Chapter 2

Biology of the Mind

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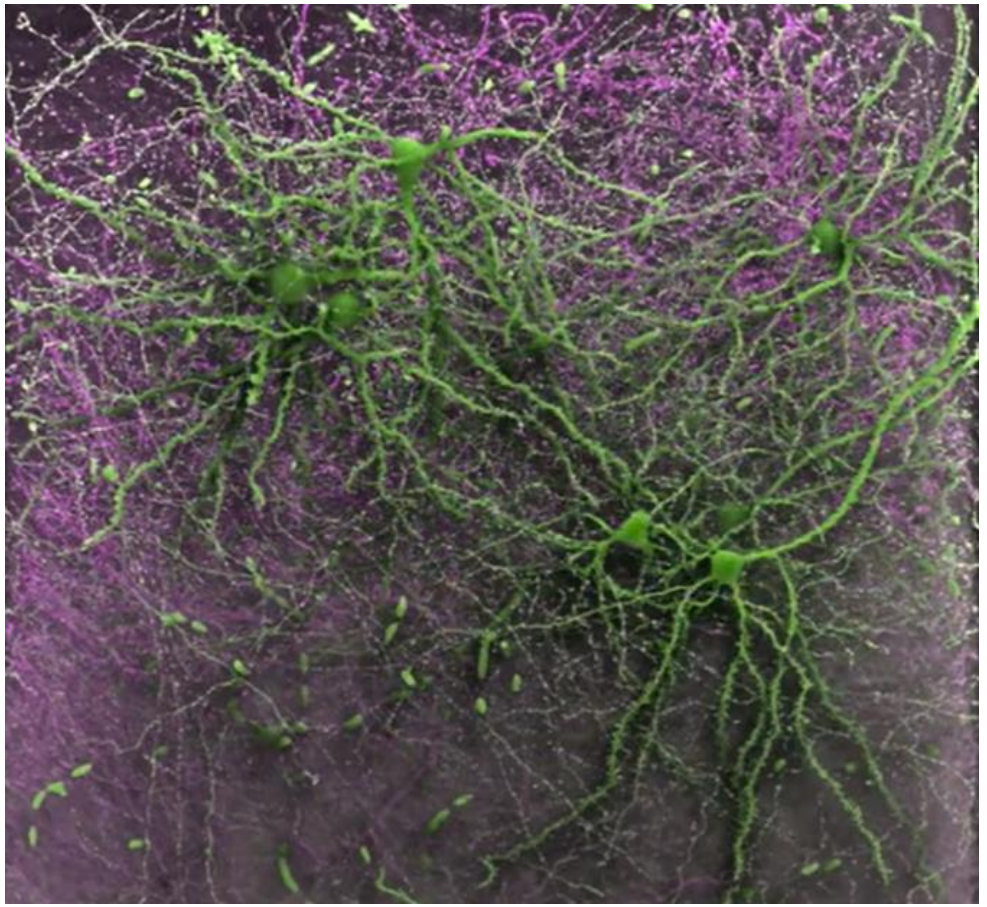
Learning Objective Questions: Week 2

- How do neurons communicate? How do neurotransmitters influence us?
- What are the two major divisions of the nervous system, and what are their basic functions?
- How does the endocrine system transmit information and interact with the nervous system?

