Cognitive Neuroscience

Cognitive Process

Assoc. Prof. Atanas Kirjakovski

Grading System

Course Evaluation

Term	Percentage
Attendance	**15%**
Mid-term	**35%**
Final	**40%**
In-class Project Presentation	**10%**
Penalty Exam I	**100%**
Penalty Exam II	**100%**
MakeUp	**40%**

Exams

- Includes mid-term, final, makeup, excuse, upgrade, and penalty exams.
  - **Mid-term Exam:** Covers course content taught before the exam.
  - **Final Exam:** Covers all course content from the entire semester.
  - **Make-up Exam:** Equivalent to the final exam, replaces final exam results.
  - **Excuse Exam:** For students who missed mid-terms due to documented reasons.
  - **Upgrade Exam:** For students with final grades between 30.00 and 49.99, applicable to two courses per semester.
  - **Penalty Exam:** Extra exam for students who fail a course and need to retake it.
- Special provisions are available for graduating students, those with disabilities, and students needing to retake failed courses.

Grading

- Based on semester activities, midterm, and final exams.
- Minimum 40 points from final exam required to pass a course.
- Minimum 50 points from all required to pass a course.

Grade Announcements

- Grades are entered into the HELLO system and can be appealed within 48 hours.
- Students can object the grades via online tool in 48 hours after the grades are announced.

Grade Calculation

	Percent	Hypothetical Points	Subtotal Points
Attendance	15%	100	15
Midterm	35%	60	21
Final	40%	72	28.8
In-class	10%	40	4
		Total	**68.8**

https://ibu.kirjakovski.mk

Prof. Kirjakovski IBU Blog

2021

Jun 12	MAKE-UP EXAM: Computer Aided Education	Computer Aided Education (2020/2021)
Jun 04	IMPORTANT: Repeated Final Exam for Some Students	Social Psychology (2020/2021)
May 24	LECTURE 11: Organizational Theory, Dynamics, and Change	Organizational Psychology (2020/2021)
May 20	COURSE EVALUATION: Organizational Psychology	Organizational Psychology (2020/2021)
May 20	FINAL EXAM: Computer Aided Education	Computer Aided Education (2020/2021)

SCAN ME

DO NOT RE-UPLOAD THE CONTENT!

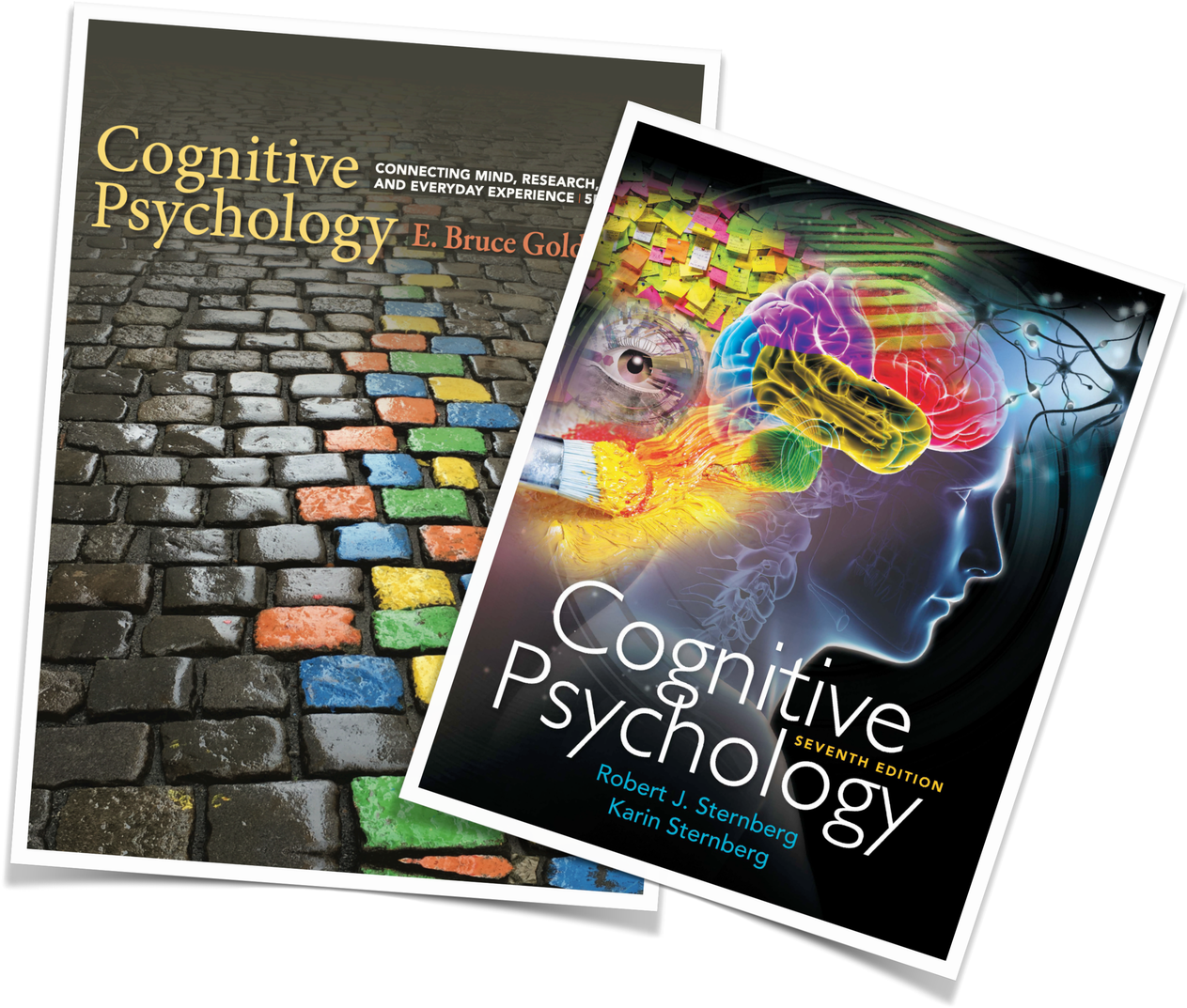
Academic Calendar

- 1 *Oct 2025, Week 1*
  INTRODUCTION TO COGNITIVE PSYCHOLOGY
- 8 *Oct 2025, Week 2*
  COGNITIVE NEUROSCIENCE
- 15 *Oct 2025, Week 3*
  PERCEPTION
- 22 *Oct 2025, Week 4*
  ATTENTION
- 29 *Oct 2025, Week 5*
  MEMORY
- 5 *Nov 2025, Week 6*
  CONCEPTUAL KNOWLEDGE
- **MIDTERM EXAMS (10–15 NOV 2025)**
- **EXCUSE EXAMS (24–28 NOV 2025)**
- 19 *Nov 2025, Week 7*
  VISUAL IMAGERY
- 26 *Nov 2025, Week 8*
  LANGUAGE
- 3 *Dec 2025, Week 9*
  PROBLEM SOLVING & CREATIVITY
- 10 *Dec 2025, Week 10*
  JUDGMENT, DECISIONS, AND REASONING
- 17 *Dec 2025, Week 11*
  HUMAN INTELLIGENCE
- 24 *Dec 2025, Week 12*
  COGNITIVE DISORDERS (+ REVIEW)
- **WINTER BREAK (31 DEC 2025 – 9 JAN 2026)**
- **FINAL EXAMS (12–17 JANUARY 2026)**
- **MAKEUP EXAMS (19–24 JAN 2026)**

Study Materials

Main text: Goldstein, E. B. (2019). Cognitive psychology: Connecting mind, research, and everyday experience (5th ed.). Cengage Learning.

Supplementary text: Sternberg, R. J., & Sternberg, K. (2017). Cognitive psychology (7th ed.). Cengage Learning.



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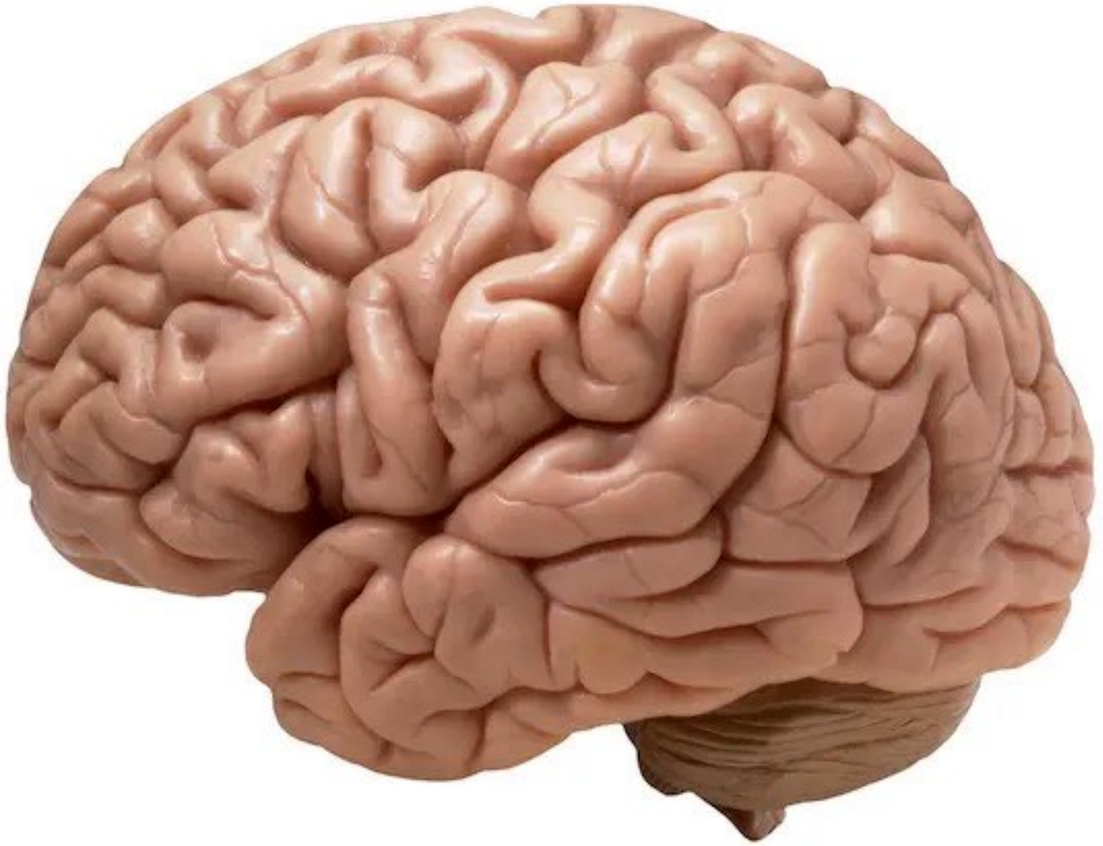
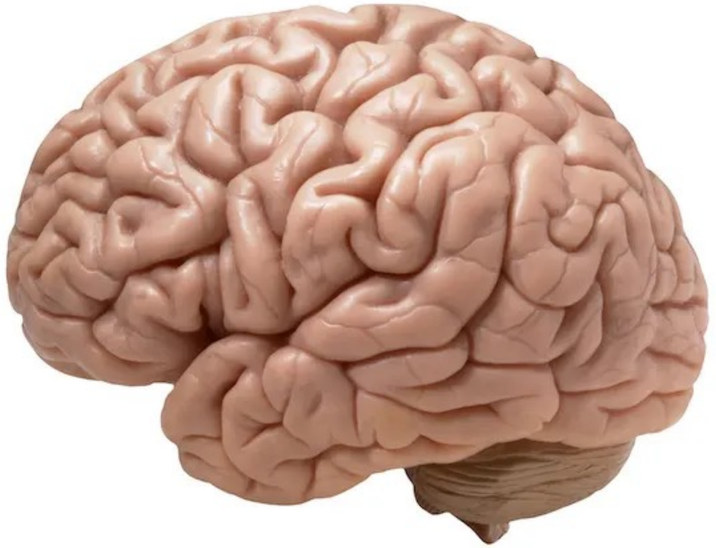
The Brain

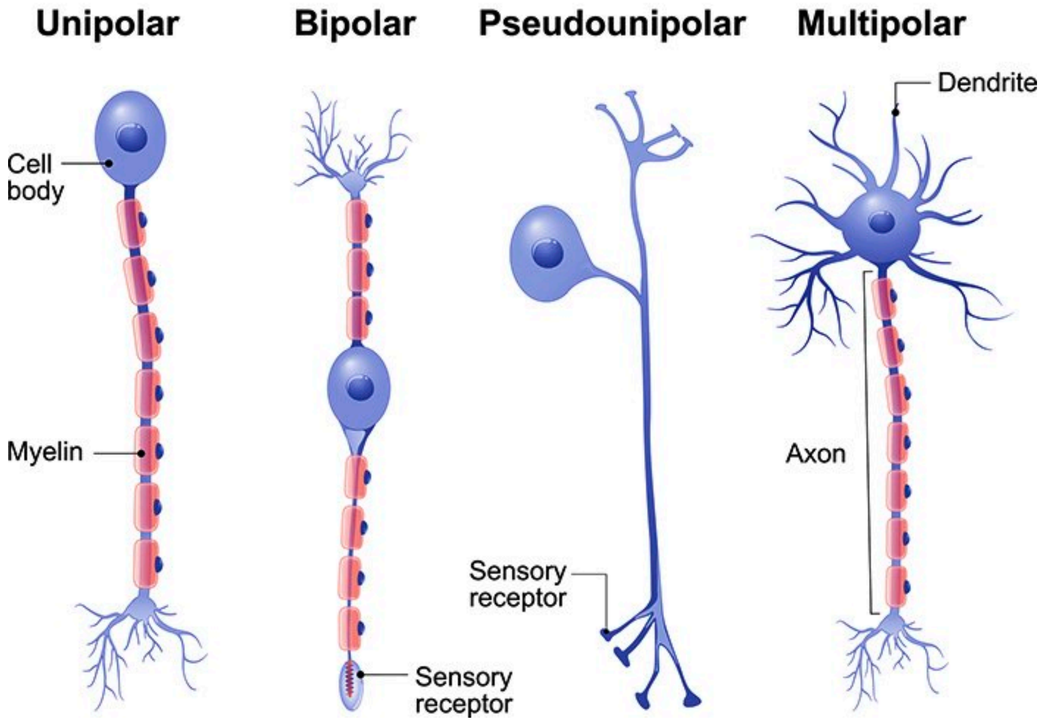


Some Amazing Brain Facts

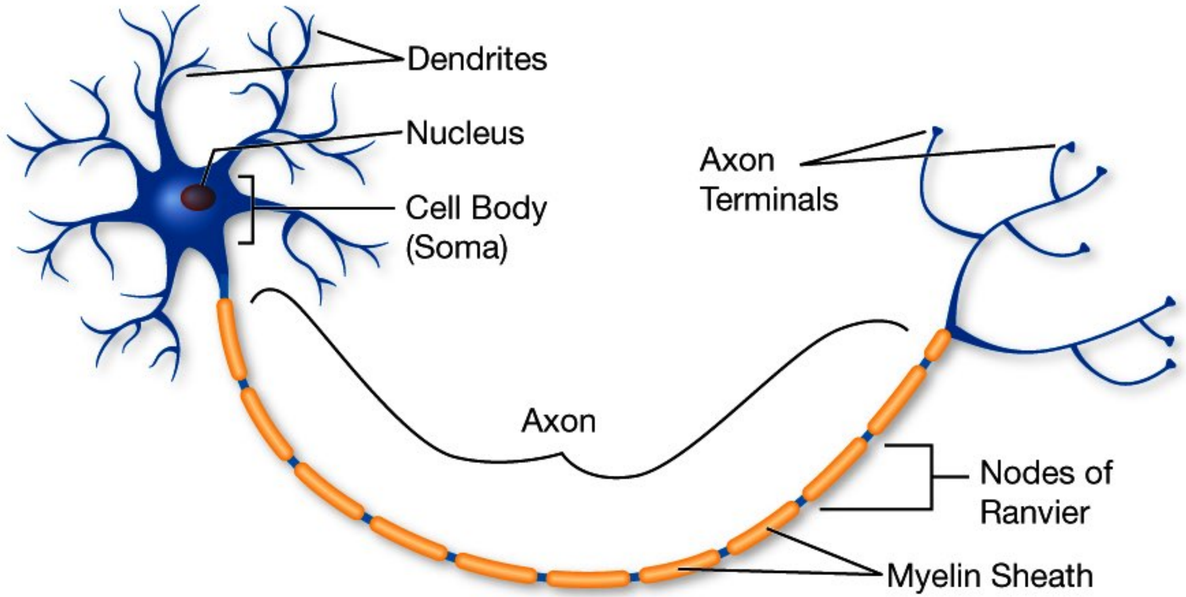
- Your brain has about 86 billion neurons – almost as many stars as in the Milky Way galaxy.
- There are 1,000 to 10,000 synapses (connections to other neurons) for a "typical" neuron.
- The adult human brain is about 2% of the total body weight.
- The average brain weight of the adult male is around 1.34 kg, for the adult female 1.2 kg. (weight itself is not necessarily an indicator of intelligence. For example, elephants brain weights around 5 kg)
- Signals in your neurons can travel at the same speed as Formula 1 cars (360 km/h).
- Your brain is hyper-efficient, running on just 20 watts of power (a computer, by contrast, needs 65–250 W, and for a computer to simulate the 86 trillion connections of the human brain in real-time, it would need 12 gigawatts – around 600 million times the power!).



