoactive drugs, those drugs that have an impact on psychological processes. Psychoactive drugs are generally grouped and classified by their effects, not their chemical compositions. These drugs have their effects by acting on various aspects of neural transmission at the synapse. Almost any substance may act as a drug, even a psychoactive drug, sometimes depending on the amount consumed or how it is taken. For instance, even drinking and then urinating excessive amounts of water (30 liters per day) can sufficiently alter the electrolyte balance of the body to induce a drunken-like state. And the amino acid tryptophan, found in turkey and warm milk, has sedative properties. To be considered here are recreational drugs and drugs of abuse, not therapeutic drugs.





How neurotransmitters work	Agonist drugs (mimics neurotransmitter effects)	Antagonist drugs (blocks neurotransmitter effects)
(Step 1) Production		
(1) Neurotransmitter is produced.	Drug serves as a precursor for neurotransmitter synthesis (e.g., L-DOPA is used to make dopamine).	Drug blocks production.
(Step 2) Storage and release		
(2) Neurotransmitter is stored in vesicle. When impulse arrives, neurotransmitter is released.	Drug increases the release of neurotransmitter (e.g., black widow spider venom increases acetylcholine release).	Drug blocks neurotransmitter storage and/or release.
(Step 3) Reception		
(3) Neurotransmitter binds to postsynaptic receptors and activates them.	Drug attaches to receptors and activates them (e.g., Nicotine activates acetylcholine receptors and morphine activates endorphin receptors).	Drug blocks neurotransmitter by filling receptor space but doesn't activate the neuron (e.g., drugs for schizophrenia block dopamine).
(Step 4) Inactivation		
(4) Excess neurotransmitter is deactivated by reuptake or enzymatic breakdown.	Drug blocks inactivation of neurotransmitter leaving more in the synapse to stimulate receptors (e.g., cocaine and nicotine block reuptake of dopamine and norepinephrine).	

Routes of Drug Administration: Drugs can be taken into the body by a number of different routes. For psychoactive drugs the goal is usually the same, to get the drug into the bloodstream and ultimately to the brain. For some drugs this may be done in a number of different ways. However, for other drugs it may be necessary to utilize a particular route of administration, as it may be either risky or ineffective to take them in other ways. A major factor that determines how a drug should be taken is the degree to which it is water soluble versus lipid soluble. Water solubility allows it to be readily carried by blood plasma, lipid solubility affects how readily it can cross the blood brain barrier (primarily composed of fats generated by the glial cells) of the central nervous system.

Oral Administration / Ingestion - Eating or drinking the substance. This is a very common method of taking drugs (alcohol, pills, mushrooms, marijuana, opium/morphine). Also the most complicated route of administration as the drug must interface through the lining of the stomach and small intestine. Delays occur if the drug must first dissolve (pills), and if there are other substances such as food or beverages competing with the drug for access through the stomach and small intestine lining. In some cases particular foods may even deactivate a drug, or otherwise alter its effects. The drug must then pass through the liver on the way to the bloodstream. Liver enzymes may also affect the drug by partially or almost completely metabolizing it into a deactivated form (nicotine). Overall, this route requires about 20 minutes before enough of the drug gets into the system to start affecting the nervous system. However, it also allows for longer lasting effects as the drug continues to be absorbed into the system. Another advantage is that this route offers a limited degree of control in that one can regulate the intake easily, and there is the option of 'taking back' some of the ingested drug by emptying the contents of the stomach. Long-term drawbacks include ulcers, tumors, liver dysfunction.

Inhalation / Smoking - Inhaling various gases, atomized particles, or smoke. This is another common method of taking drugs (nicotine from cigarette smoke, marijuana, opium, crack cocaine, chemical fumes, nitrous oxide). It is very fast and efficient because the drug interfaces directly through the lung tissues into the bloodstream. From this point the drugs pass directly to the heart and then right to the brain (hence no initial filtering by the liver). The drug can be entering the brain within 5 to 8 seconds, faster than any other route of administration. The drug does not initially pass through the liver, so no amount of it is metabolized before reaching the brain. However the drug cannot