Neural Communication

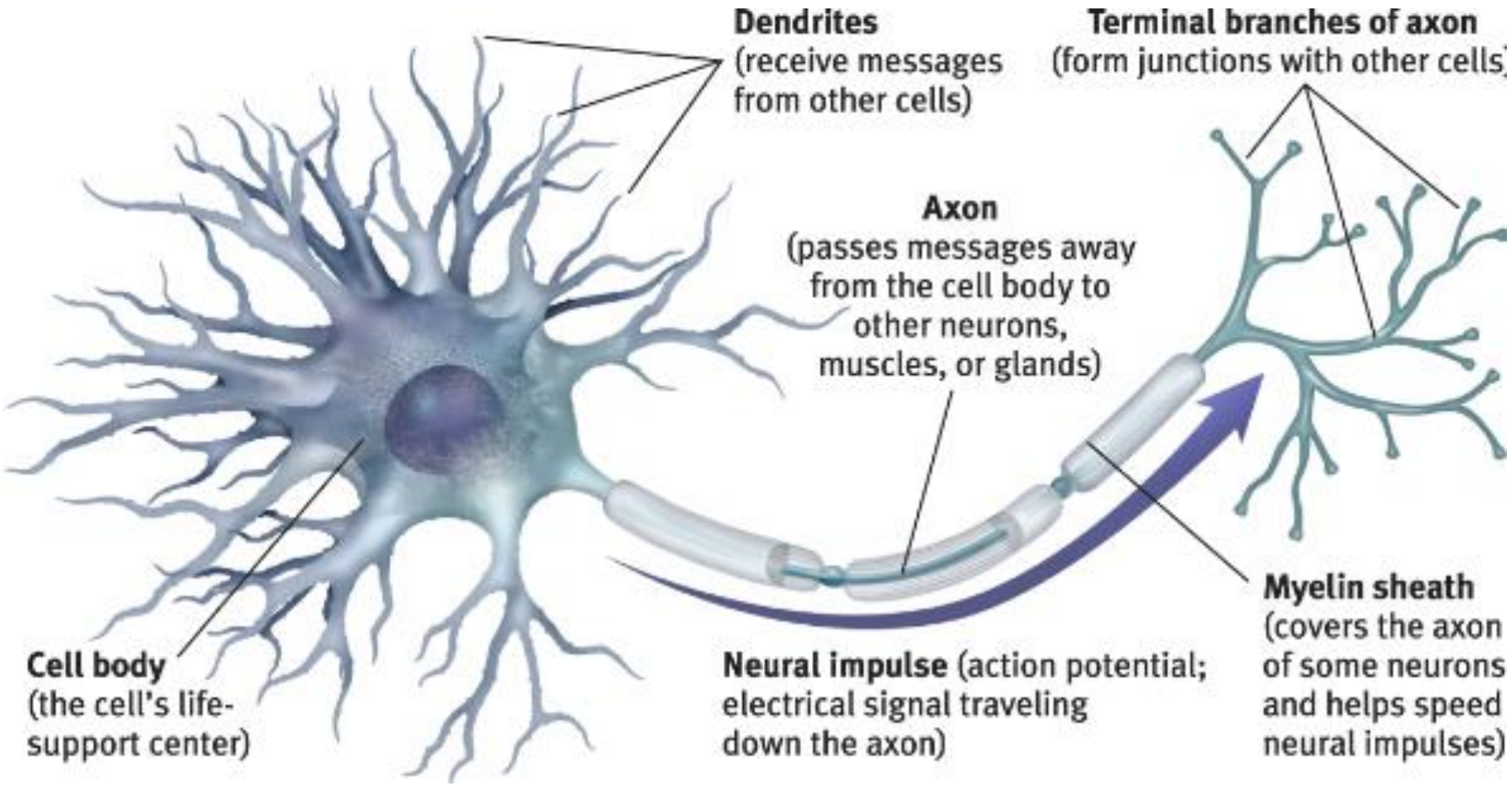


https://www.youtube.com/watch?v=m0rHZ_RDdyQ

Cells in the Nervous System

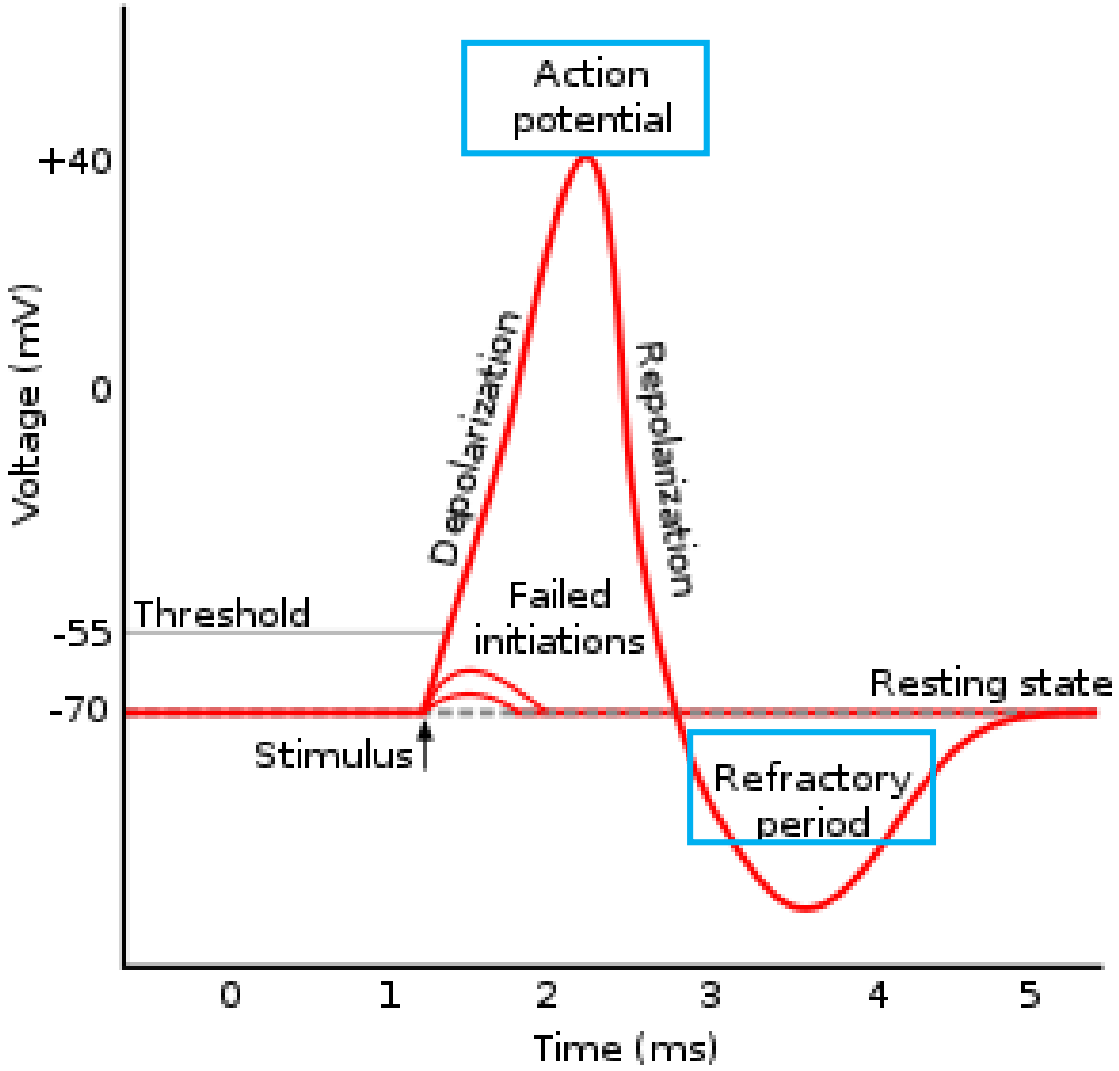
- Cell types
  - **Neurons** : building blocks of the nervous system; transmit information
  - **Glial cells**: cells in the nervous system that support, nourish, and protect neurons; they also play a role in learning, thinking, and memory.