The Neuron Itself



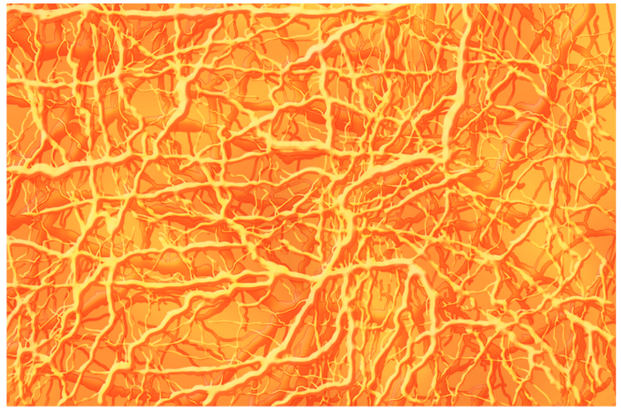
Neuron shapes



Typical motor neuron

Early Conceptions of Neurons

- Camillo Golgi (1843–1926) developed a staining technique in which a thin slice of brain tissue was immersed in a solution of silver nitrate.
- Ramon y Cajal (1852–1934) discovered that nerve net was not continuous but was instead made up of individual units connected together.
- **Nerve net:** Initially, the neural networks were believed to be continuous.
- **Neuron doctrine:** The idea that individual cells transmit signals in the nervous system, and that these cells are not continuous with other cells as proposed by nerve net theory.



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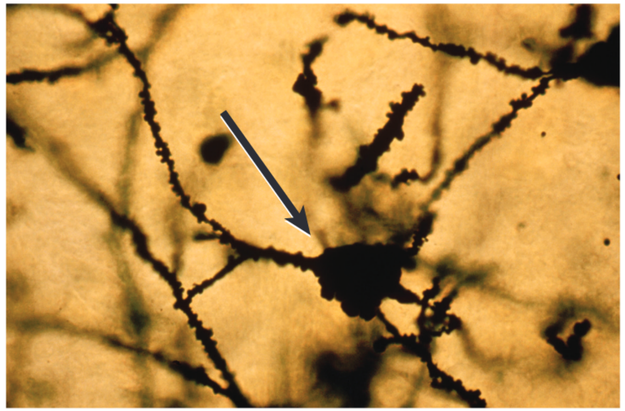
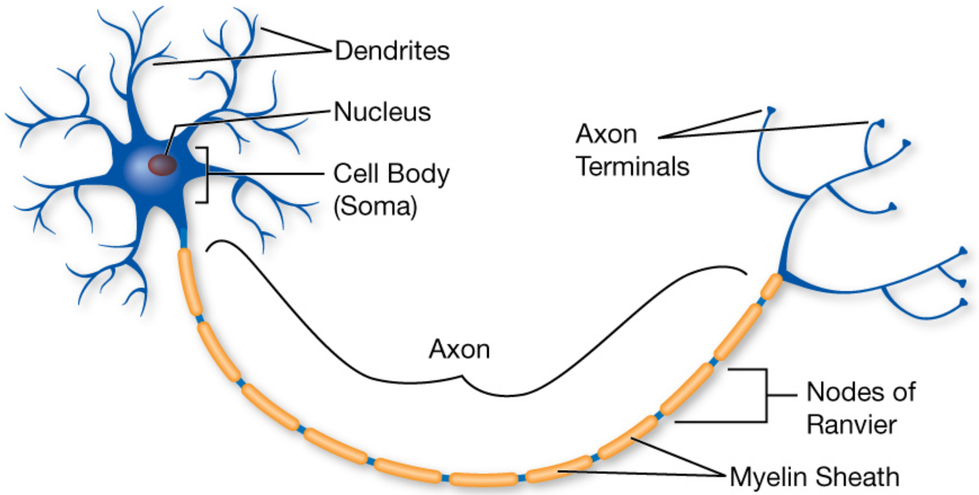


(b)

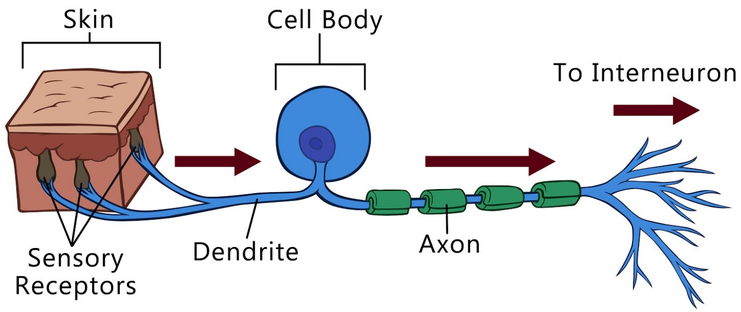
Structure of a Neuron

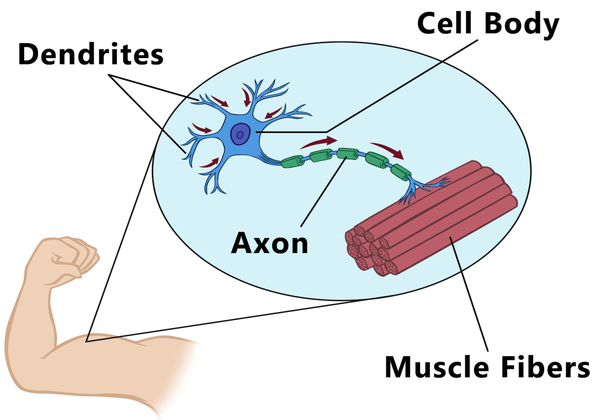
- **Cell body:** The central part of a neuron (or other cell), which contains the nucleus.
- **Cell membrane:** The skin that surrounds a cell.
- **Axon:** The sending end of the neuron; the long cable-like structure extending from the cell body.
- **Terminal button:** A structure at the end of the branch of an axon that can release chemicals into the space between neurons.
- **Dendrite:** The treelike part of a neuron that receives messages from the axons of other neurons.

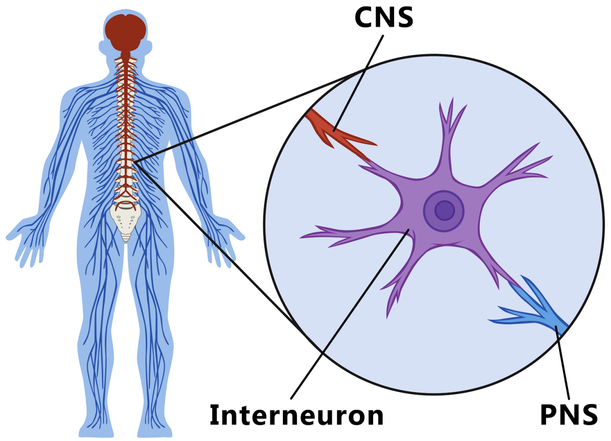


Neuron Types

- **Sensory neuron (receptors):** A neuron that responds to signals from sensory organs and transmits those signals to the brain and spinal cord.
- **Motor neuron:** A neuron that sends signals to muscles in order to control movement (and also to bodily organs, such as glands).
- **Interneuron:** A neuron that is connected to other neurons, not to sense organs or muscles.
- **Brain circuit:** A set of neurons that work together to receive input, operate on it in some way, and produce specific output.



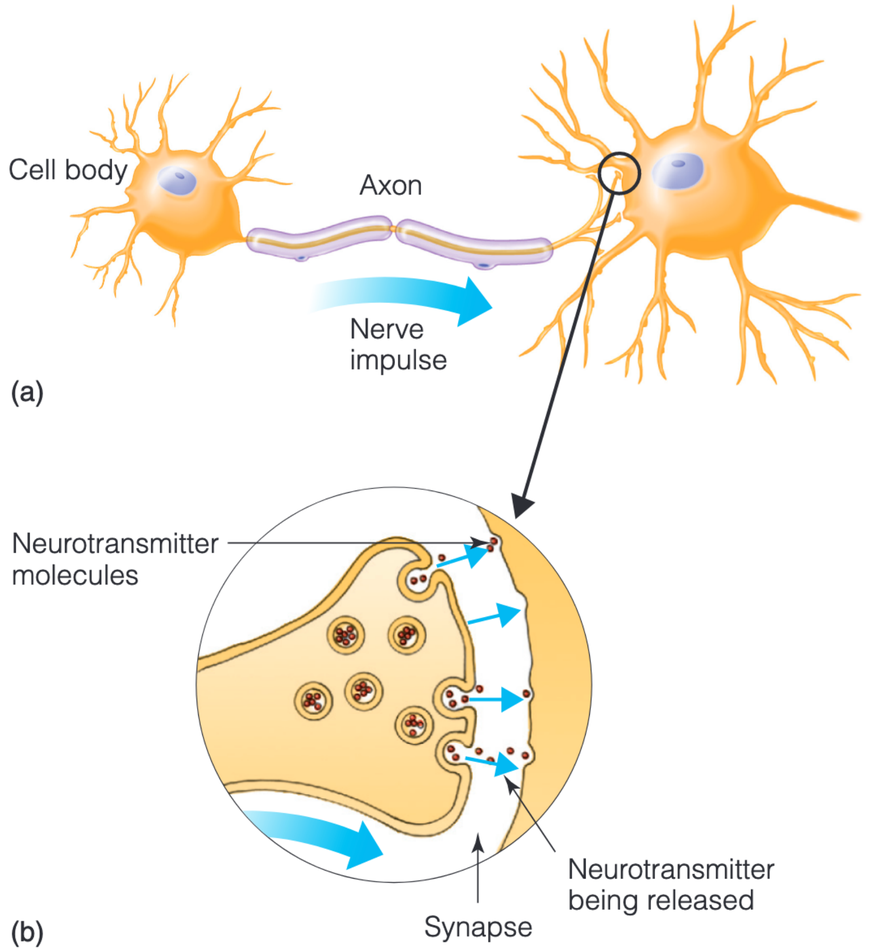




The Synapse

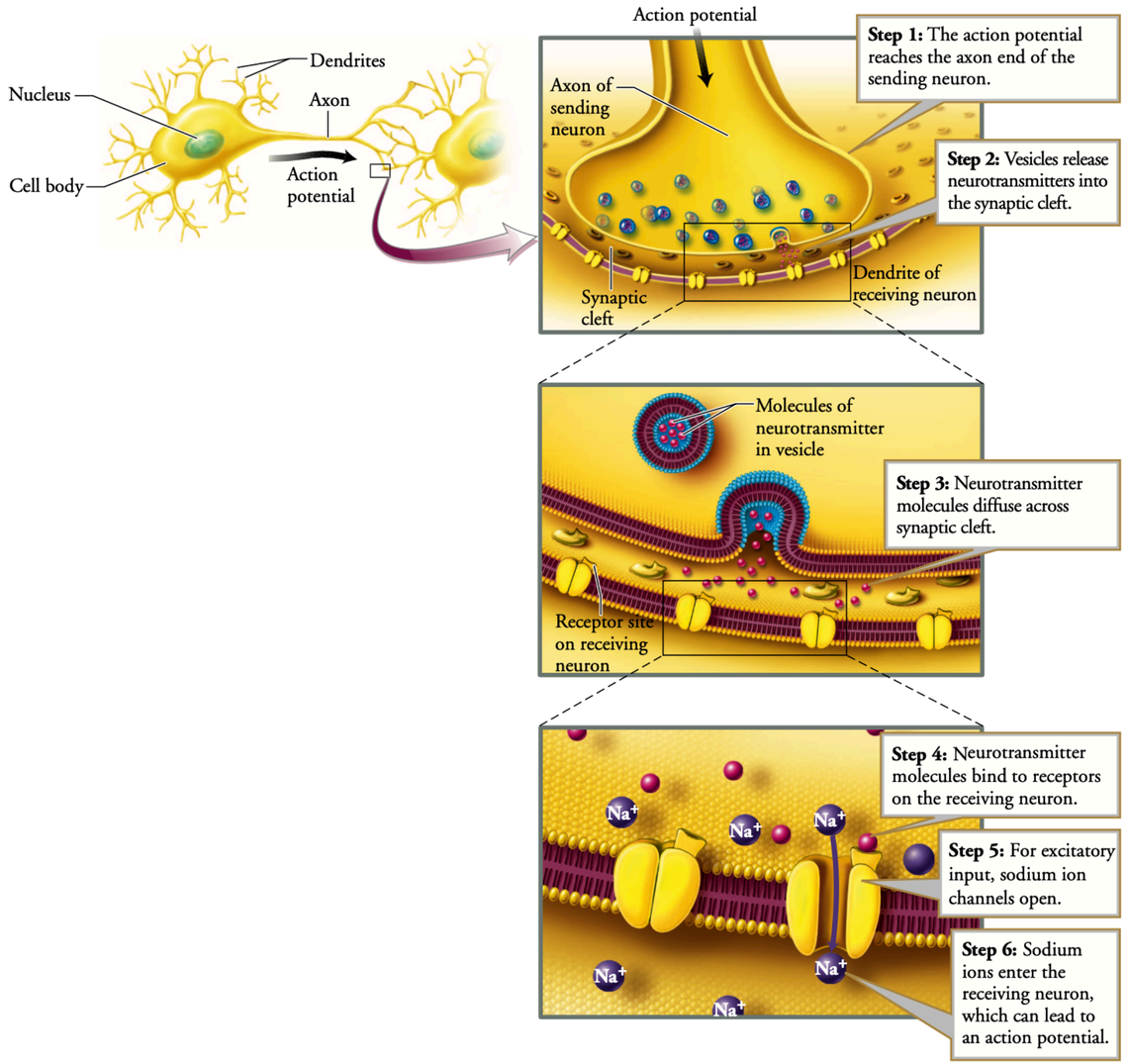
- **Synapse:** The place where an axon of one neuron sends signals to the membrane (on a dendrite or cell body) of another neuron; the synapse includes the sending portions of an axon, the receiving portions of the receiving neuron, and the space between them.

- **Synaptic cleft:** The gap in the synapse between the axon of one neuron and the membrane of another across which communication occurs.



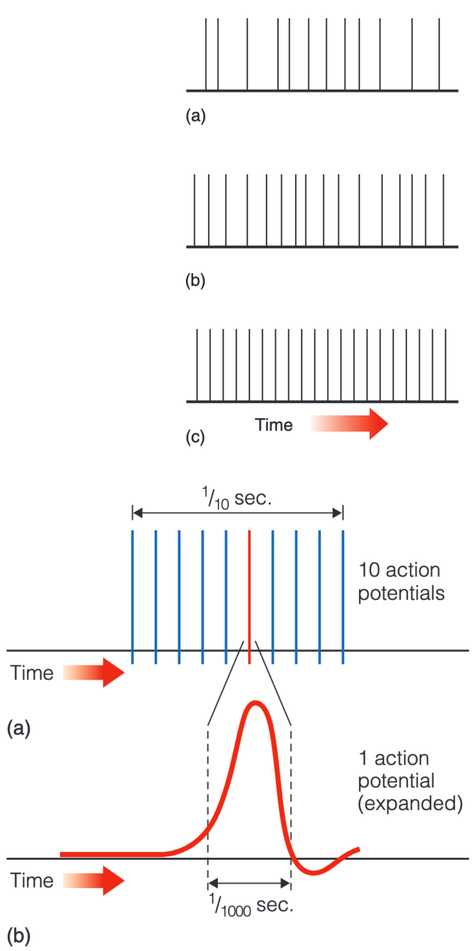
Neurotransmitters

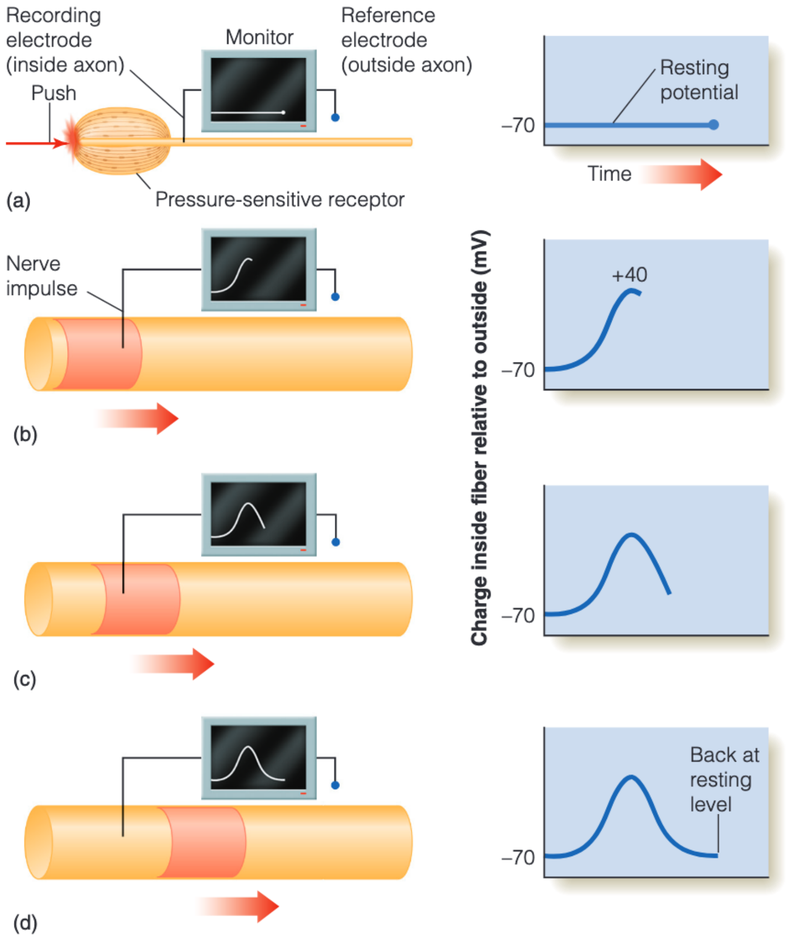
- **Neurotransmitter:** A chemical that carries a signal from the terminal button of one neuron to the dendrite or cell body of another; often referred to as a neurotransmitter.
- **Receptor:** A site on a dendrite or cell body where a neurotransmitter molecule attaches itself; like a lock that is opened by one key, a receptor receives only one type of neurotransmitter.
- **Endogenous cannabinoids:** Neurotransmitter substances released by the receiving neuron that then influence the activity of the sending neuron.
- **Reuptake:** The process by which surplus neurotransmitter in the synaptic cleft is reabsorbed back into the sending neuron so that the neuron can effectively fire again.
- Neurotransmitters can be **excitatory** inputs, making the receiving neuron more likely to have an action potential, or they can be **inhibitory** inputs, making the receiving neuron less likely to have an action potential.