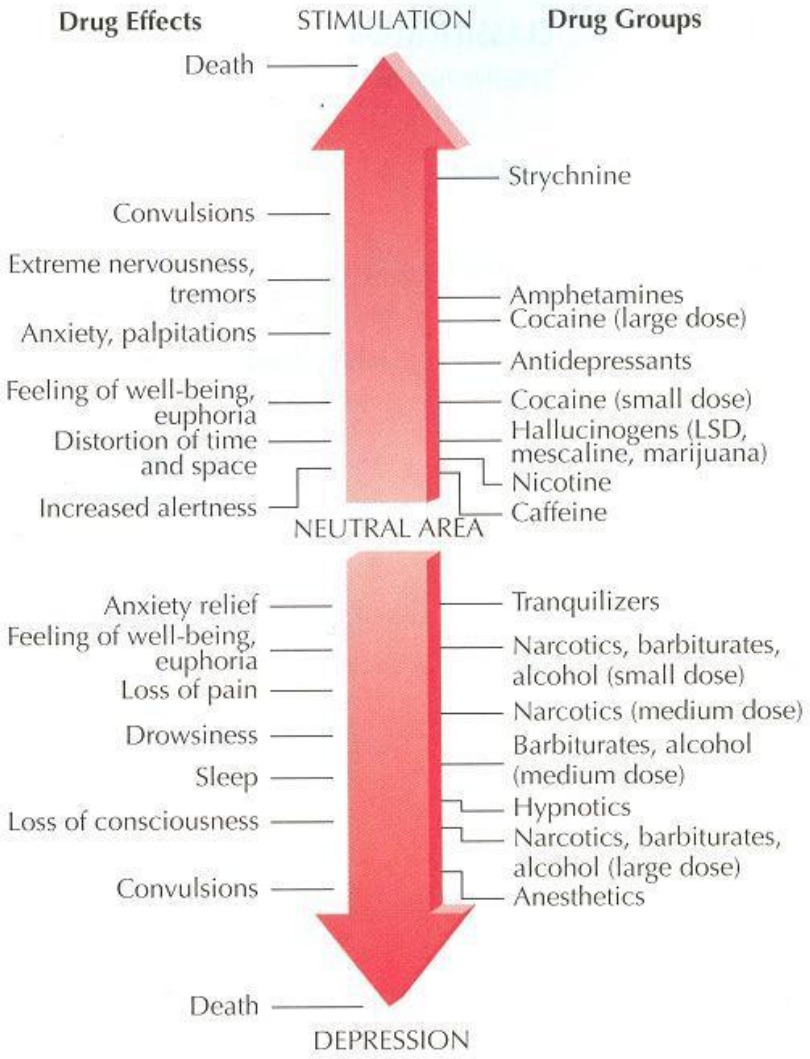
be stored in the lungs, so once administration is stopped the effects may rapidly decrease. Also, the drug needs to be can more water soluble (salt or acidic) to readily pass into the bloodstream by this route. Long-term drawbacks include a number of lung diseases and heart problems.

Injections – The various forms of injecting drugs are most commonly used medically. The most effective method would be to directly inject a drug into the carotid artery, from which it would enter directly into the brain. However, arteries are simply very difficult to locate in order to perform such an injection. Because they are blue (deoxygenated blood) veins are utilized instead. Intravenous injection (iv) generally utilizes the brachial artery in the arm, and is sometimes used by recreational drug users. The drug follows the bloodstream to the heart, interfaces with the lungs, goes back to the heart, and then to the brain. This takes about 10 to 15 seconds. Other than this slight delay of onset the initial impact is as intense as that obtained by inhalation. Again the drug does not initially pass through the liver, so no amount of it is metabolized before reaching the brain. A particular advantage is that only the veins and arteries are exposed to the drug, so substances that might be irritating to other forms of tissue can be taken this way. Dangers include infections, transfer of disease, and eventually the collapse of the veins at points of repeated injections. Less commonly used recreationally are intramuscular (im) and subcutaneous (sc) injections. The larger the muscle injected into, the longer it takes for affective amounts of the drug to enter the bloodstream, but also more drug can be injected and effects can last for an extended period. Injecting drugs under the skin is more often used medically and absorption is slow. One last form of injection is interperitonial (ip), used in medical research with animal subjects. Drugs are injected into the fluid filled sack holding the guts because veins and other points of injection are just too difficult to readily find with small animals.

Absorption via Mucous Membranes – Snorting utilizes the mucous membranes lining the nasal cavities. Oral absorption occurs through the mucous membranes of the mouth, palate, and throat. Anal and vaginal suppositories are also an option. A number of drugs are commonly administered this way (powdered cocaine, nicotine from cigars or chewing tobacco, LSD, alcohol). Onset is fairly rapid as large numbers of capillaries may directly interface with the mucous membranes lining the nasal cavities, mouth, and palette. These routes also bypass initial filtering by the liver, as drug goes directly into bloodstream, to heart and lungs, and then to the brain. Absorption is not as fast as inhalation or iv., but faster than other forms of injection or ingestion. This method is better adapted for more lipid soluble (alkaline) forms of drugs than other routes of administration, particularly inhalation. Drawbacks include local anesthetic effects, and with long-term use tissue deterioration or tumors.