Neuron



- Cell body (soma)
- Dendrites
- Axon
- Axon Terminals
- Myelin sheath

Action Potential

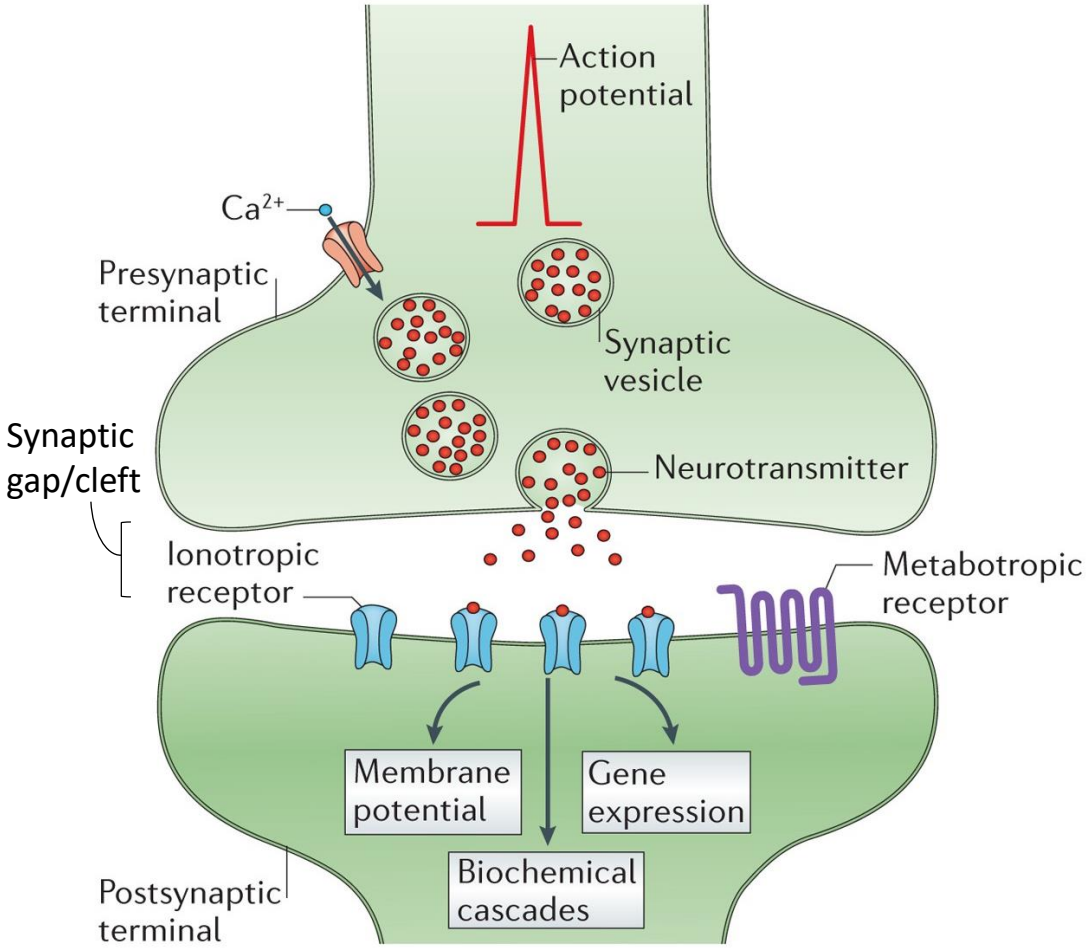


- The messages neurons carry are electrical signals, or nerve impulses, called **action potentials**.
- A very specific kind of change in **membrane potential**.
- **All-or-none principle**: Either an axon conducts a nerve impulse or it does not.

Intercellular Communication

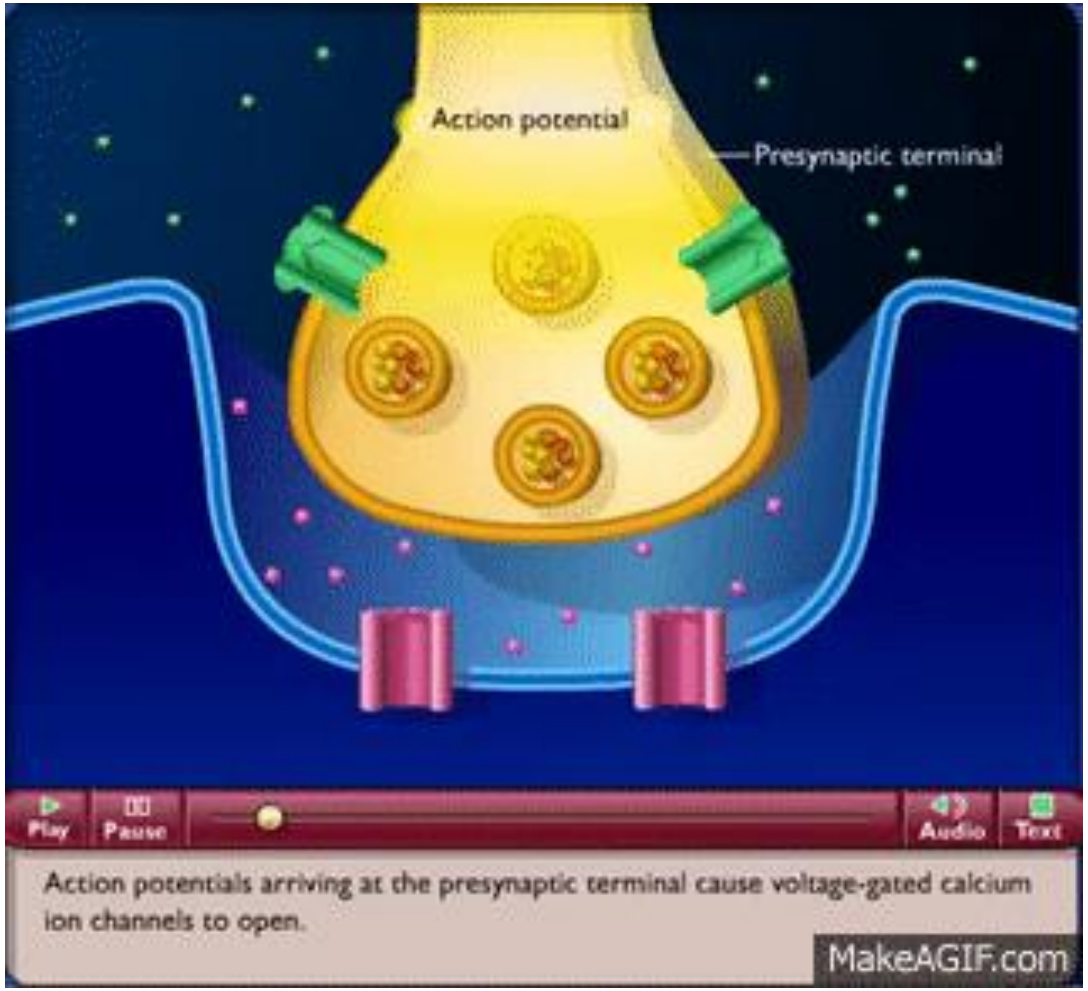
- **Synapse**: also called neuronal junction, the site of transmission of electric nerve impulses between two nerve cells (neurons) or between a neuron and a gland or muscle cell (effector).
- **Neurotransmitters**: neuron-produced chemicals that cross the synaptic gap to carry messages to other neurons or to muscles and glands.