Neural Signals

- Edgar Adrian was able to record electrical signals from single sensory neurons, an achievement for which he was awarded the Nobel Prize in 1932.
- **All-or-none law:** States that if the neuron is sufficiently stimulated, it fires, sending the action potential all the way down the axon and releasing chemicals from the terminal buttons; either the action potential occurs or it doesn't.
- **Resting potential:** The negative charge within a neuron when it is at rest.
- **Action potential:** The shifting change in charge that moves down the axon.
- **Rate of nerve firing:** The number of action potentials that traveled down the axon per second. Related to the intensity of stimulus.
- **Ion:** An atom that has a positive or negative charge.
- **Myelin:** A fatty substance that helps impulses efficiently travel down the axon.
- Recording from a neuron: microelectrodes – recording and reference electrodes.



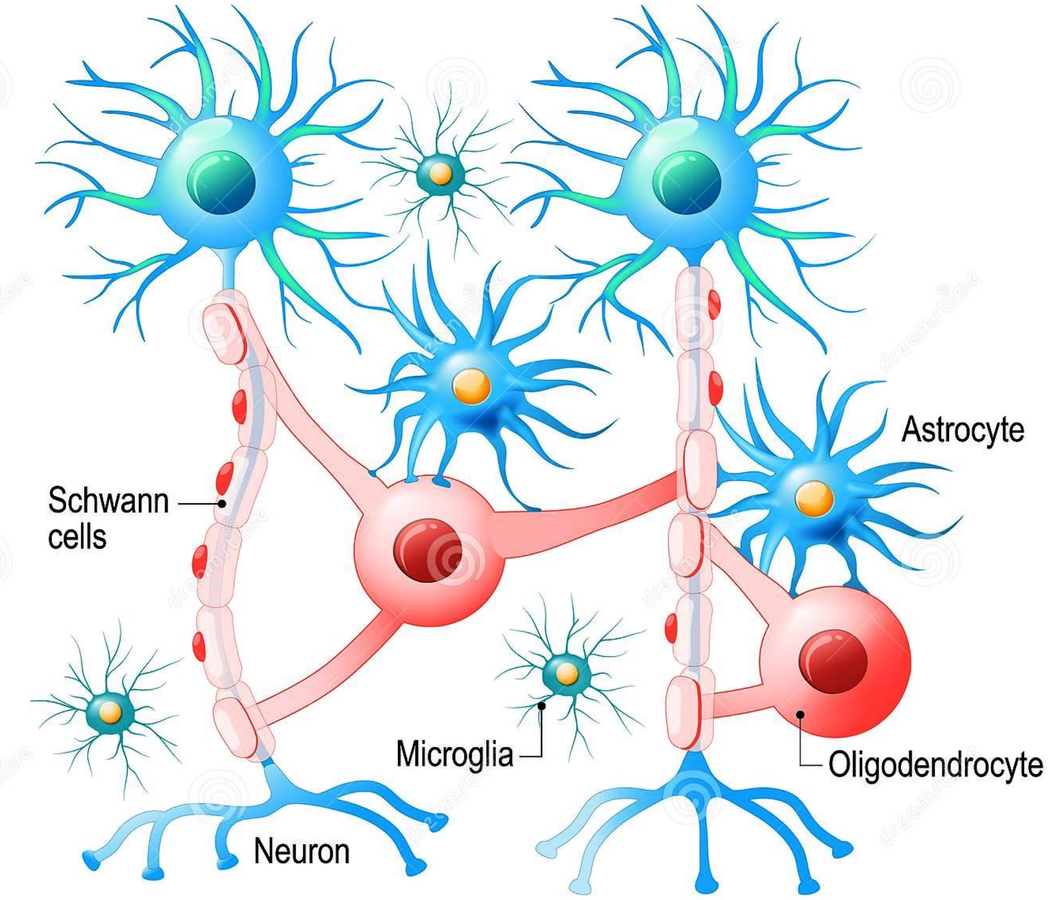


Glial Cells

- The average human brain contains about ten times as many **glial cells** (the name comes from the Greek word for “glue”) as neurons.

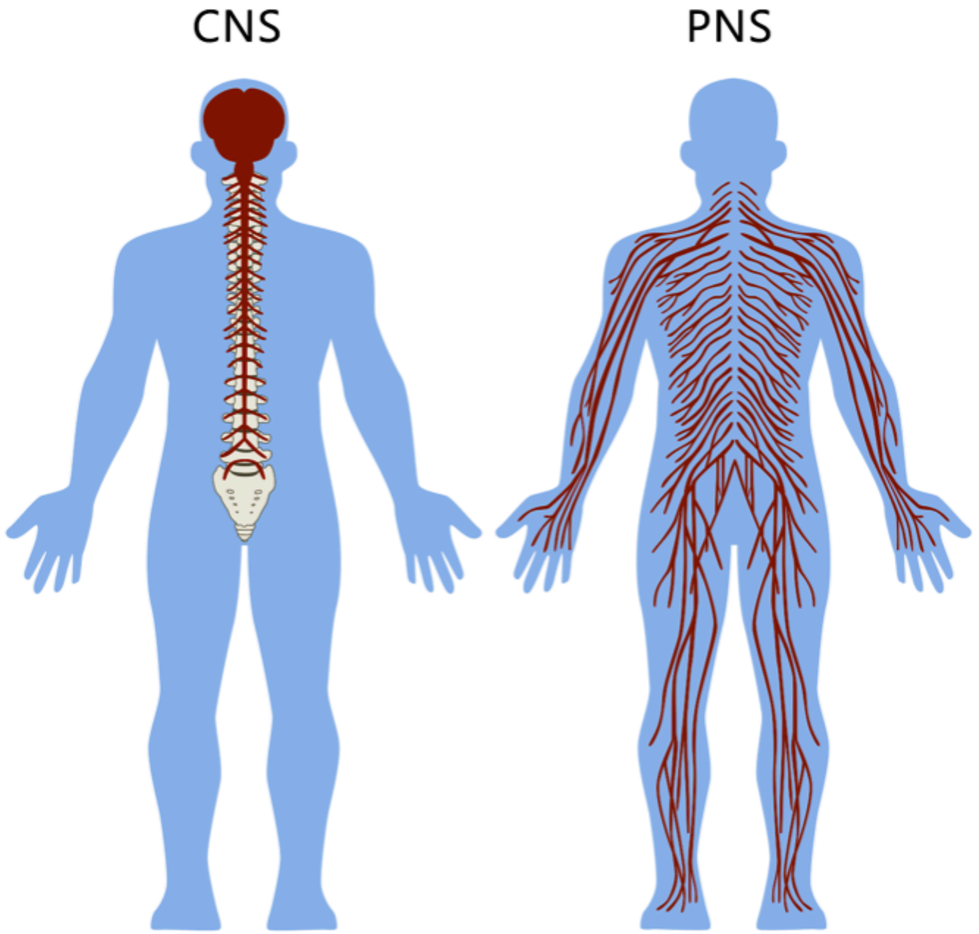
- **Glial cell:** A type of cell that helps neurons to form both synapses and connections when the brain is developing, influences the communication among neurons, and generally helps in the “care and feeding” of neurons.

- Glial cells also coordinate the activity of vast sets of brain circuits and can prod neurons to form additional synapses.



The Nervous System — Division

- The nervous system has two major parts: the central nervous system (CNS) and the peripheral nervous system (PNS).
- **Central nervous system (CNS):** The spinal cord and the brain.
- **Peripheral nervous system (PNS):** The autonomic nervous system and the sensory-somatic nervous system.



The Peripheral Nervous System (PNS)

- The peripheral nervous system (PNS) allows the brain both to affect the organs of the body and to receive information from them.

- The PNS has two parts: **the autonomic nervous system** and **the sensory-somatic nervous system**.

- **Autonomic nervous system (ANS):** Controls the smooth muscles in the body, some glandular functions, and many of the body's self-regulating activities, such as digestion and circulation.

- **Sensory-somatic nervous system (SSNS):** Part of the peripheral nervous system that consists of neurons in the sensory organs (such as the eyes and ears) that convey information to the brain as well as neurons that actually trigger muscles and glands.

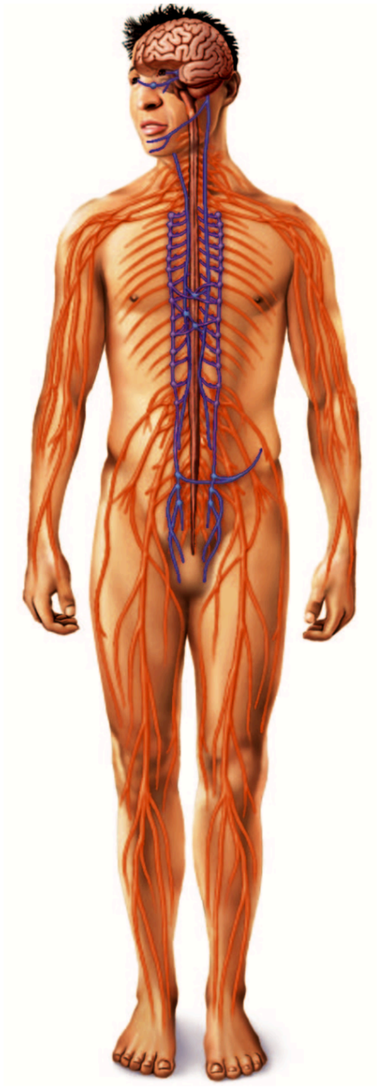
Autonomic Nervous System (ANS)

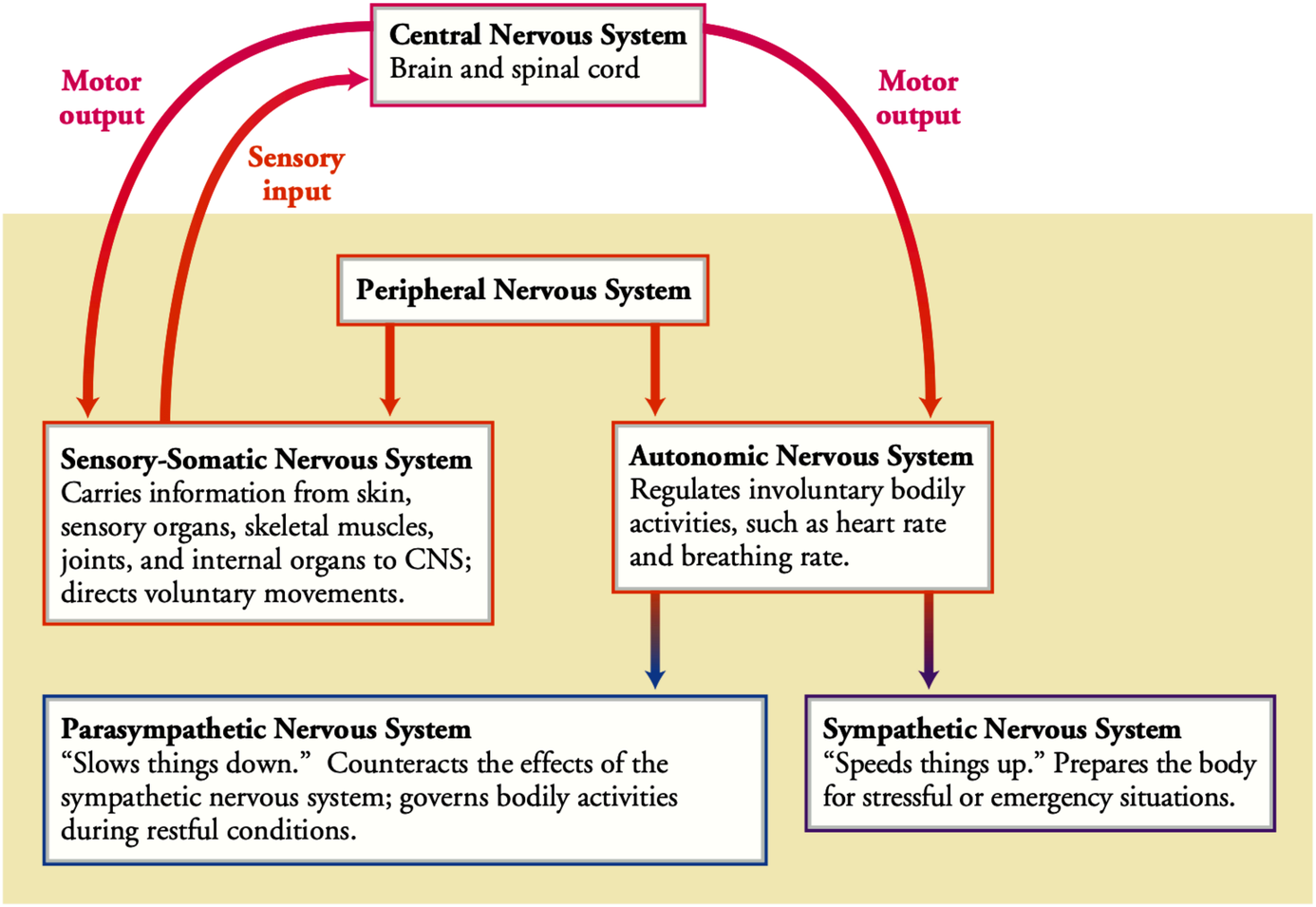
- The ANS has two branches — which are often referred to as “nervous systems” in their own right — **the sympathetic** and **parasympathetic nervous systems**.

- **Sympathetic nervous system:** Part of the autonomic nervous system that readies an animal to fight or to flee by speeding up the heart, increasing breathing rate to deliver more oxygen, dilating the pupils, producing sweat, decreasing salivation, inhibiting activity in the stomach, and relaxing the bladder.

- **Parasympathetic nervous system:** Part of the autonomic nervous system that is “next to” the sympathetic nervous system and that tends to counteract its effects.

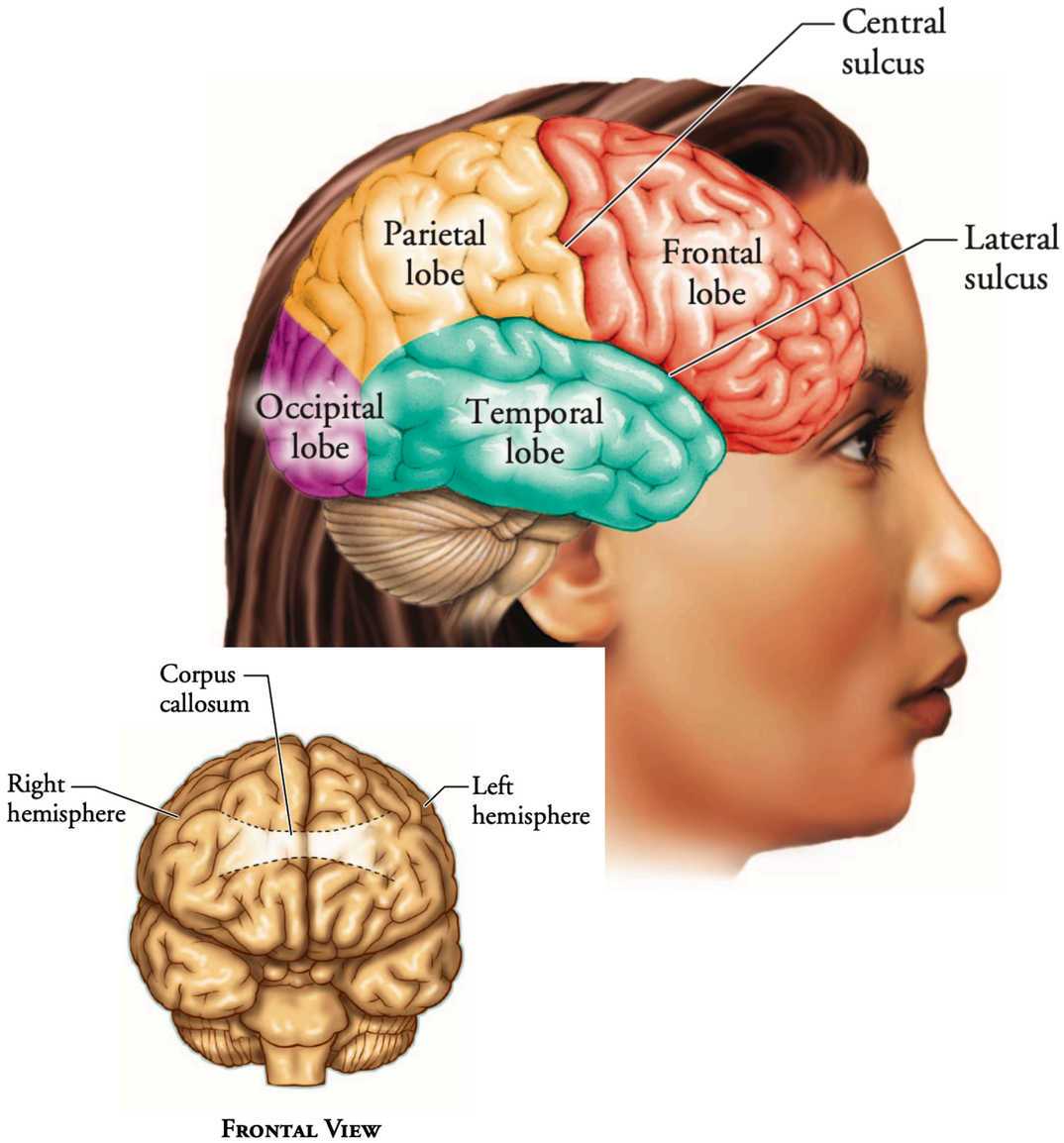
Major Parts of the Nervous System





The Lobes of the Brain

- **Cerebral hemisphere:** A left or right half-brain, shaped roughly like half a sphere.
- **Lobes:** The four major parts of each cerebral hemisphere – occipital, temporal, parietal, and frontal; each lobe is present in each hemisphere.
- **Corpus callosum:** The large bundle of axons that connects the two halves of the brain.