Absorption Through the Skin – This method generally results in slow rates of absorption. Used primarily for medical applications, but also a means of accidental absorption of drugs and other chemicals (nicotine skin patches, LSD, chemical solvents). Drugs can get stock piled in the fatty tissues of the skin layers, so it may take time to completely remove drugs from the system. Skin irritation most common drawback, but a long-term build up to toxic levels of the chemical agents is also possible.

Psychoactive Drugs



Spectrum and continuum of drug action. Many drugs can be rated on a stimulation-depression scale according to their effects on the central nervous system. Although LSD, mescaline, and marijuana are listed here, the stimulation-depression scale is less relevant to these drugs. The principal characteristic of such hallucinogens is their mind-altering quality.

Psychoactive drug A substance capable of altering attention, memory, judgment, time sense, self-control, mood, or perception.

Stimulant A substance that increases activity in the body and nervous system.

Depressant A substance that decreases activity in the body and nervous system.

Physical dependence Physical addiction, as indicated by the presence of drug tolerance and withdrawal symptoms.

Withdrawal symptoms Physical illness and discomfort following the withdrawal of a drug.

Drug tolerance A reduction in the body's response to a drug.

Psychological dependence Drug dependence that is based primarily on emotional or psychological needs.

Stimulants: These drugs increase energy, activity, alertness, vigilance, and concentration. They are most commonly used to fend off fatigue and to stay awake, but are also used to obtain a high.

Caffeine – Probably the most commonly used drug, caffeine is found in coffee, tea, and soft drinks. Caffeine blocks the receptors for adenosine, a chemical that inhibits arousal and wakefulness. So the end result is increased arousal.

Caffeine Content of Common Dietary and Medicinal Sources

Source	Standard Amount (mgs)
Beverages:	
Rockstar - Punched (16 oz)	120
Red Bull (12 oz)	115.5
Rockstar (16 oz)	80
Jolt (12 oz)	72
Mountain Dew (12 oz)	55
Diet Coke (12 oz)	45
Dr. Pepper (12 oz)	41
Coca-Cola Classic (12 oz)	34
Coffee (8 oz):	
Brewed	80-135
Instant	65-100
Decaf Brewed	3-4
Tea (8 oz):	
Ice tea	47
Brewed	40-60
Instant	30
Green tea	15
Chocolate:	
Hot cocoa (8 oz)	14
Chocolate milk (6 oz)	4
Chocolate bar (1 oz)	3-6
Medications (per tablet):	
Vivarin	200
No-doz	100
Midol - Maximum Strength	65
Anacin	32
Dristan	30

Adapted from: Center for Science in the Public Interest

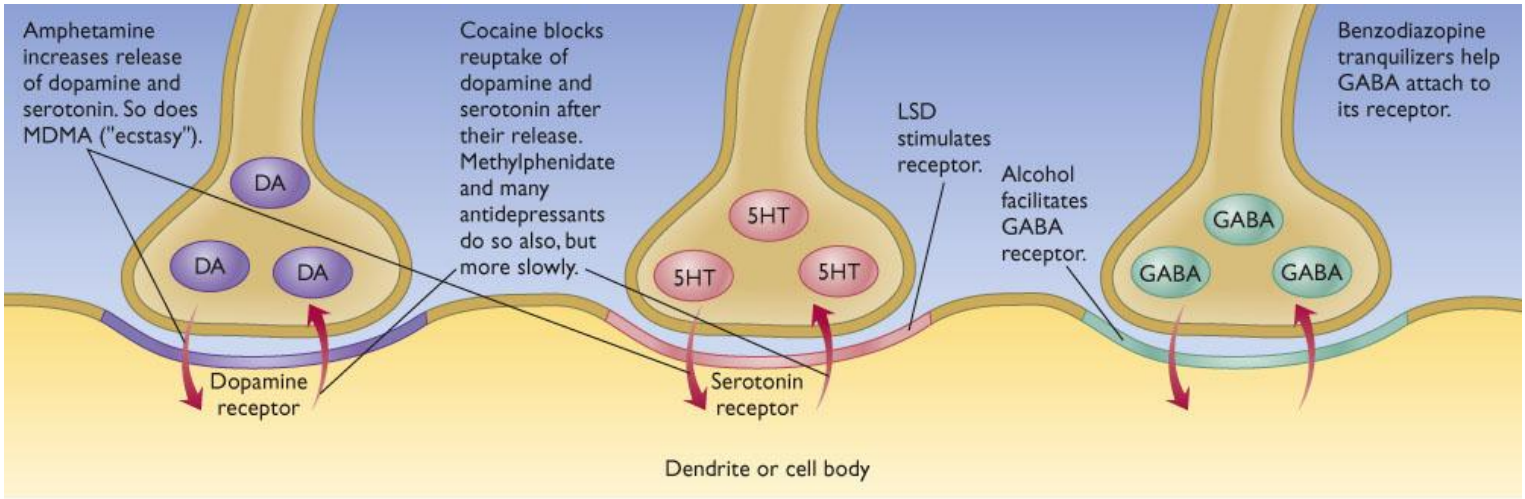
Nicotine – Found in tobacco products. Tobacco in the form of cigars, pipe tobacco, and chewing tobacco is moist, slightly oily, and alkaline. The route of administration is by absorption via the mucous membranes of the mouth, palate, and throat (as is the case with nicotine gum). Deeply inhaling cigar or pipe smoke into the lungs is ineffectual because the lungs don't readily absorb these alkaline, lipid soluble forms. The tobacco in cigarettes is dried, and as a result it is more acidic. Only a small portion of the nicotine is absorbed via the mucosa. The smoke must be taken into the lungs to deliver the nicotine for absorption. And nicotine can also be absorbed through the skin, hence the nicotine patch. Most commercial smoking remedies amount to nothing more than changing the method of nicotine delivery. Nicotine stimulates acetylcholine synapses. The receptors at these synapses are actually called nicotinic receptors. Although nicotine is toxic, and less than a gram can be fatal, the amounts taken to produce the characteristic effects are usually around 20-30 milligrams. The real health hazard related to smoking, especially cigarette smoking, comes from all the other chemicals in the smoke: Tar, bleach in the paper, chemicals to enhance flavor and accelerate burning, as well as traces of fertilizers and pesticides.