Chemical Synapse

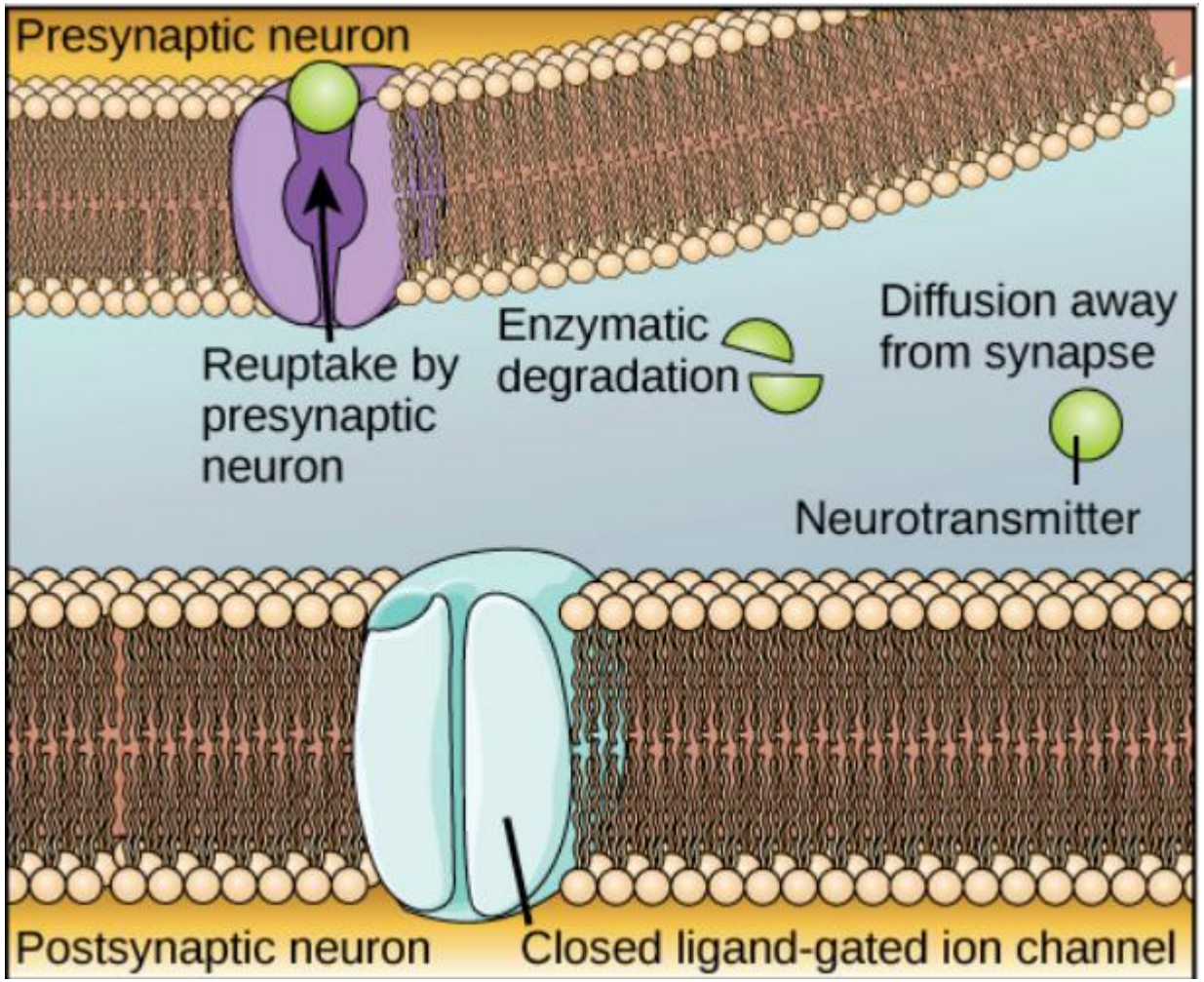


- The common type
- Voltage gated Ca+ channels open.
- **Synaptic vesicle** fuse with the membrane.
- **Neurotransmitters** are release into the **synaptic gap/cleft**.