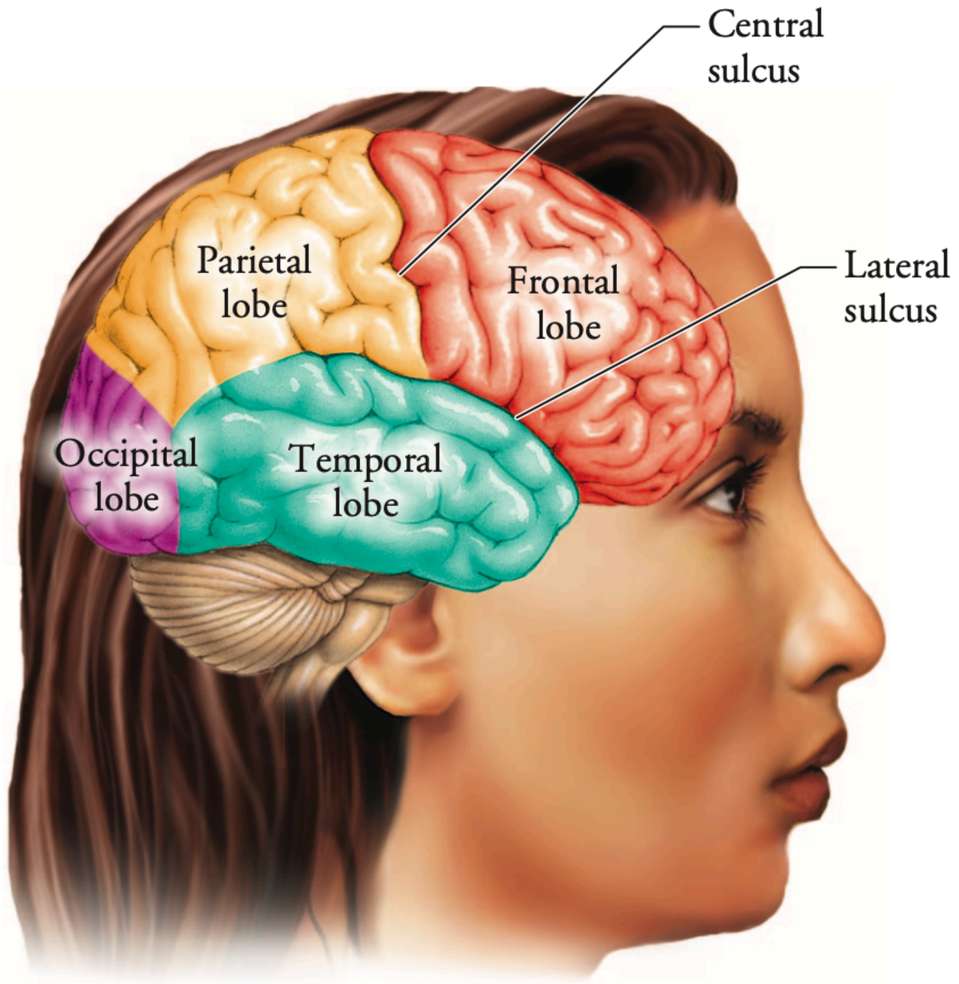


The Cerebral Cortex

- **Cerebral cortex:** The convoluted pinkish-gray outer layer of the brain where most mental processes arise.
- **Subcortical structures:** Parts of the brain located under the cerebral cortex.
- **Sulcus:** A crease in the cerebral cortex.
- **Gyrus:** A bulge between sulci in the cerebral cortex.
- **Brain system:** A set of brain circuits that work together to accomplish a particular task.

The Cerebral Cortex — Lobes

- **Occipital lobes:** The brain lobes at the back of the head; concerned entirely with different aspects of vision.
- **Temporal lobes:** The brain lobes under the temples, in front of the ears; among its many functions are processing sound, entering new information into memory, storing visual memories, and comprehending language.
- **Parietal lobes:** The brain lobes at the top, rear of the brain; among their functions are attention, arithmetic, touch, and registering spatial location.
- **Frontal lobes:** The brain lobes located behind the forehead; critically involved in planning, memory search, motor control, speech control, reasoning, and emotions.



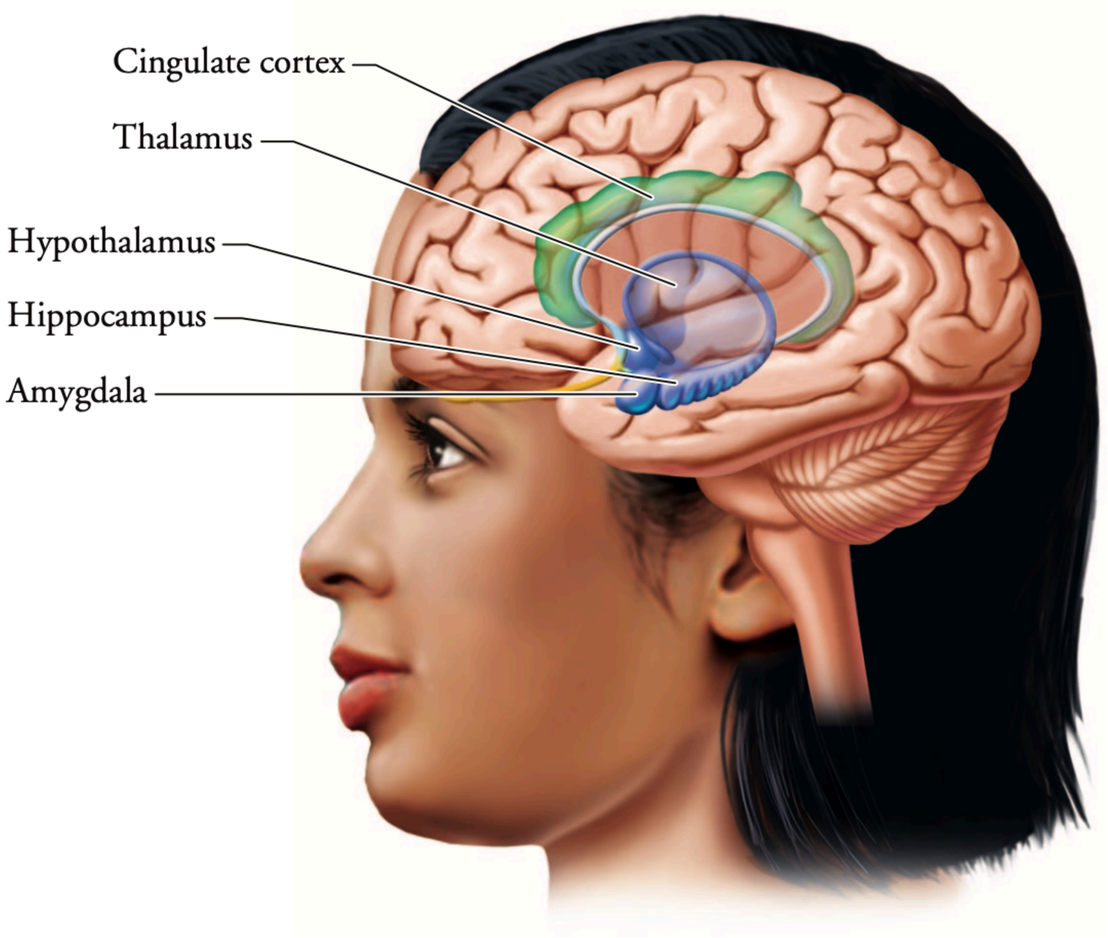
Subcortical Areas — The Limbic System

- **Thalamus:** A subcortical structure that receives signals from sensory and motor systems and plays a crucial role in attention, sleep, and other functions critical to daily life; often thought of as a switching center.

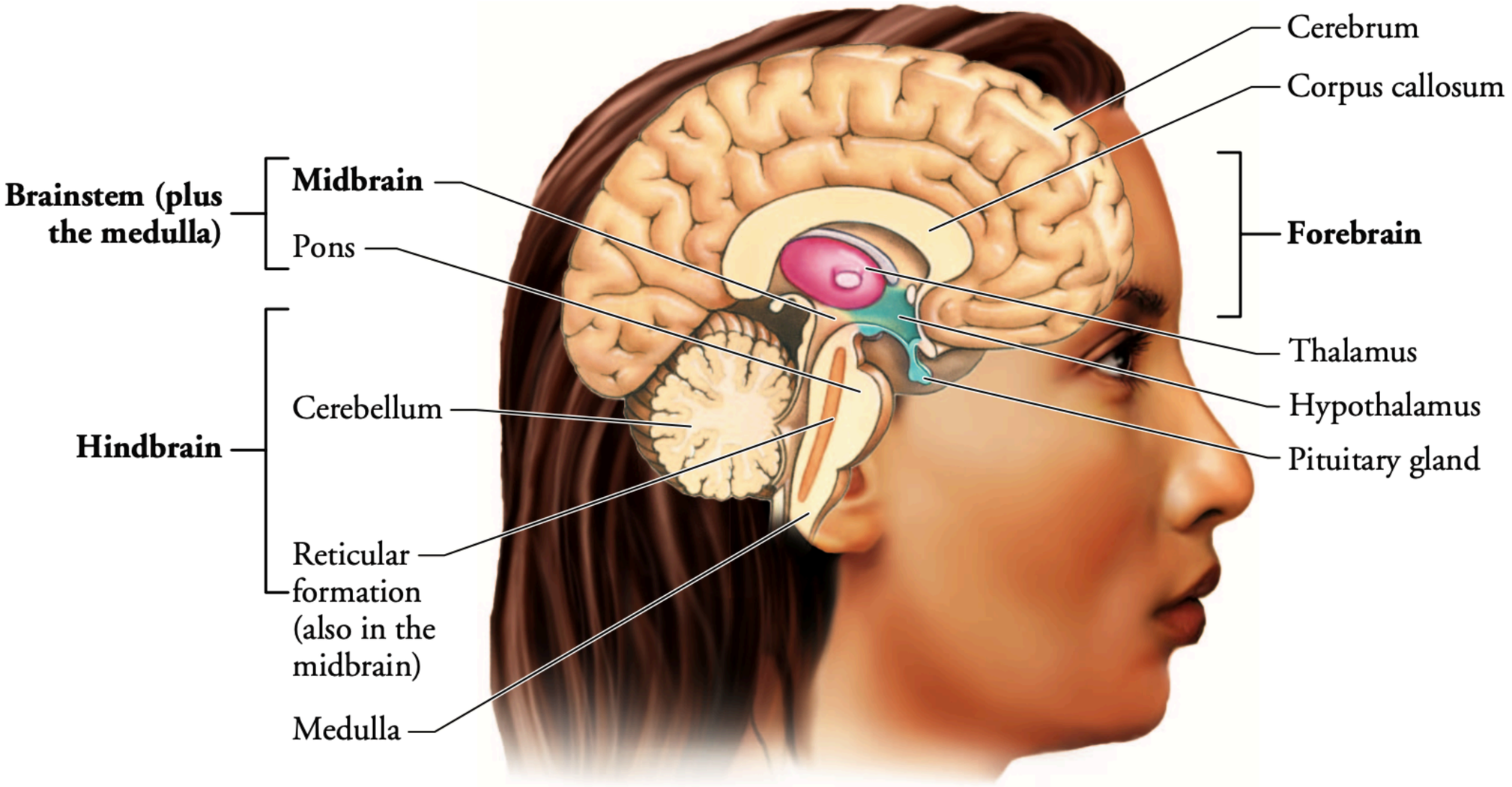
- **Hypothalamus:** A brain structure that sits under the thalamus and plays a central role in controlling eating and drinking and in regulating the body's temperature, blood pressure, heart rate, sexual behavior, and hormones.

- **Hippocampus:** A subcortical structure that plays a key role in allowing new information to be stored in the brain's memory banks.

- **Amygdala:** A subcortical structure that plays a special role in fear and is involved in other types of strong emotions, such as anger.

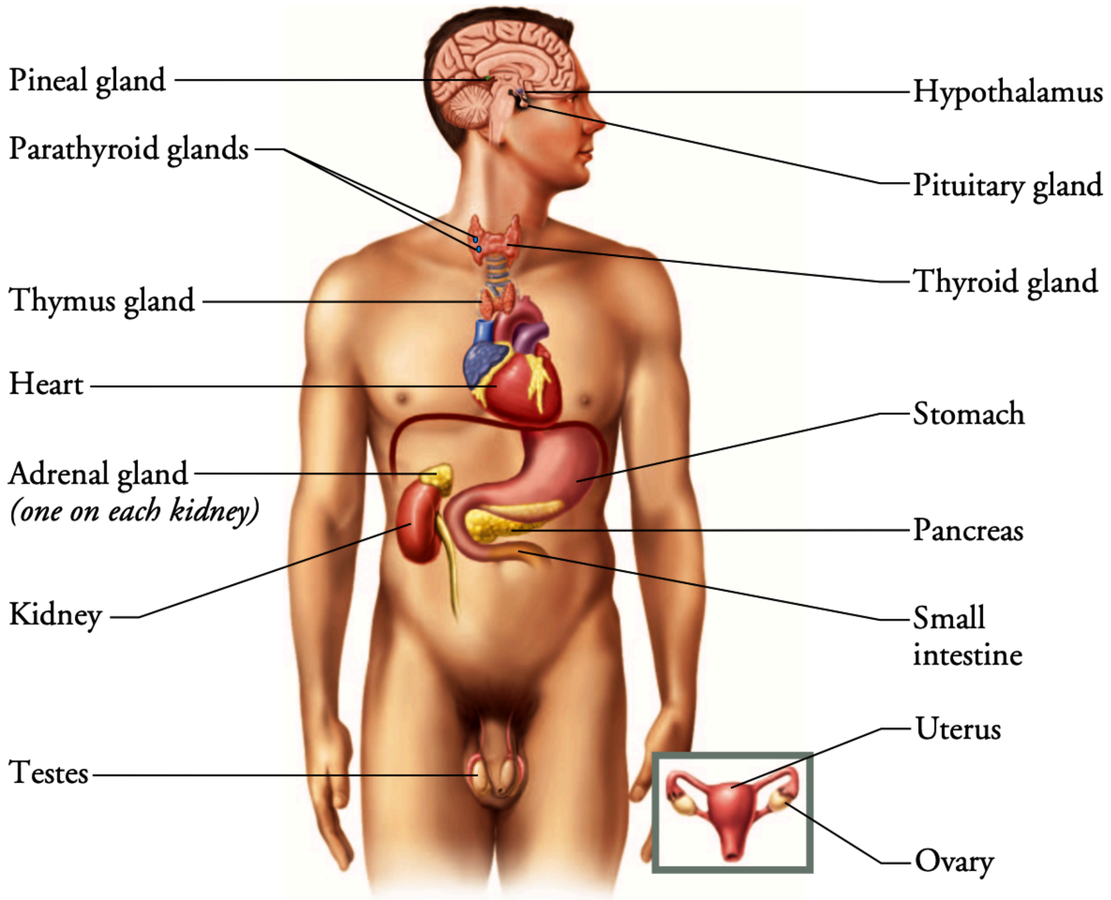


Key Subcortical Brain Areas



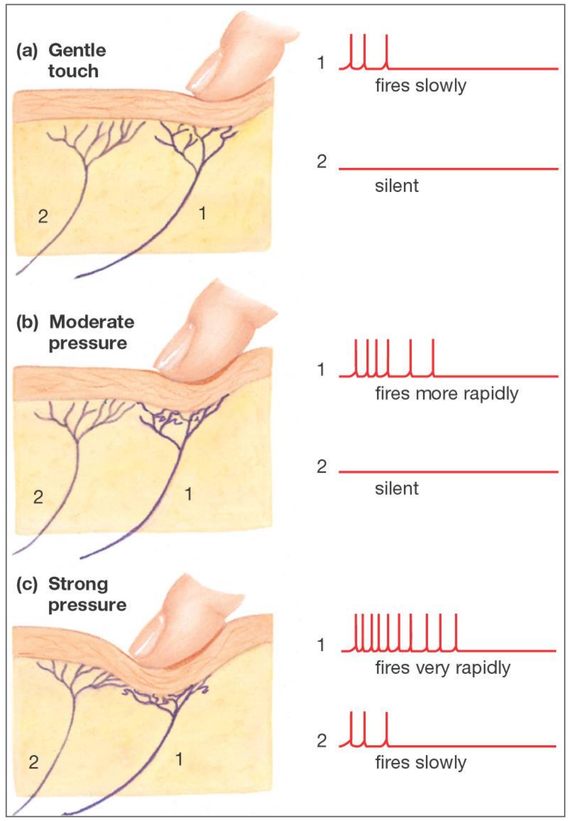
The Neuroendocrine and Neuroimmune Systems

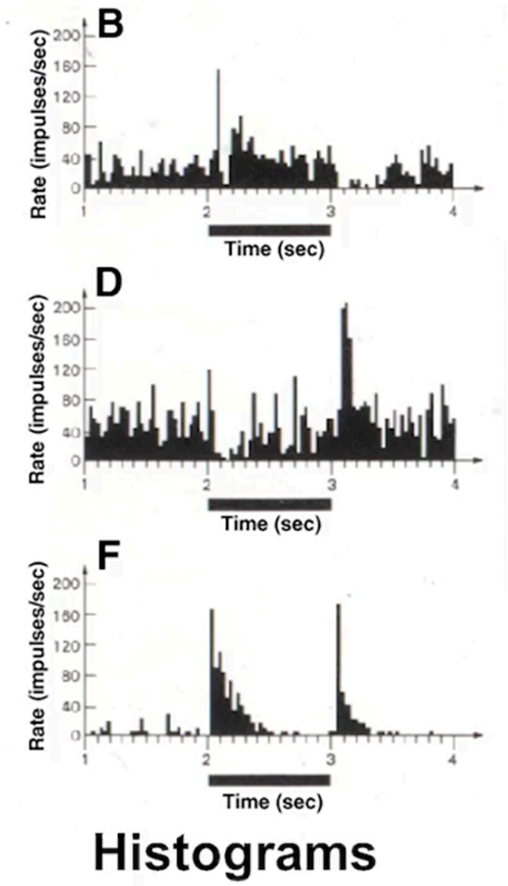
- **Neuroendocrine system:** The system that makes hormones that affect many bodily functions and that also provides the CNS with information.
- **Hormone:** A chemical that is produced by a gland and can act as a neurotransmitter substance.
- **Pituitary gland:** The "master gland" that regulates other glands but is itself controlled by the brain, primarily via connections from the hypothalamus.
- **Hypothalamic-pituitary-adrenal (HPA) axis:** The system of the hypothalamus, pituitary gland, and adrenal glands that is activated by stress, injury, and infection and that works to fight off infection.