Cocaine – Derived from coca leaves, cocaine was first isolated in 1880. Sigmund Freud and Karl Koller introduced it as a means of weaning addicts away from morphine in 1884. It was soon discovered to be addicting in its own right, and Freud himself became addicted for a time. The alkaline form is cocaine hydrochloride, which is usually snorted and absorbed via the nasal mucosa. Free-basing is a chemical process that strips the hydrochloride radical from the cocaine base producing an acidic form known as crack that can be smoked. A much more intense, but short-lived high results from smoking crack. Cocaine works by preventing the reuptake of dopamine (and to a lesser degree serotonin) released into the synapses, especially those in the pleasure centers of the brain (ventral-medial hypothalamus). As a result dopamine remains in the synapses longer and can repeatedly bind with the post-synaptic receptors stimulating the adjacent neurons. Cocaine is also an effective local anesthetic and coagulating agent, so it has medical uses in oral and nasal surgery. Procaine (Novocaine: Developed in 1905) and lidocaine (Xylocaine: Developed in 1948) are both synthetic chemical derivations of cocaine that produce the anesthetic effects without the euphoric effects or addictive potential.

Methylphenidate (Ritalin) – Prescribed for attention deficit disorder, Ritalin helps those with this disorder focus their attention reduces distractions. For those without attention deficit disorder it acts as a more general stimulant. Ritalin works on the same receptors as cocaine, by the same means. However, taken in pill form it reaches the brain gradually and continues to be absorbed over a longer time frame. Crushed and snorted it can be quite similar to cocaine.

Amphetamine and methamphetamine – Amphetamines were first synthesized in the 1940s and used extensively by the military. Methamphetamine was discovered in the late 1980s, produced from various cold medications treated with household solvents such as drain cleaner. Both can be taken orally, but the preferred way to administer methamphetamine is by smoking. Smoking methamphetamine produces an intense high rivaling that of crack cocaine, but it is far less expensive. Amphetamine and methamphetamine work by both blocking the reuptake of dopamine (and to a lesser degree serotonin) and by increasing the amount of neurotransmitter released into the synapses, especially those in the pleasure centers of the brain (ventral-medial hypothalamus).

Cocaine, amphetamine, and methamphetamine – As the method of action for each of these is similar there are a number of common effects. First, reuptake of the neurotransmitters is blocked so the remain available and active longer. That results in more stimulation of the adjacent neurons, but also allows for the neurotransmitter molecules to be carried away. This can occur faster than the neurons can produce more, so after the drug wears off there is a shortage of neurotransmitter. This results in what is known as a crash, wherein the user is listless, tired, and depressed. Prolonged excessive use of any of these in any form can lead to paranoid delusions (amphetamine psychosis) and certain kinds of hallucinations. The body also adapts to prolonged use by increasing the number of dopamine receptors. The result is that more dopamine is needed to stimulate the neurons. When one stops using, the normal amounts released are often insufficient, reducing one's general level of arousal and experience of pleasure. So various things that might otherwise provide pleasure do not, a condition known as ahedonia. It can take years for the body to readjust, which is why a good number of addicts relapse. All of these have a high potential for addiction, but the risk of addiction is much greater for crack cocaine and methamphetamine due to the intense high produced from smoking them. Crack cocaine and methamphetamine also rapidly increases heart rate and blood pressure, which can result in heart attack or stroke.