Chemical Synapse



Signal Termination



- For the signal to end, the synaptic cleft must be cleared of neurotransmitter.
  - Reuptake
  - Degradation
  - Diffuse away
- For example:
  - Acetylcholinesterase (AChE) breaks down acetylcholine
  - Norepinephrine is quickly reabsorbed by presynaptic cell

Signal Termination

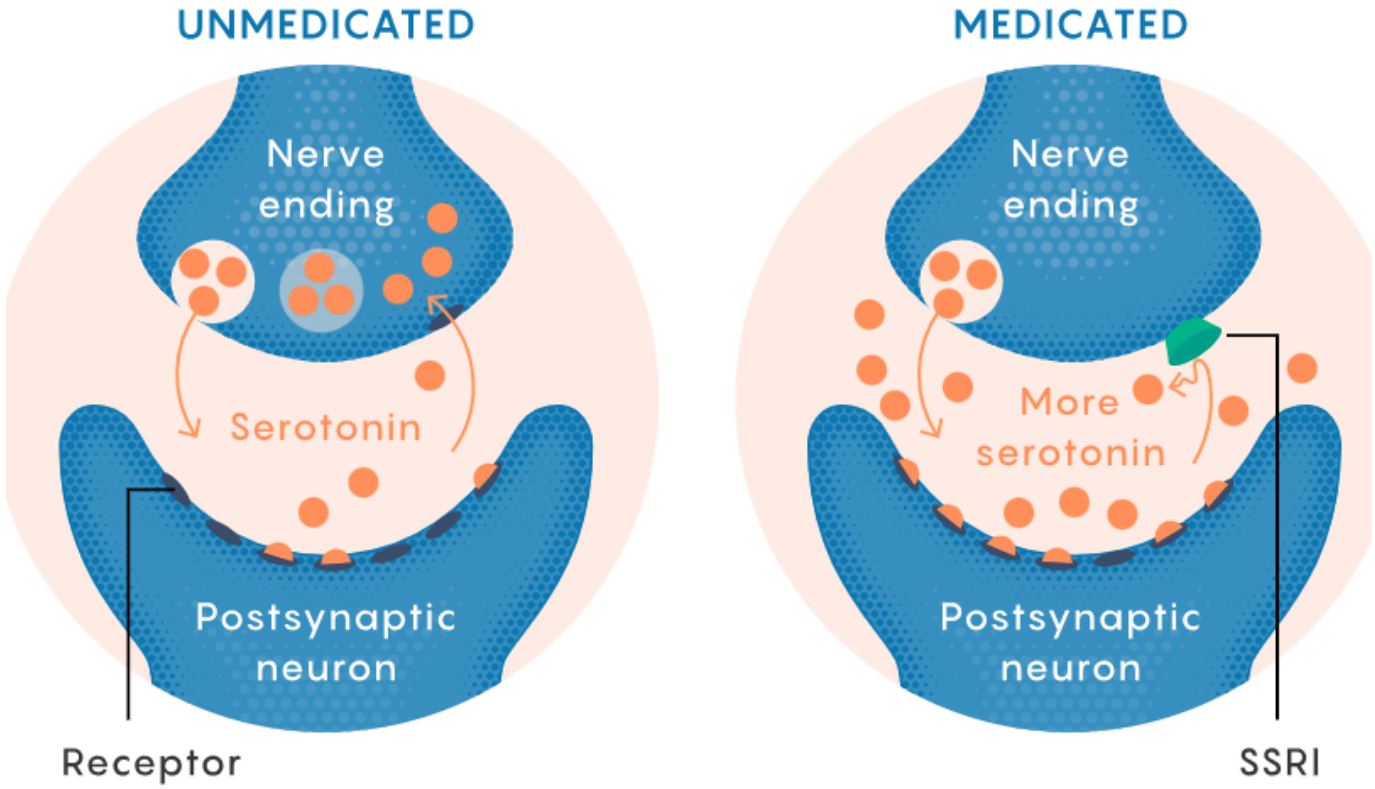
- Short existence of neurotransmitters at synapse prevents continuous excitation or inhibition of postsynaptic cell.
- Anything that interferes with the processes that terminate the synaptic signal can have significant physiological effects.
  - For instance, some insecticides kill insects by inhibiting **acetylcholinesterase** (AChE).
  - On a more positive note, drugs that interfere with reuptake of the neurotransmitter serotonin in the human brain are used as antidepressants, for example, Prozac.