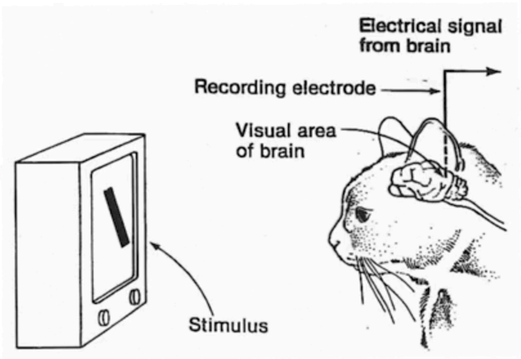


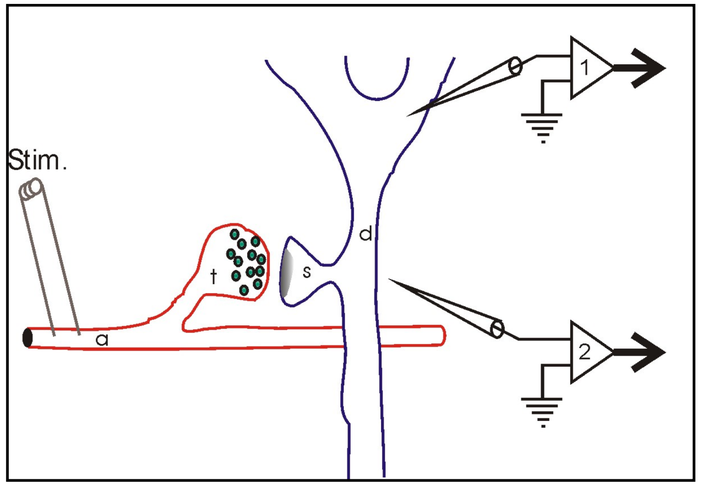
Single-Cell Recording

- **Single-cell recording:** The technique in which tiny probes called micro-electrodes are placed in the brain and used to record neural firing rates.



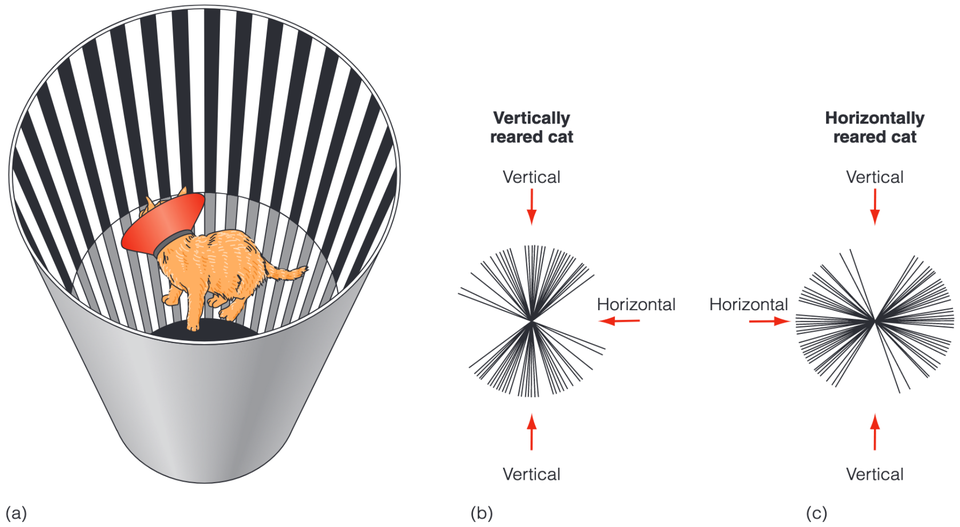


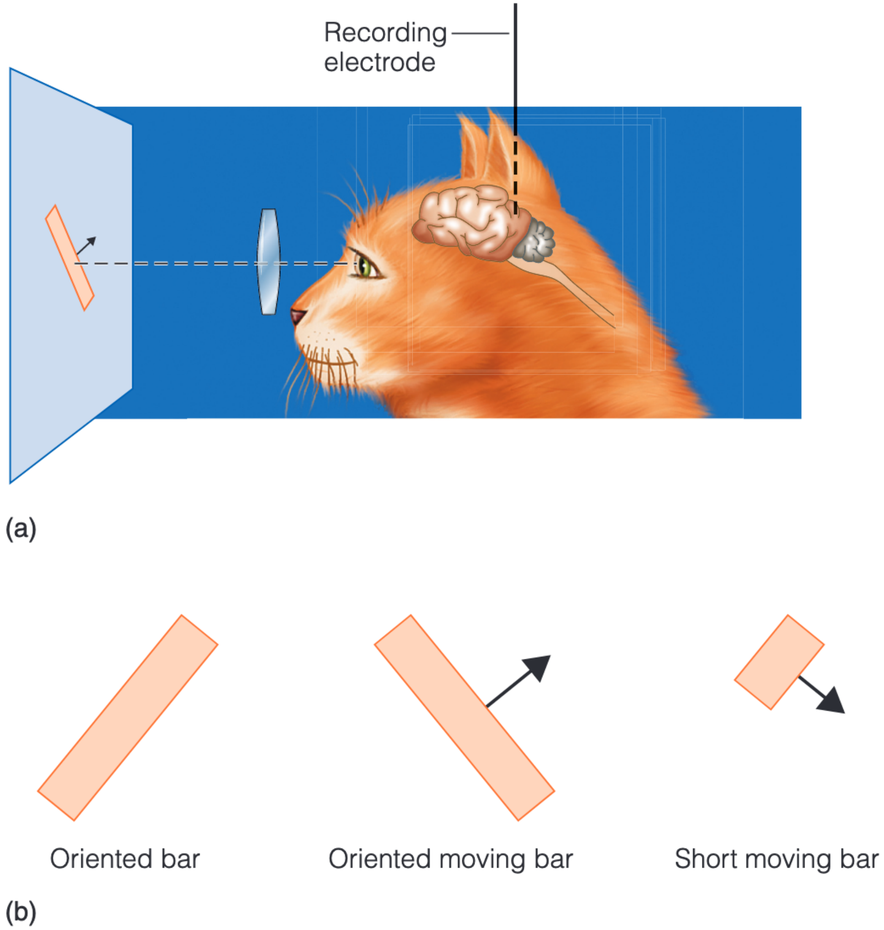




Representation by Neural Firing

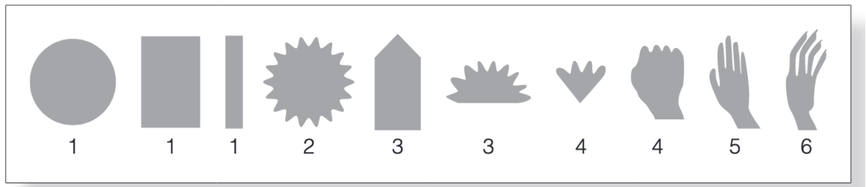
- **Feature detectors:** Neurons that respond to specific stimulus features such as orientation, movement, and length (Hubel & Wiesel, 1959).
- **Experience-dependent plasticity:** The structure of the brain is changed by experience (Blakemore & Cooper, 1970).





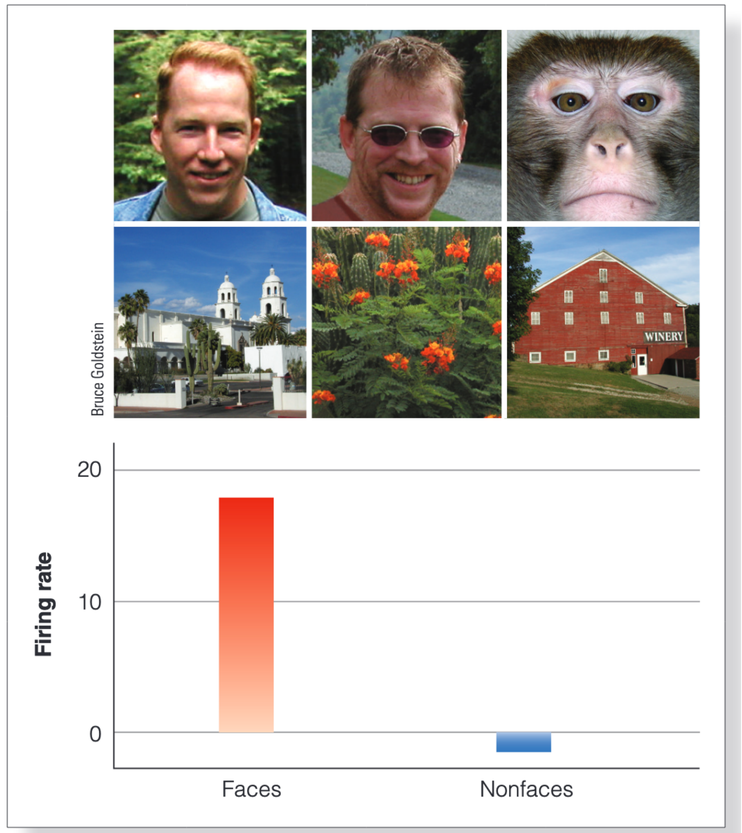
Response to Complex Stimuli

- Gross's research team presented a variety of different stimuli to anesthetized monkeys.
- After expanding the types of stimuli presented, they also found some neurons that responded best to faces.
- **Hierarchical processing:** Progression from lower to higher areas of the brain.



➤ **Figure 2.12** Some of the shapes used by Gross et al. (1972) to study the responses of neurons in the temporal lobe of the monkey's cortex. The shapes are arranged in order of their ability to cause the neuron to fire, from none (1) to little (2 and 3) to maximum (6).

(Source: Based on Gross et al., 1972.)

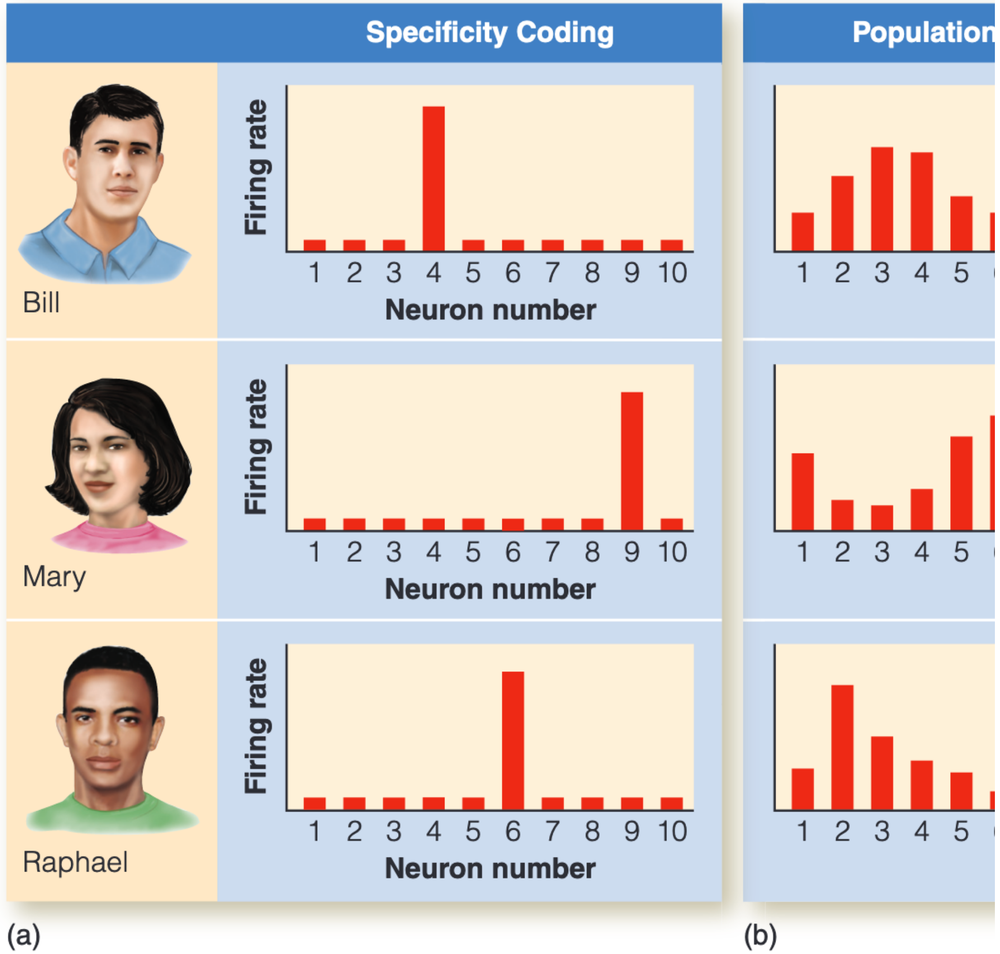


➤ **Figure 2.13** Firing rate, in nerve impulses per second, of a neuron in the monkey's temporal lobe that responds to face stimuli but not to nonface stimuli.

(Source: Based on E. T. Rolls & M. J. Tovee, 1995.)

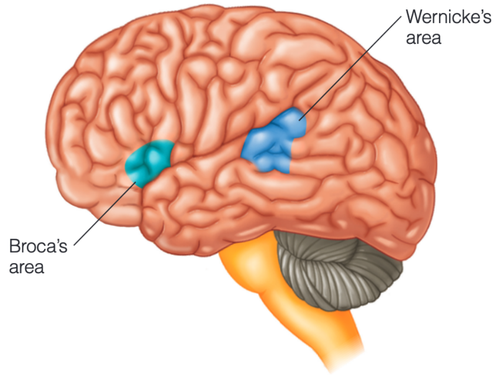
Sensory Coding

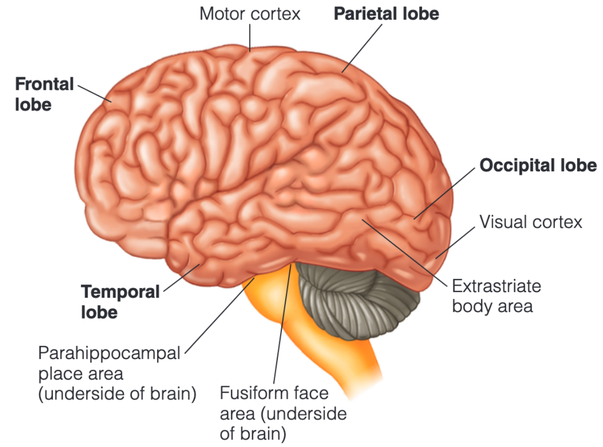
- **Specificity coding:** The idea that an object could be represented by the firing of a specialized neuron that responds only to that object.
- **Population coding:** The representation of a particular object by the pattern of firing of a large number of neurons.
- **Sparse coding:** Occurs when a particular object is represented by a pattern of firing of only a small group of neurons, with the majority of neurons remaining silent.

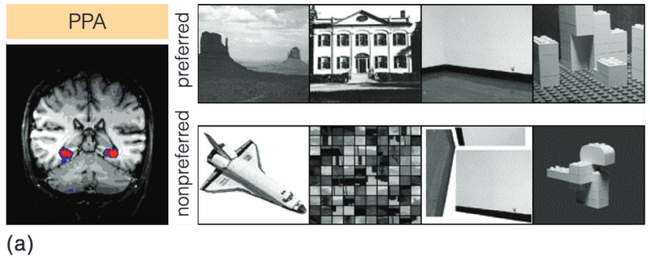


Localized Representation

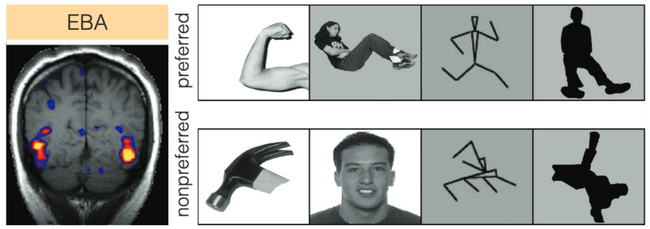
- **Localization of function:** Specific functions are served by specific areas of the brain.
- **Neuropsychology:** The study of the behavior of people with brain damage.
- Localization determined by recording from neurons.
- Localization demonstrated by brain imaging.