Sedatives / Depressants: These drugs decrease arousal, decrease anxiety, promote relaxation, and have generally calming effects. They are often used to take the edge off of social situations, to suppress inhibitions, or as sleep aids.

Alcohol - Alcohol is produced by the fermentation of sugar and/or starches found in fruits, vegetables, and grain. Archaeological evidence points to the use of wine by ancient cultures going back at least 7,500 years ago. Actually there is a class of basic organic compounds referred to as alcohols. The type we consume and use for its sedative effects is ethanol, each molecule contains two carbon atoms. Propanol has three carbon atoms per molecule, is commonly used as rubbing alcohol, and is quite toxic when taken internally. Methanol is the alcohol derived from the cellulous found in wood and husks. Each molecule has one carbon atom. It is extremely toxic, often fatal, if taken internally.

The effects of drinking ethanol follow a rather orderly progression the amount ingested increases. This is because alcohol first sedates the higher centers of the brain (areas in the frontal lobe responsible for deliberate thought, decision making, as well as those areas responsible for inhibiting emotional responses and impulsivity). It does this by facilitating synaptic transmission where GABA (an inhibitor) is the primary neurotransmitter. So it's as if the brakes are off, and one acts out in ways that would normally be inhibited. However, as one continues to consume more alcohol other areas of the brain become sedated. This causes slowed reaction times, difficulty in comprehension, and loss of coordination. With still more alcohol an individual can become incoherent, and may lapse into unconsciousness as progressively lower centers in the brain are sedated.

>TABLE B–1 THE BEHAVIORAL EFFECTS OF BLOOD-ALCOHOL LEVELS

Levels of Alcohol in the Blood	Behavioral Effects
0.05%	Feels good; less alert
0.10%	Is slower to react; less cautious
0.15%	Reaction time is much slower
0.20%	Sensory-motor abilities are suppressed
0.25%	Is staggering (motor abilities severely impaired); perception is limited as well
0.30%	Is in semistupor
0.35%	Is at level for anesthesia; death is possible
0.40%	Death is likely (usually as a result of respiratory failure)

Source: Data from *Drugs, Society, and Human Behavior*, 3d ed., by Oakey Ray, 1983, St. Louis, MO: The C. V. Mosby Co.

An interesting point to consider about alcohol is that it is legal. The FDA often employs a criterion for approving new drugs as safe. It entails comparing the lethal dose to the effective dose. For most drugs that ratio has to be in excess of 20 to 1. For drugs used to treat terminal conditions such as AIDS or cancer the acceptable limit may be lowered to 10 to 1, as the patients are already at great risk. Yet for alcohol the ratio between what can kill you (0.40% of blood volume) and what induces pleasurable effects (0.05% of blood volume) is only 8 to 1.

Minor Tranquilizers / Anxiolytics – Most of these are synthetic compounds known as benzodiazepines. Chlordiazepoxide (Librium) was developed in 1947 but not sold commercially until the 1960s. It became the number one prescription drug during that decade. When diazepam (Valium), a more potent benzodiazepine, was introduced in the early 1970s it supplanted librium as the number one prescription drug. Another drug of the same class is alprazolam (Xanax), currently the most prescribed drug of this type. Flunitrazepam (Rohypnol) also belongs to this class of drugs. All of these drugs produce a calming effect by facilitating inhibitory synapses that utilize the neurotransmitter GABA. For the most part these drugs are used to reduce anxiety and stress. However, rohypnol is particularly potent and also produces poor muscle coordination and memory impairment. Easily dissolved in water or alcohol it has no color, odor, or taste. As such it has been used to subdue sexual assault victims, hence the term 'date rape drug.'

Barbiturates – These drugs produce heavy sedation, often referred to as sleeping pills. Barbital (Veronal), the first drug of this class, was synthesized in 1903. Phenobarbital (Luminal) was developed in 1912, amobarbital (Amytal) in 1923, pentobarbital (Nembutal) and secobarbital (Seconal) in 1930. Over 2,500 different barbiturates have been synthesized. They differ primarily in their lipid solubility, with greater lipid solubility translating into crossing the blood-brain barrier more quickly and thus rapidly affecting brain function. Nembutal and Seconal are the fastest acting. The sedation produced by barbiturates is not actually sleep. Rather, the individual is rendered unconscious. There is little, if any, REM sleep under the influence of barbiturates. They are highly addictive and they also suppress respiration, in large doses they may do so completely.