Types of Neurotransmitters

Neurotransmitters	Function	Examples of Malfunctions
Acetylcholine	Voluntary muscle control, parasympathetic system	↓ Alzheimer's disease
Epinephrine and Norepinephrine	Sympathetic system, fight-or-flight responses, wakefulness, alertness	↓ Depress mood
Dopamine	Smooth muscle movements, postural stability, feelings of pleasures	↑ Schizophrenia ↓ Parkinson's disease
Serotonin	Mood, sleep, eating, dreaming	↓ Depression
GABA	Brain stabilization	↓ Seizures, tremors, and insomnia
Glutamate	Brain excitation	↑ Migraines or seizures
Endorphins	Natural painkillers	Oversupply with opiate drugs can suppress the body's natural endorphin supply.

Serotonin & Depression

- Drugs called selective serotonin reuptake inhibitors (SSRIs) raise serotonin levels in the brain.



After a neuron releases serotonin to stimulate a neighboring cell, it takes up the serotonin again.

By blocking reuptake, SSRIs raise the serotonin levels in the synapse.

Socrative Time!
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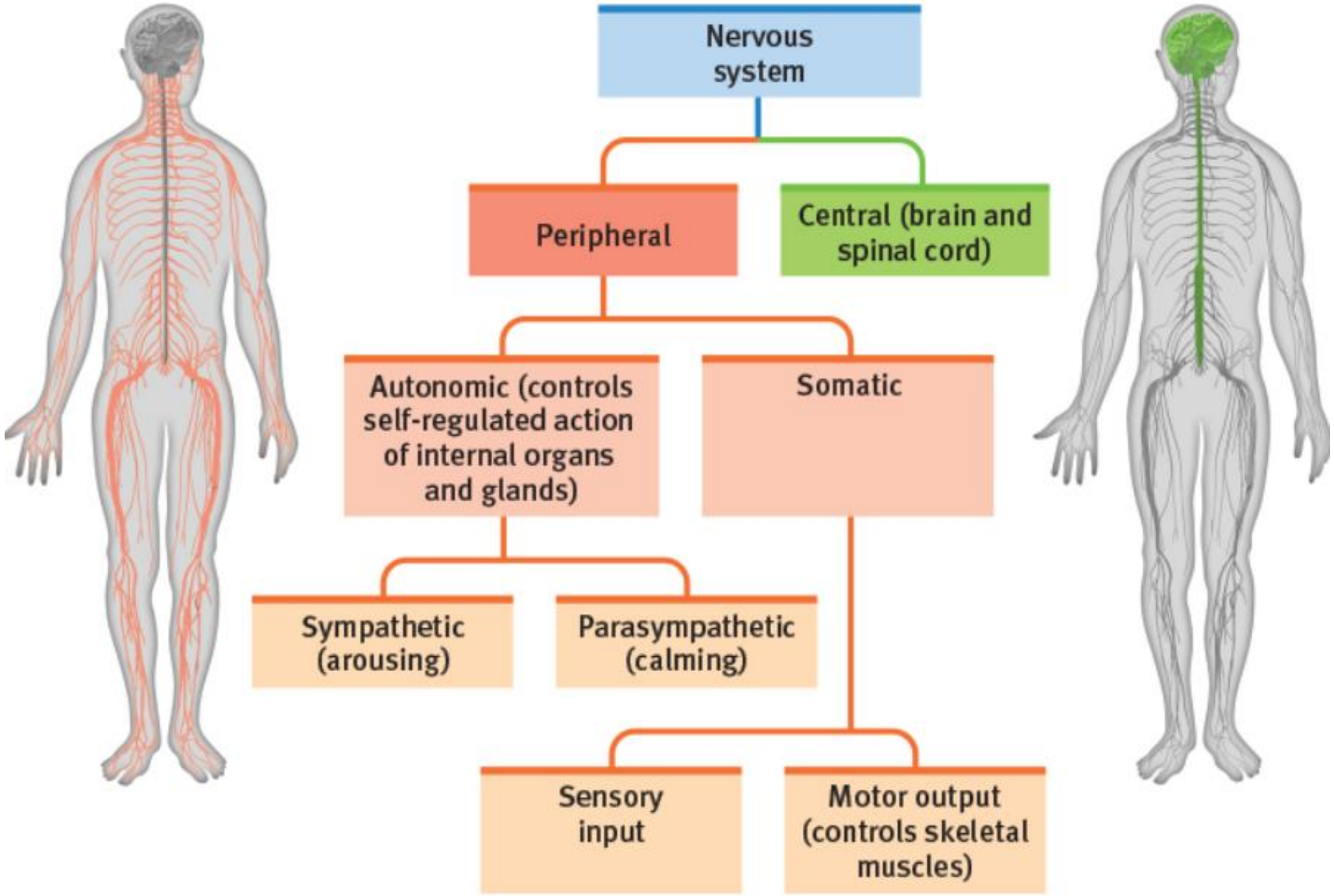
Divisions of the Nervous System