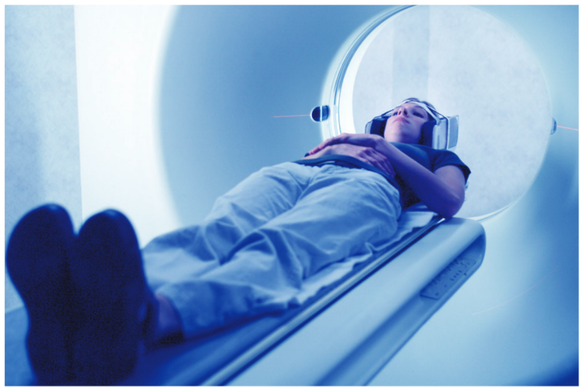


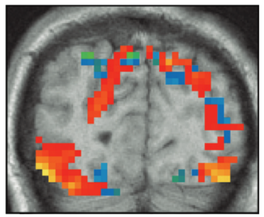
(a)



(b)

- Fusiform Face Area (FFA)
- Parahippocampal Place Area (PPA)
- Extrastriate Body Area (EBA)


Photodisc/Getty images
(a)

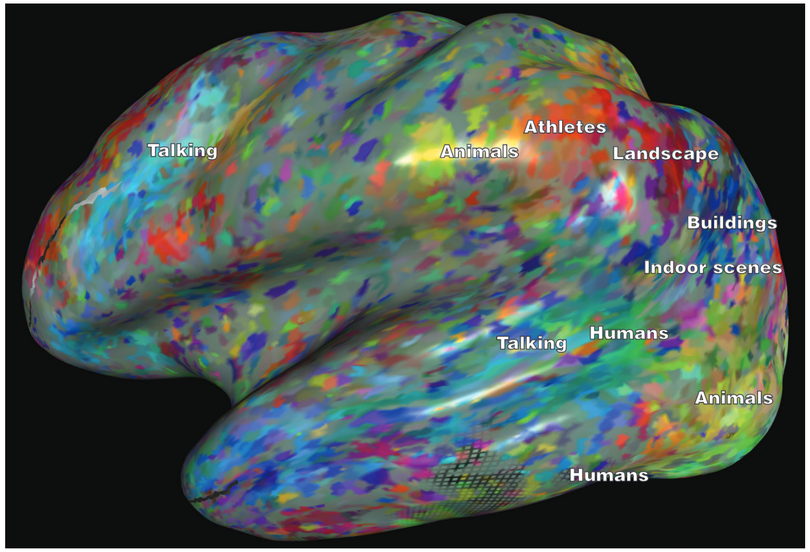


(b)

Moving Images

- Huth's participants viewed 2 hours of film clips while in a brain scanner. To analyze how the voxels in these participants' brains responded to different objects and actions in the films (Huth et. al., 2012).

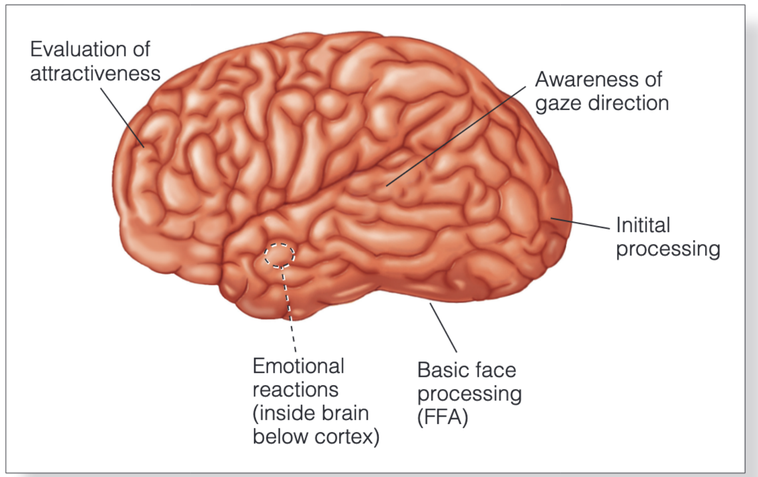
Movie Clip	Labels	Movie Clip	Labels
	butte.n desert.n sky.n cloud.n brush.n		city.n expressway.n skyscraper.n traffic.n sky.n
	woman.n talk.v gesticulate.v book.n		bison.n walk.v grass.n stream.n



Distributed Representation

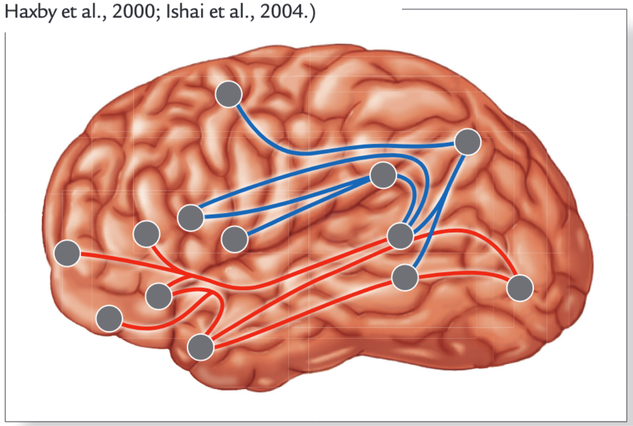
- **Distributed representation:** When given perception or representation activates many areas of the brain.

- Modern researchers have shown that damage to areas outside of Broca's and Wernicke's areas can cause problems in producing and understanding language (Ross, 2010).



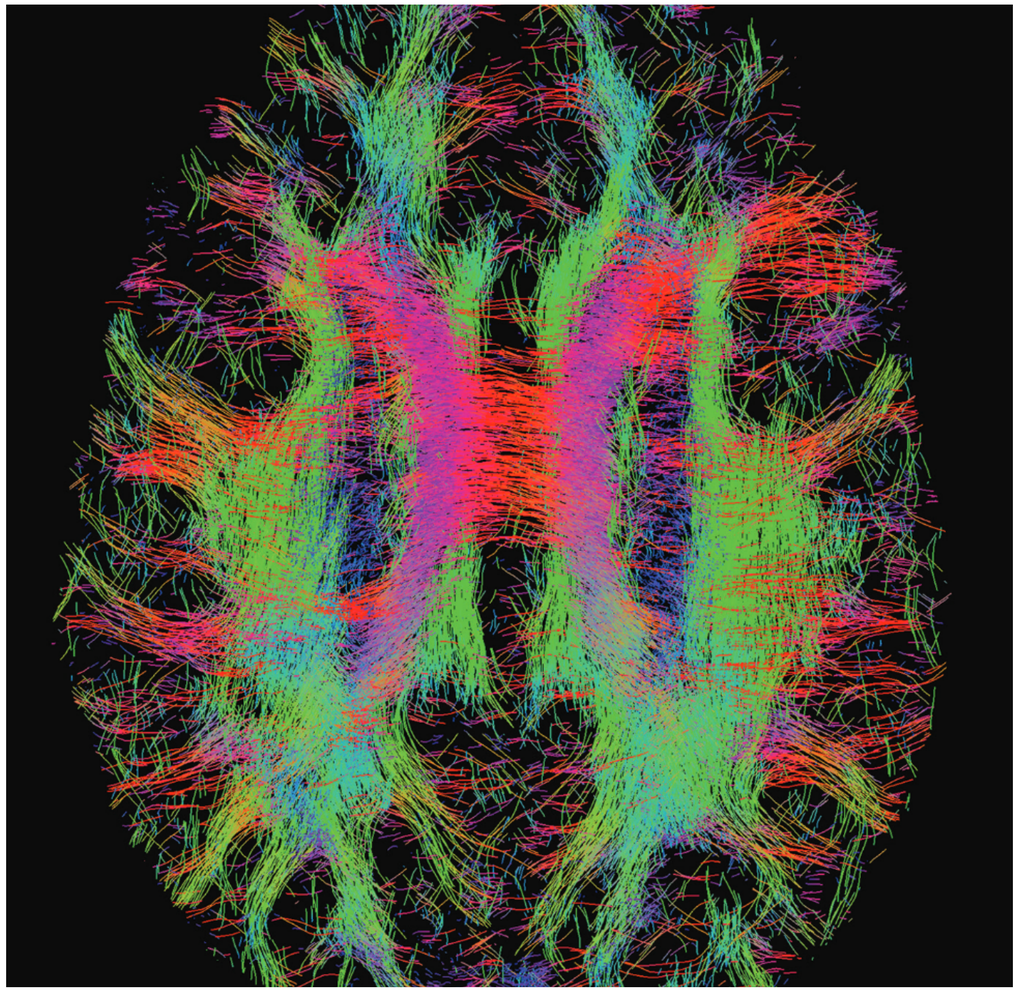
➤ **Figure 2.21** Areas of the brain that are activated by different aspects of faces.

(Sources: Adapted from Ishai, 2008; based on data from Calder et al., 2007; Gobbini & Haxby, 2007; Grill-Spector et al., 2004; Haxby et al., 2000; Ishai et al., 2004.)



Neural Networks

- **Neural networks:** Interconnected areas of the brain that can communicate with each other.
- Complex structural pathways called networks that form the brain's information highway.
- Within these structural pathways there are functional pathways that serve different functions.
- These networks operate dynamically, mirroring the dynamic nature of cognition.
- There is a resting state of brain activity, so parts of the brain are active all the time, even when there is no cognitive activity.

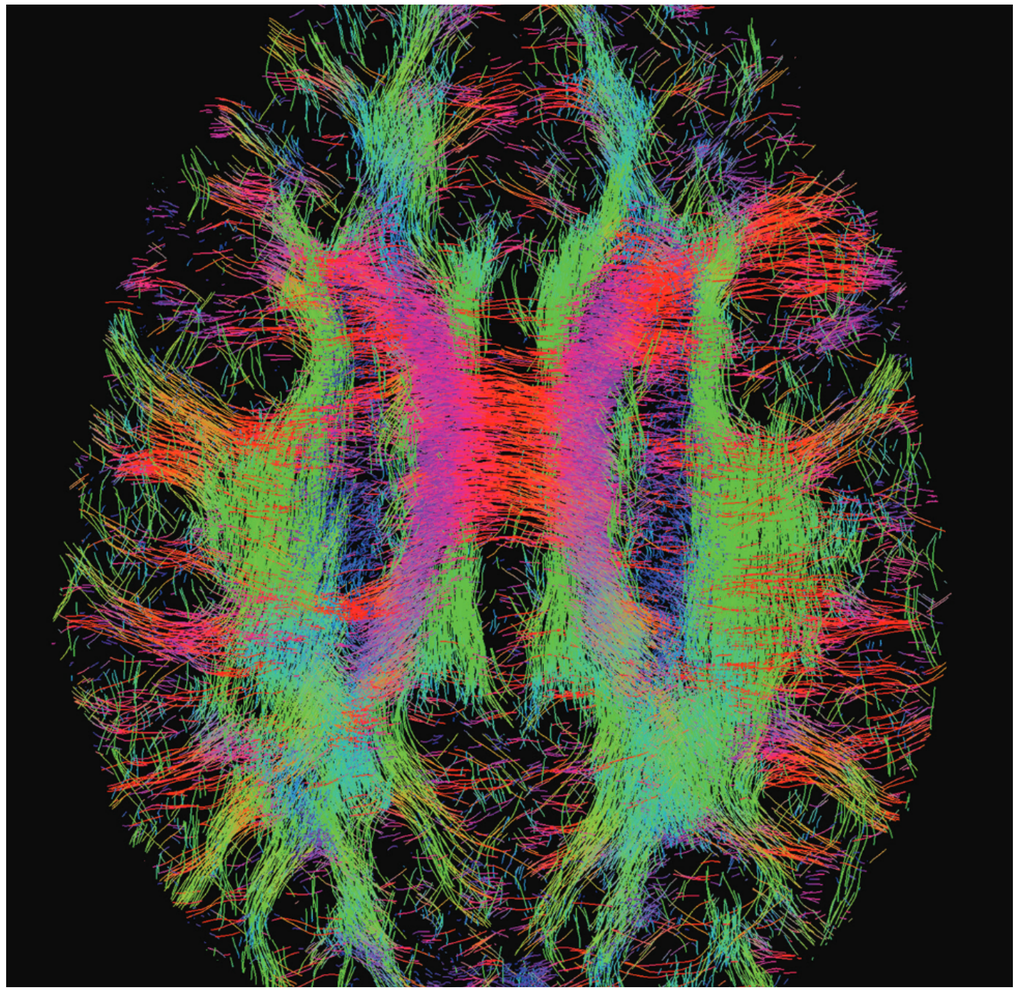


Structural Connectivity

- **Track-weighted imaging (TWI):** Based on detection of how water diffuses along the length of nerve fibers.

- **Connectome:** Indicates the “structural description of the network of elements and connections forming the human brain”.

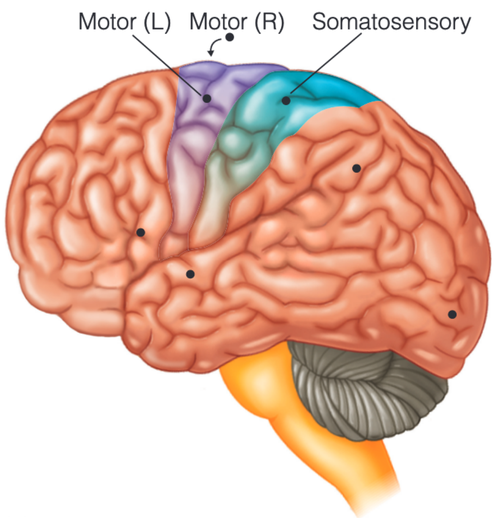
- Determining the brain’s wiring diagram is an important step in understanding how different areas of the brain communicate, because communication depends on structural connections.



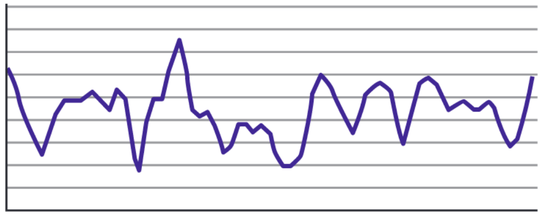
Functional Connectivity

- **Functional connectivity:** The extent to which neural activity in two brain areas are correlated.

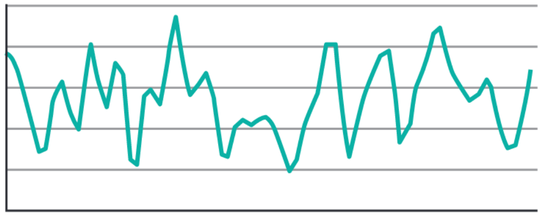
- **Resting-State Functional Connectivity:** Usually measured as fMRI response measured while a person is at rest.