Synergism – This term refers to the tendency for certain drugs to interact in such a way as to greatly magnify their effects beyond a mere additive summing of those effects. This is particularly true when one combines various sedatives such as combining alcohol with either barbiturates or benzodiazepines. These combinations have often result in disastrous consequences such as coma and death. Part of the reason for this is that although they all produce sedative effects they do so by slightly different modes of action. So when combined they may affect different brain mechanisms. While either drug alone may make someone a bit drowsy, taken in combination a person becomes far more sedated than would result from just doubling the dosage of either one. For example, say three shots of alcohol produces a certain effect, and one valium also produces about the same effect. Now six shots of alcohol or two valium will produce about twice that effect. The problem is that combining three shots of alcohol and one valium can produce a far greater effect than that produced by merely doubling the dosage of either one alone. Three shots of alcohol and one valium may well produce better than five times the effect. And that can lead to sedation of lower brain functions, including those in the medulla governing heart rate and respiration.

Narcotics / Opiates: These drugs are potent analgesics. But they also produce a relaxed, unresponsive, dreamlike state. The opium poppy produces a sort of white paste during a 7 to 10 day period each year. Whether eaten, or dried and smoked, it relieves pain. In larger doses, or for those without pain it produces euphoria. Archaeological evidence suggests its use goes back to at least 6,000 years ago. Opium actually contains in excess of 30 related alkaloid compounds, producing varying degrees of analgesic and euphoric effects. Morphine, the primary and most potent active ingredient, was isolated from opium in 1806 by Frederich Serturner. Codeine, the second most important of these compounds was isolated in 1832. In 1874 the compound diacetylmorphine was developed, it is a transformation of morphine made by attaching two acetyl groups to the morphine molecule. In 1898 Bayer Laboratories began marketing it under the brand name Heroin. That slight chemical modification increases the lipid solubility of the molecule so it can enter the brain more rapidly, making it about three times as potent as morphine, producing a significantly greater initial high. However, once in the brain the acetyl groups detach and the heroin reverts to morphine. Methadone is another opium derivative, while Vicadin and Oxycotin are synthetic opiates. They all act on the central nervous system by mimicking the endorphins naturally produced by the body to inhibit and suppress the perception of pain. For the most part they block pain by their action in the brain, not by acting on pain receptors in the skin. And of course their euphoric effects are due to their effects on the brain. Excessive doses can result in extreme sedation, and can suppress the lower brain functions of the medulla governing heart rate and respiration.

Marijuana and Hashish: These drugs produce a calming effect and decreases the perception of pain. But these effects are qualitatively different than those produced by other sedatives and opiates. Marijuana and hashish also produce minor hallucinations, or sensory distortions, especially a perception that time is passing slower than normal. People under the influence of these drugs exhibit pupil dilation, often talk excessively, find things funnier than usual,

and may exhibit cravings for particular foods. Marijuana also has medical uses as an anti-emetic, pain reliever, and treatment for glaucoma. Marijuana is simply the leaves, or flower tops (buds), from the cannabis plant. Hashish is produced by manually extracting the resin from the leaves, in purest form it is nothing but resin, though usually it contains pieces of the leaves as well. Hash oil is made by boiling the plants in alcohol, filtering the solid parts, then evaporating the liquid to until it is a thick, dark oil. The primary psychoactive agent in all of these preparations is Delta-9 Tetrahydrocannabinol (THC). The concentration of THC, and thus the potency, of various forms of marijuana and hashish varies widely. In typical marijuana there may be a 2% to 5% concentration of THC. Prime marijuana, often only the flower tops may contain 7% to 10% THC. Hashish may yield 7% to 14% THC, while hash oil may well contain more than 50% THC. In the brain THC attaches to feedback receptors on the axon terminals of pre-synaptic neurons normally activated by anandamide and/or sn-2 arachidonylglycerol. So normally when one of these neurons releases its neurotransmitter causes the post-synaptic neuron to release these chemicals so the pre-synaptic neuron stops releasing the neurotransmitter. THC resembles these reverse feedback transmitters so the pre-synaptic neuron never releases its neurotransmitter. Neurons utilizing these chemicals are especially numerous in areas that control memory and movement. Prolonged use of marijuana has been linked to short-term memory loss as well as decreases in drive and ambition. However, those effects may subside after discontinued use once all the THC clears the system. That may take considerable time, as THC gets stored in the body's fat cells.