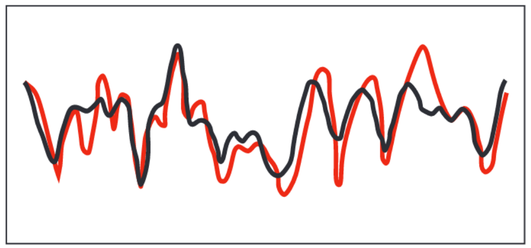
(a)



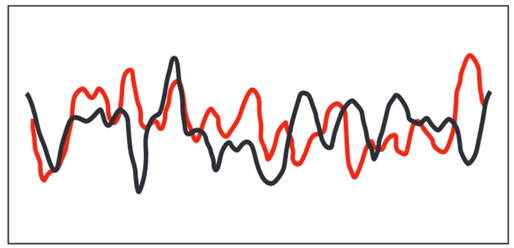
(b) Response at *Motor (L)* seed location



(c) Response at *Somatosensory* test location

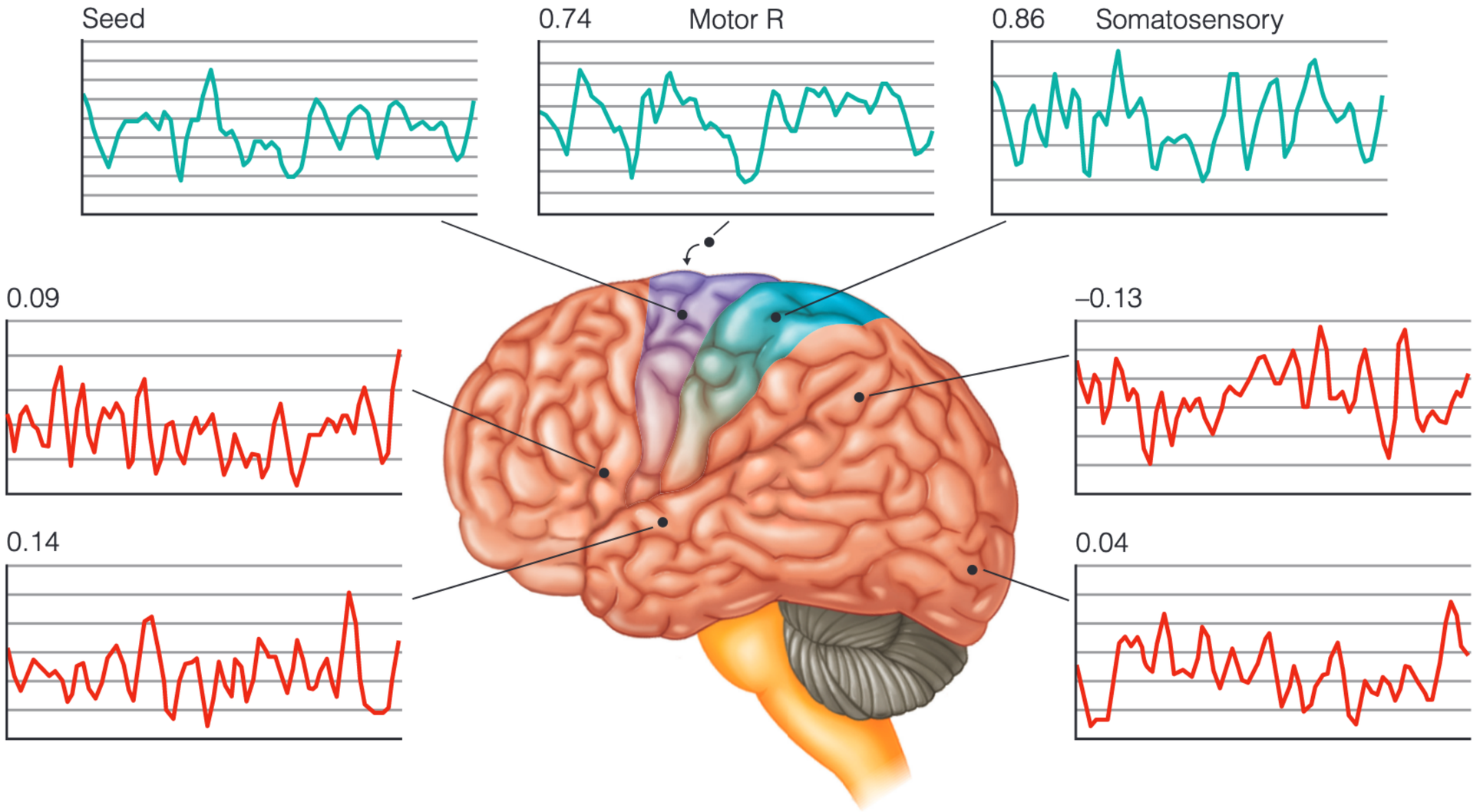


Seed response (black) and test response at *Somatosensory* test location (red)
Correlation = 0.86



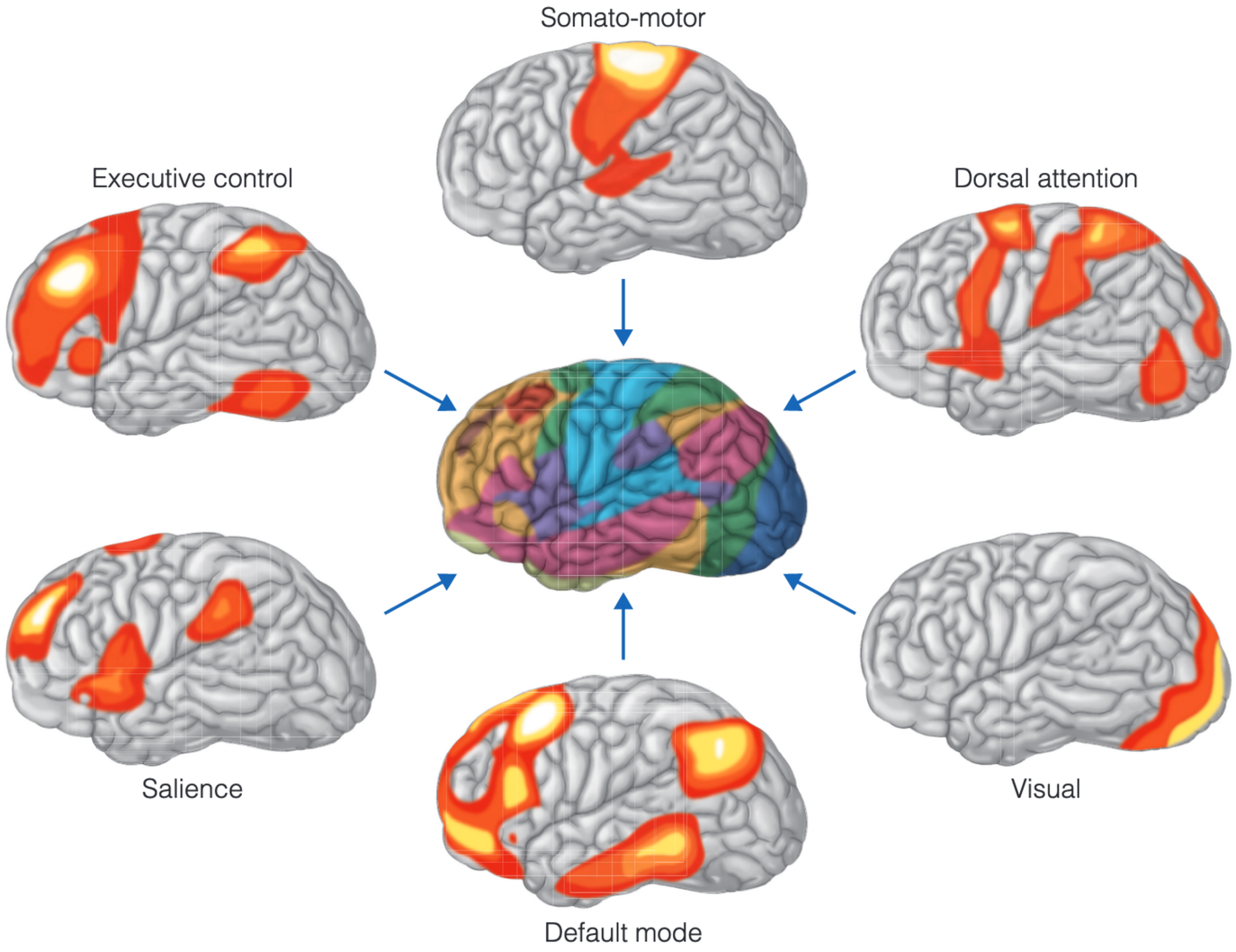
Seed response (black) and test response at another test location (red)
Correlation = 0.04

Functional Connectivity



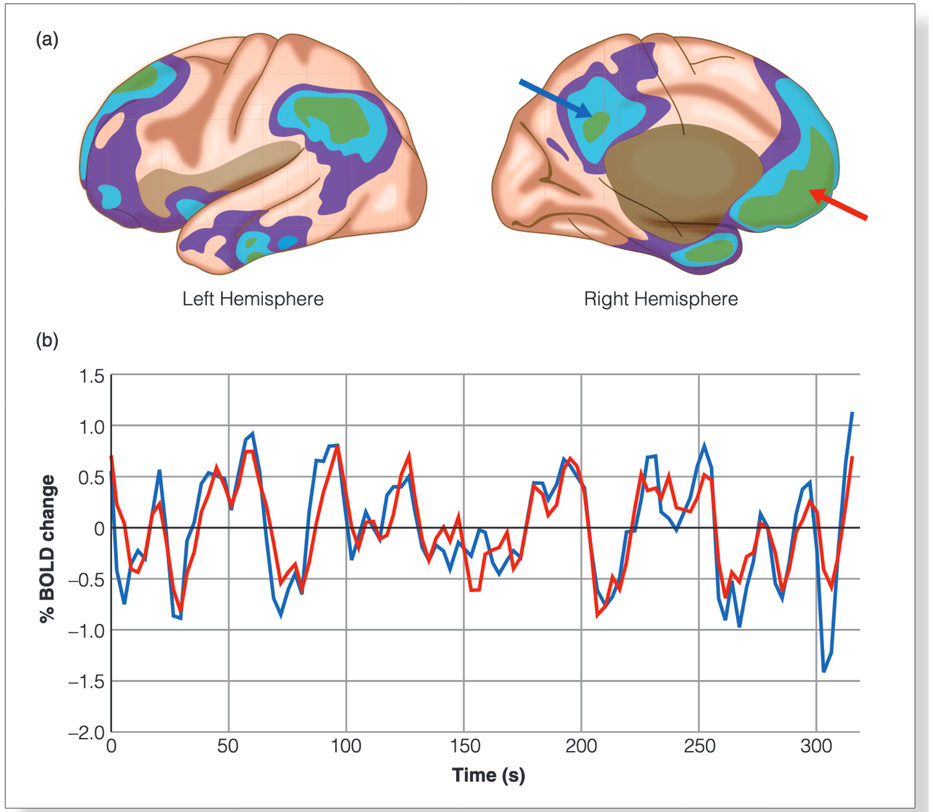
Six Major Brain Networks

- Six major brain networks determined by the resting-state fMRI procedure. Note that all of these networks increase activity during a task and decrease activity when at rest, except the default mode network, which decreases activity during a task, and increases activity when there is no task.



The Default Mode Network

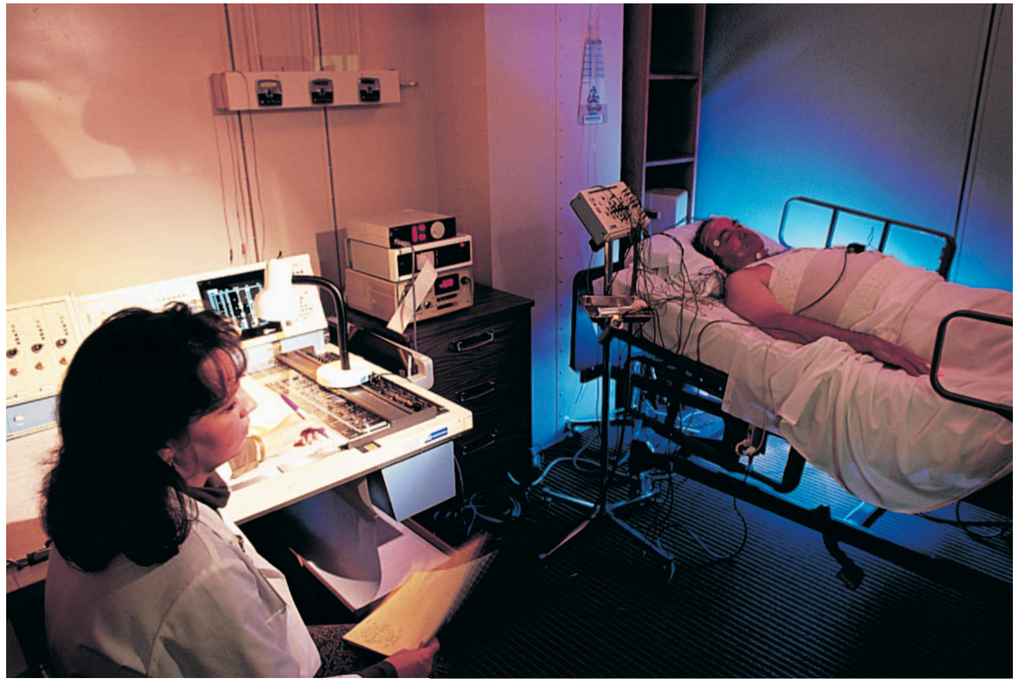
- **Default Mode Network (DMN):** A network of structures that respond when a person is not involved in specific tasks.
- One interesting observation is that when the DMN is active, people's minds tend to wander.
- Mind wandering decreases performance on tasks that require focused attention.

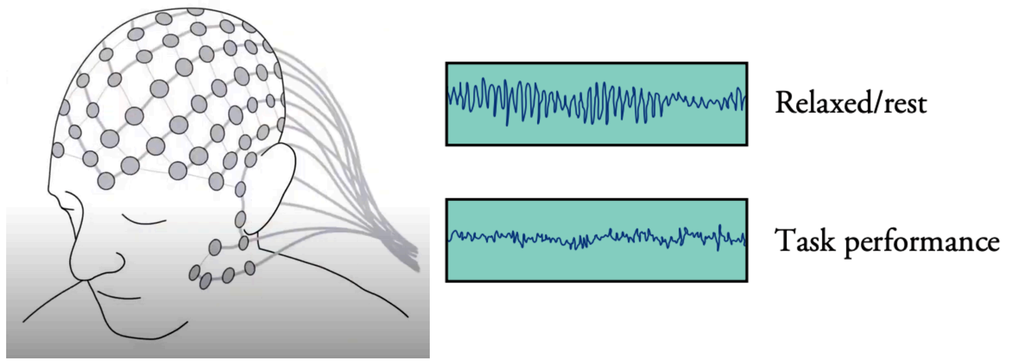


➤ **Figure 2.29** (a) Brain areas that decrease their activity during task performance. (b) Resting-state activity at two points in the right hemisphere, indicated by the arrows above. The fact that the resting state activity is correlated indicates that these areas are functionally connected. All of these areas, taken together, are called the *default mode network*.
(Source: From Raichle, 2015)

Recording Techniques

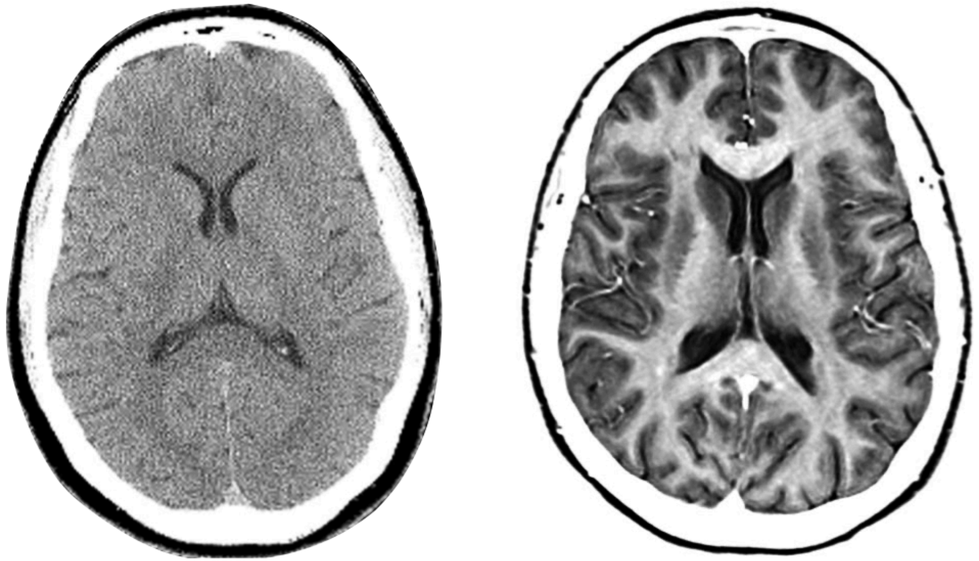
- **Electroencephalograph:** A machine that records electrical activity in the brain.
- **Electroencephalogram (EEG):** A tracing of brain waves of electrical fluctuation over time.
- **Event Related Potentials (ERP):** Recorded electrical activity over time or in response to a specific sensory, cognitive, or motor event.
- **Magnetoencephalography (MEG):** A technique for assessing brain activity that relies on recording magnetic waves produced by neural activity.
- Neither EEG nor MEG is very sensitive to activity in subcortical brain structures.





Neuroimaging — Structure

- **Neuroimaging:** Brain-scanning techniques that produce a picture of the structure or functioning of regions of the brain.
- **Computer-assisted tomography (CT):** A neuroimaging technique that produces a three-dimensional image of brain structures using X rays.
- **Magnetic resonance imaging (MRI):** A technique that uses magnetic properties of atoms to take sharp pictures of the three-dimensional structure of the brain.

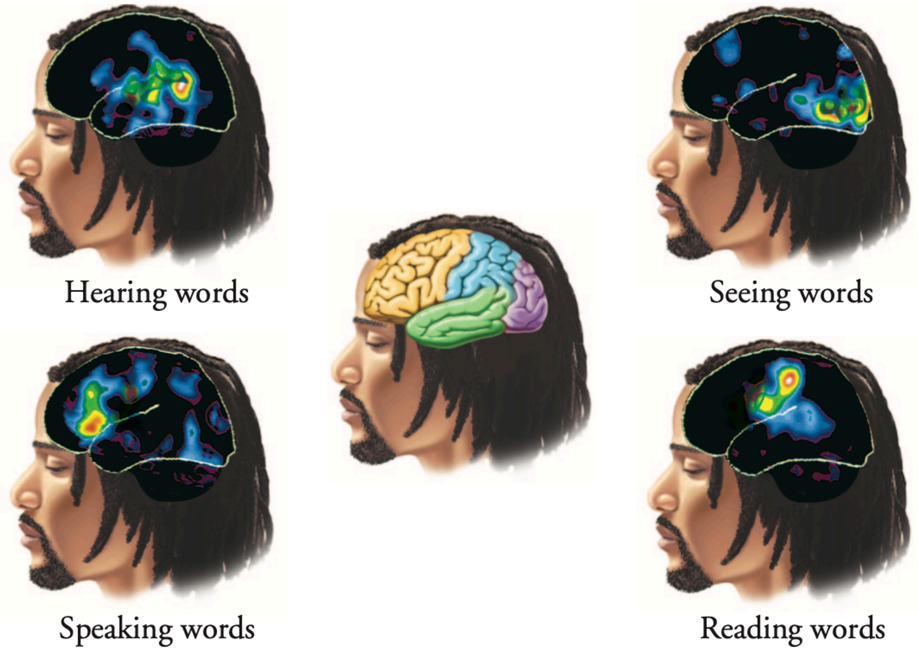


On the left, a computer-assisted tomography (CT) scan, and on the right, a magnetic resonance imaging (MRI) scan. MRI provides much higher resolution images of structures of the brain.