Hallucinogens: These drugs produce hallucinations, extreme sensory distortions. They may also produce transcendental experiences having a certain spiritual quality. In extreme cases they may produce disordered thoughts similar to those found in schizophrenic patients. However, as a class of psychoactive drugs hallucinogens have little addictive potential.

Mescaline – Derived from the peyote cactus native to Mexico and the southwester United States. Readily absorbed when eaten, it passes the blood-brain barrier with difficulty. Maximum concentrations in the brain are reached 30 to 120 minutes after ingestion. However, it may remain in the brain for up to 10 hours. Evidence suggests it affects serotonin receptors.

Psilocybin – This drug is found in mushrooms native to Mexico. The dried mushrooms contain up to .05% psilocybin, which is chemically similar to LSD.

LSD – Derived from the fungus ergot, which grows on grains such as rye, d-lysergic acid diethylamide (LSD) was first synthesized in 1938 by Albert Hoffman. In 1943 he accidentally spilled a flask full of LSD and absorbed a great quantity through his skin while cleaning it up, thus discovering its psychedelic properties.

Ecstasy / MDMA – An amphetamine derivative methylenedioxymethamphetamine (MDMA) produces stimulant effects at low doses and hallucinogenic effects at higher doses. It stimulates dopamine and serotonin axons, but damages them in the process. Of the hallucinogens, this one shows the clearest evidence of long-term brain damage.

PCP – Phencyclidine (PCP) inhibits glutamate receptors. Low doses produce sedative effects, higher does produce hallucinations, disordered thinking, memory loss, and lack of affect.

TABLE 3.1 Commonly Abused Drugs and Their Effects

Drug Category	Effects on the Nervous System	Short-term Effects	Risks (partial list)
Stimulants			
Amphetamine	Increases release of dopamine and decreases reuptake, prolonging effects	Increases energy and alertness	Psychotic reaction, agitation, heart problems, sleeplessness, stroke
Cocaine	Decreases reuptake of dopamine, prolonging effects	Increases energy and alertness	Psychotic reaction, heart problems, crime to pay for drugs, death
Methylphenidate (Ritalin)	Decreases reuptake of dopamine, but with slower onset and offset than cocaine	Increases alertness; much milder withdrawal effects than cocaine	Increased blood pressure
Caffeine	Blocks a chemical that inhibits arousal	Increases energy and alertness	Sleeplessness
Nicotine	Stimulates some acetylcholine synapses; stimulates some neurons that release dopamine	Increases arousal; abstention by a habitual smoker produces tension and depression	Lung cancer from the tars in cigarettes
Depressants			
Alcohol	Facilitates effects of GABA, an inhibitory neurotransmitter	Relaxation, reduced inhibitions, impaired memory and judgment	Automobile accidents, loss of job
Benzodiazepines	Facilitate effects of GABA, an inhibitory neurotransmitter	Relaxation, decreased anxiety, sleepiness	Dependence. Life-threatening if combined with alcohol or opiates
Narcotics			
Morphine, heroin, other opiates	Stimulate endorphin synapses	Decrease pain; withdrawal from interest in real world; unpleasant withdrawal effects during abstention	Heart stoppage; crime to pay for drugs
Marijuana			
Marijuana	Excites negative feedback receptors of both excitatory and inhibitory transmitters	Decreases pain and nausea; distorted sense of time	Impaired memory; lung diseases; impaired immune response
Hallucinogens			
LSD	Stimulates serotonin type 2 receptors at inappropriate times	Hallucinations, sensory distortions	Psychotic reaction, accidents, panic attacks, flashbacks
MDMA ("ecstasy")	Stimulates neurons that release dopamine; at higher doses also stimulates neurons that release serotonin	At low doses increases arousal; at higher doses hallucinations	Dehydration, fever, lasting damage to serotonin synapses
Rohypnol and GHB	Facilitate action at GABA synapses (which are inhibitory)	Relaxation, decreased inhibitions	Impaired muscle coordination and memory
Phencyclidine (PCP or "angel dust")	Inhibits one type of glutamate receptor	Intoxication, slurred speech; at higher doses hallucinations, thought disorder, impaired memory and emotions	Psychotic reaction

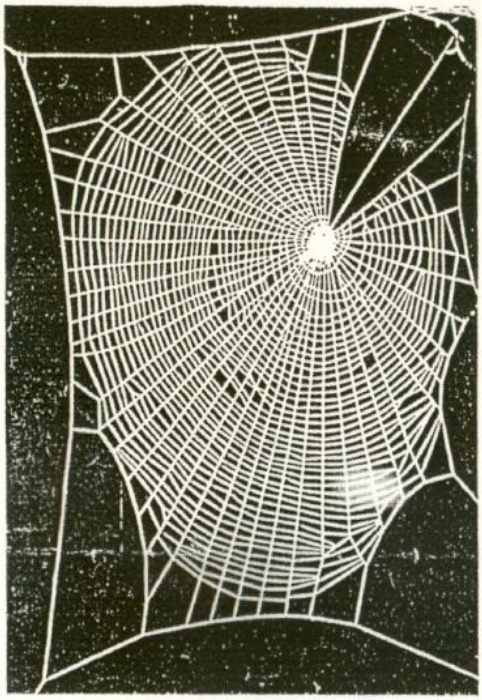
NAME	CLASSIFICATION	MEDICAL USE	USUAL DOSE	DURATION OF EFFECT
Alcohol	Sedative-hypnotic	Solvent, antiseptic	Varies	1-4 hours
Amphetamines	Stimulant	Relief of mild depression, control of narcolepsy and hyperactivity	2.5-5 milligrams	4 hours
Barbiturates	Sedative-hypnotic	Sedation, relief of high blood pressure, anticonvulsant	50-100 milligrams	4 hours
Benzodiazepines	Anxiolytic (antianxiety drug)	Tranquilizer	2-100 milligrams	10 minutes-8 hours
Caffeine	Stimulant	Counteract depressant drugs, treatment of migraine headaches	Varies	Varies
Cocaine	Stimulant, local anesthetic	Local anesthesia	Varies	Varied, brief periods
Codeine	Narcotic	Ease pain and coughing	30 milligrams	4 hours
GHB	Sedative-hypnotic	Experimental treatment of narcolepsy, alcoholism	1-3 grams (powder)	1-3 hours
Heroin	Narcotic	Pain relief	Varies	4 hours
LSD	Hallucinogen	Experimental study of mental function, alcoholism	100-500 milligrams	10 hours
Marijuana (THC)	Relaxant, euphoriant; in high doses, hallucinogen	Treatment of glaucoma and side effects of chemotherapy	1-2 cigarettes	4 hours
MDMA	Stimulant/hallucinogen	None	125 milligrams	4-6 hours
Mescaline	Hallucinogen	None	350 micrograms	12 hours
Methadone	Narcotic	Pain relief	10 milligrams	4-6 hours
Morphine	Narcotic	Pain relief	15 milligrams	6 hours
PCP	Anesthetic	None	2-10 milligrams	4-6 hours, plus 12-hour recovery
Psilocybin	Hallucinogen	None	25 milligrams	6-8 hours
Tobacco (nicotine)	Stimulant	Emetic (nicotine)	Varies	Varies

Question marks indicate conflict of opinion. It should be noted that illicit drugs are frequently adulterated and thus pose unknown hazards to the user.

Table 10.6 SEXUAL EFFECTS OF COMMONLY ABUSED AND ILLICIT DRUGS

DRUGS	EFFECTS
Alcohol	Chronic abuse causes hormonal alterations (reduces size of testes and suppresses hormonal function) and permanently damages the circulatory and nervous systems.
Tobacco	Decreases the frequency and duration of erections and vaginal lubrication.
Cocaine	Causes erectile disorder, inhibits orgasm, and lowers sperm count.
Amphetamines	High doses and chronic use result in inhibition of orgasm and decrease in erection and lubrication.
Barbiturates	Cause decreased desire, erectile disorders, and delayed orgasm.
Marijuana	Reduces testosterone levels in men and decreases sexual desire.

Source: Doweiko, 1999; Finger et al., 1997; Julien, 1997.



Die Wirkung von Substanzen auf den Netzbau der Spinne als biologischer Test (Peter Witt, Berlin, 1956)

Normal net of Zilla-x-notata Cl. Nets made by this spider after consuming drug-dosed flies appear opposite.

that is only sometimes prompted by LSD. Shulgin remarks that under mescaline "There is a benign empathy shown to both inanimate and living things, especially to small things." Allen Ginsberg and others have suggested that mescaline—more than other psychedelics—produces a state of mind very receptive to the complex of benevolent attitudes expressed in Wordsworth's nature poems.

There haven't yet been any studies comparing effects from mescaline with those from peyote. The Church of the Awakening used both fairly extensively and characterized mescaline effects as "identical with those we had obtained through the use of peyote itself" (in John Aiken's words).

There are many reports about the effects of peyote and mescaline coming from people who have used these substances in remarkably different ways and in a multitude of settings: from use in experimental laboratories to

Typical hashish-inspired net.

Net after about 0.04 mcg. LSD.

Net after a high caffeine dose.

Net after mescaline sulfate dose.