Neuroimaging — Function

- **Positron Emission Tomography (PET):** A neuroimaging technique that uses small amounts of a radioactive substance to track blood flow or energy consumption in the brain.

- **Functional Magnetic Resonance Imaging (fMRI):** A type of magnetic resonance imaging that detects the amount of oxygen being brought to particular places in the brain, which indicates how active those neurons are.



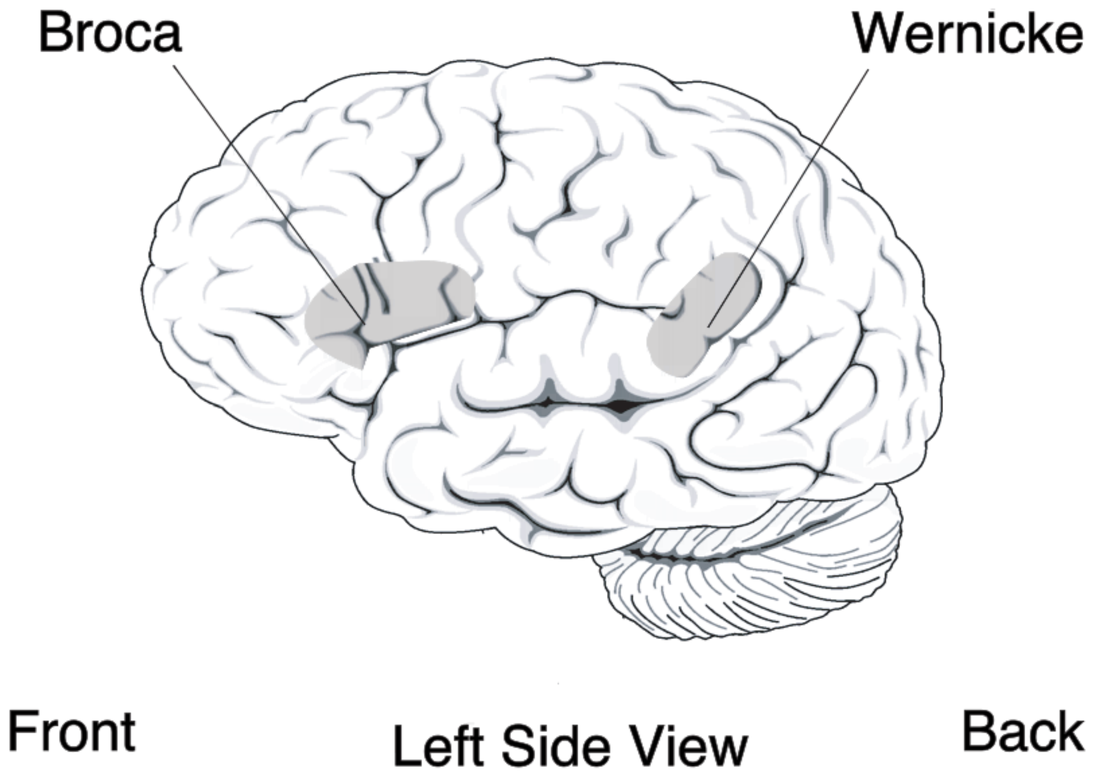
Brain Stimulation

- **Transcranial Magnetic Stimulation (TMS):** A technique in which the brain is stimulated from outside by putting a coil on a person's head and delivering a magnetic pulse (or series of magnetic pulses); the magnetic fields are so strong that they make neurons under the coil fire.

- By showing that temporarily disrupting a particular brain area in turn temporarily disrupts a particular type of behavior, this technique allows researchers to show that a brain area plays a causal role in a particular type of mental processing.

The Damaged Brain

- Brain tissue can be damaged in one way or another.
- **Lesion:** A region of impaired brain tissue.
- **Stroke:** A cause of brain damage that occurs when blood (with its life-giving nutrients and oxygen) fails to reach part of the brain, and thus neurons in that area die.
- **Broca's aphasia:** A type of aphasia (language disorder after stroke) with effortful speech. Understanding of speech is good, but speaking is difficult. Intelligence remains intact.



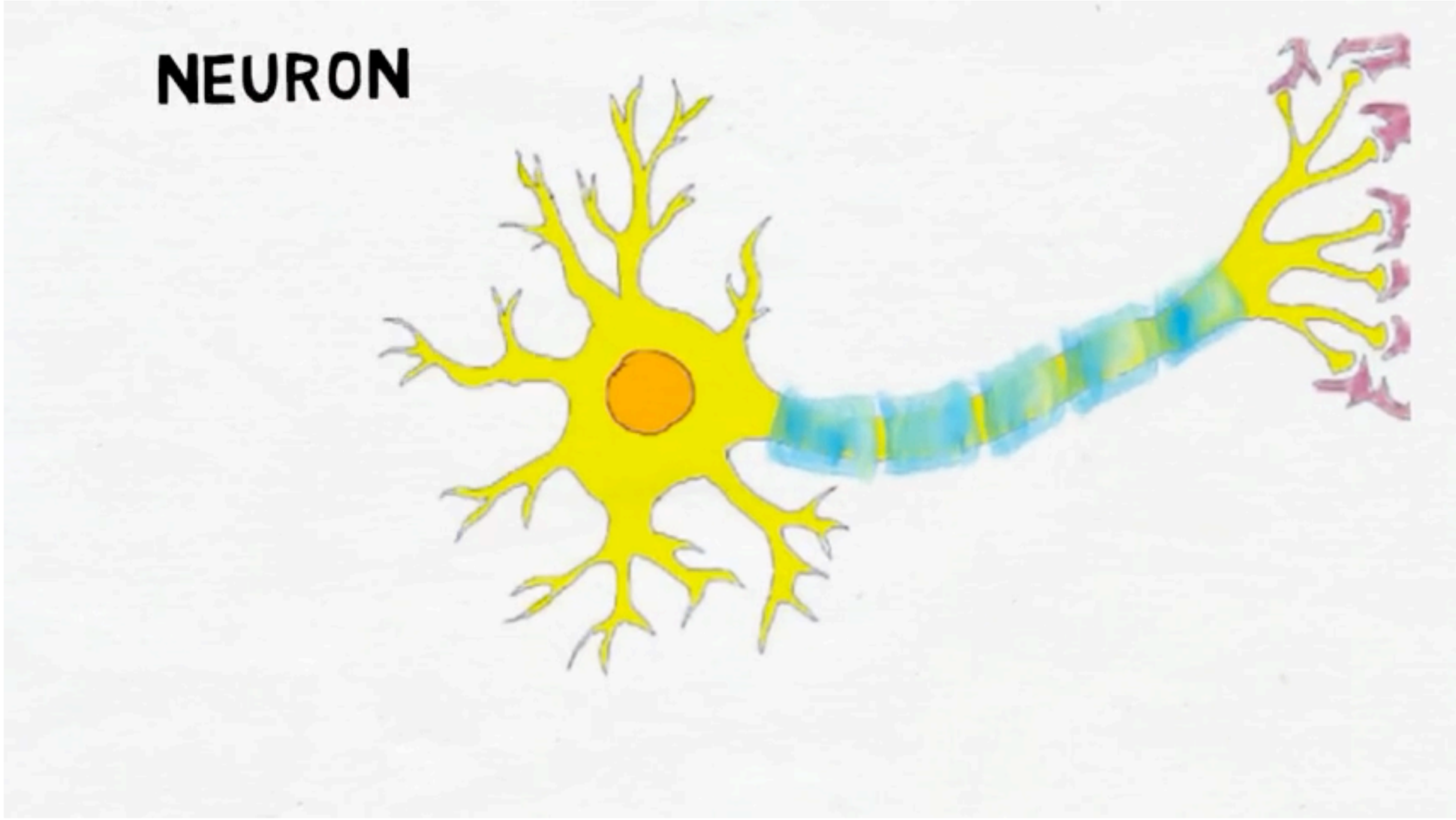
Various Techniques Used to Study Brain Function

Technique	Does the technique document changes that occur in less than a second?	Does the technique document functions of brain regions of 2 millimeters or less?	Is the technique only used on the cortex?	Size of brain region assessed by the technique	Expense of technique ("High" indicates at least $1,000 for each session with person)
Electrical stimulation	Yes	No	No	Small	Low
EEG	Yes	No	Yes	Large	Low
fMRI	Almost	Almost	No	Large	High
PET	No	Almost	No	Large	High
MEG	Yes	Yes	Yes	Small	Medium
Single-cell recording	Yes	Yes	No	Small	Low
TMS	Almost	Almost	Yes	Small	Low

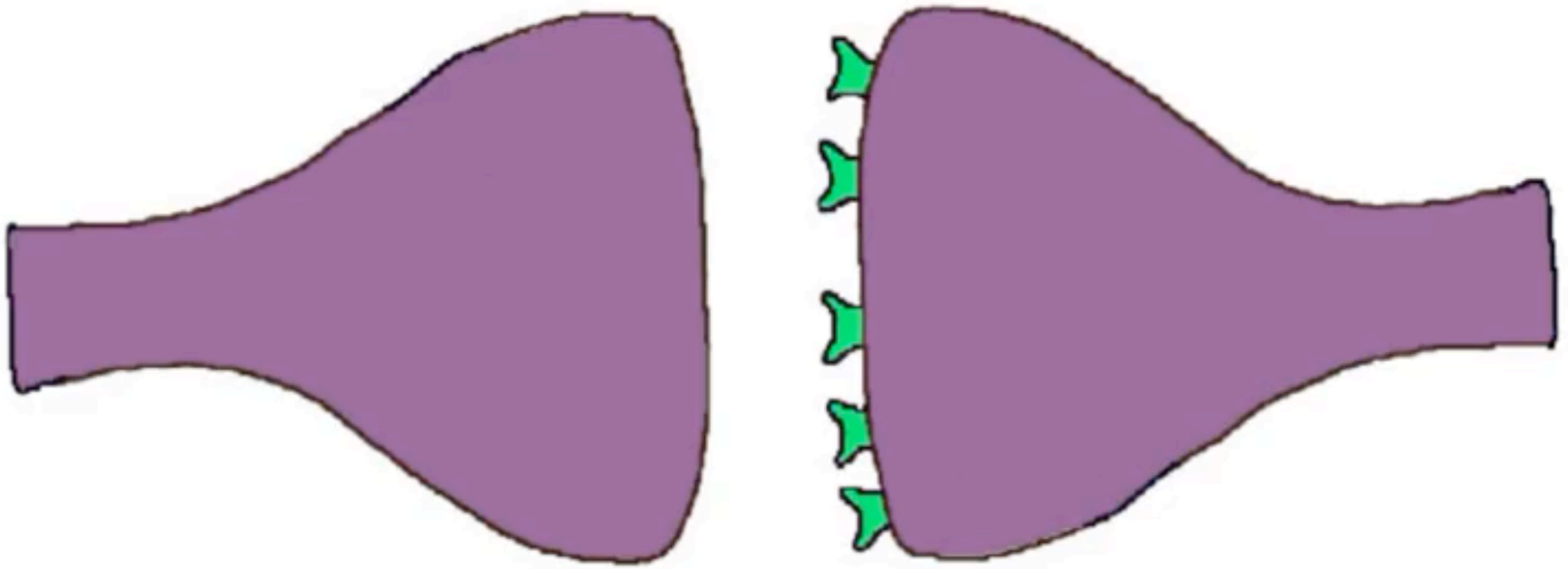
Questions, comments?

Exercises

Neuroscientifically Challenged – Neuron

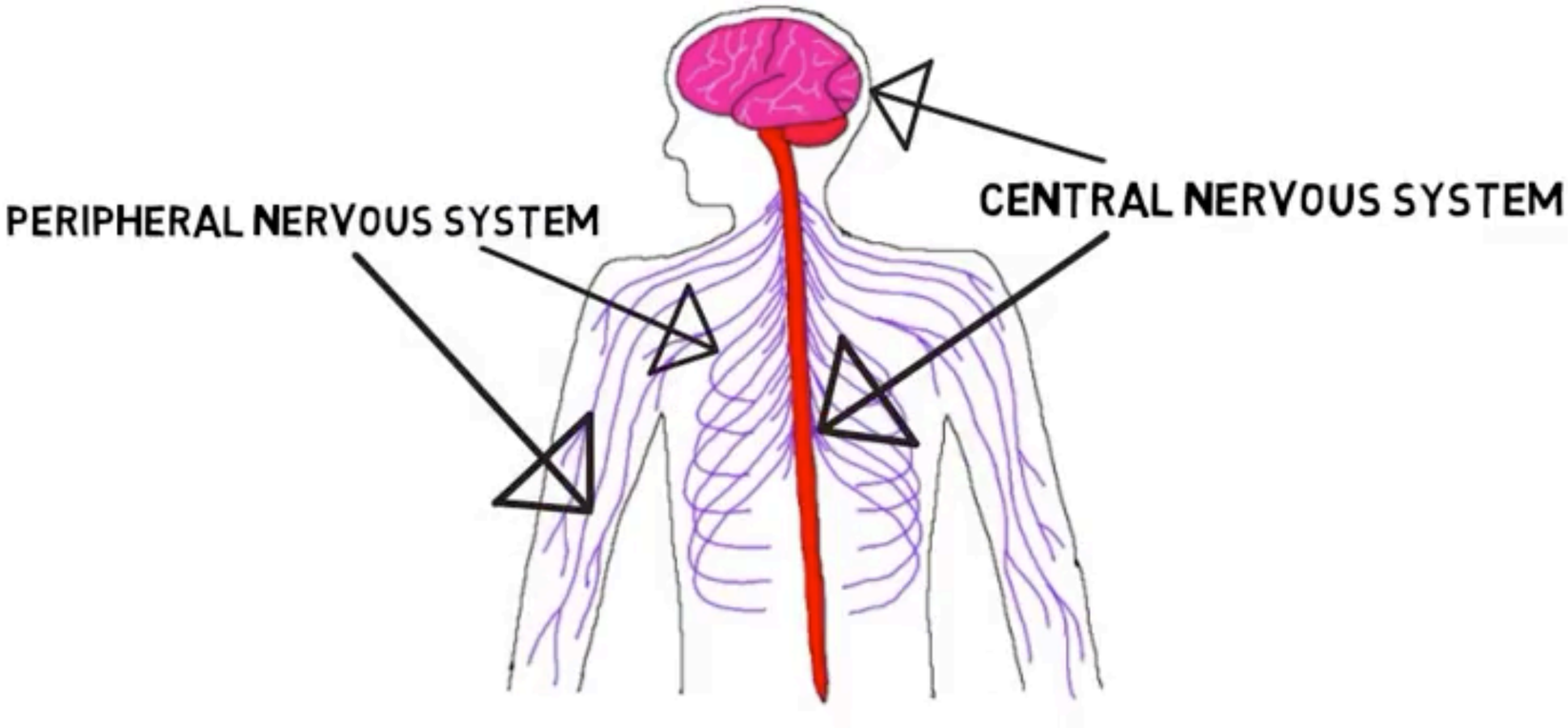


Neuroscientifically Challenged – Synapse



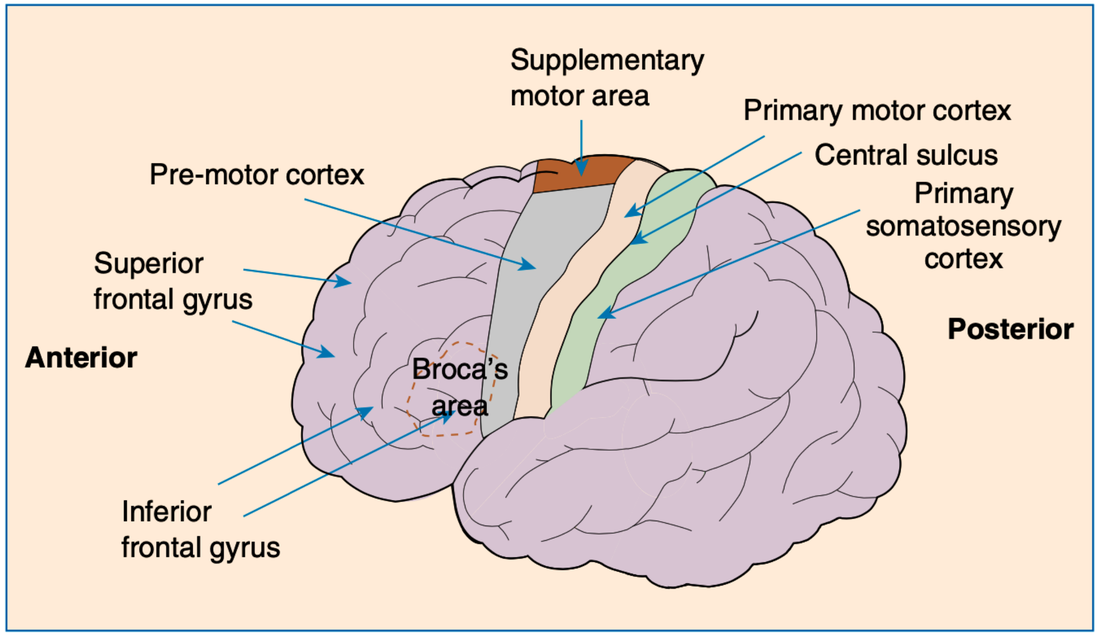
Representation by Neural Firing

Neuroscientifically Challenged – CNS and PNS



Broca's Aphasia

- **Broca's Aphasia:** It is a type of aphasia that is characterized by speech that is effortful, sparse, and halting, and impaired repetition, with relatively intact language comprehension.



Wernicke's Aphasia

- **Wernicke's Aphasia:** A type of aphasia characterized by fluently articulated speech with impaired language comprehension.