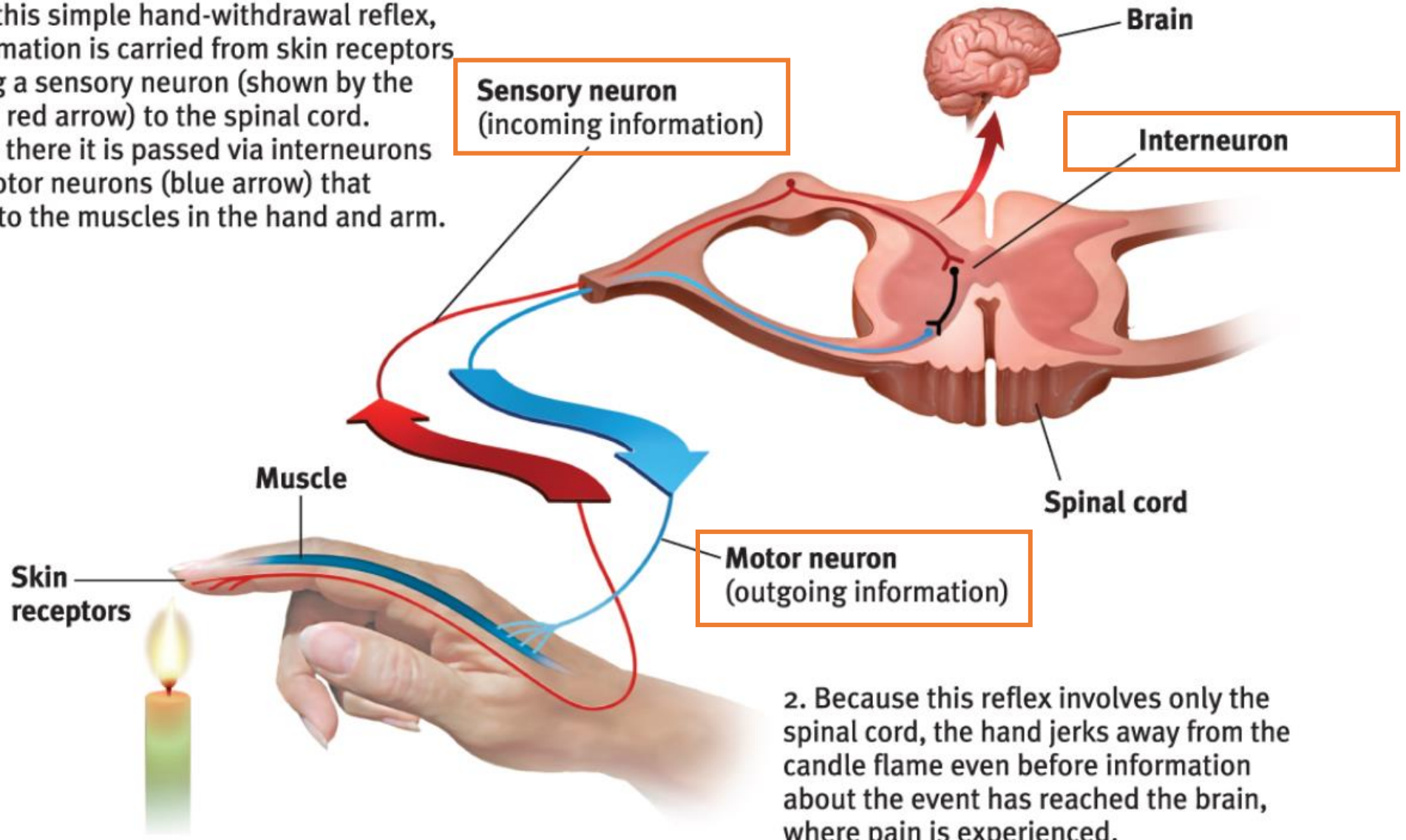
- Central Nervous System (CNS)
- Peripheral Nervous System (PNS)

Type of Neurons

- **Nerves** are electrical cables formed from bundles of axons. They link your central nervous system with your body's sensory receptors, muscles, and glands.
- Information travels in your nervous system through three types of neurons.
  - **Sensory neurons** carry messages from your body's tissues and sensory receptors inward to your spinal cord and brain for processing.
  - **Motor neurons** carry instructions from your central nervous system outward to your body's muscles and glands.
  - **Interneurons** within your brain and spinal cord communicate with one another and process information between the sensory input and motor output.

Reflex

1. In this simple hand-withdrawal reflex, information is carried from skin receptors along a sensory neuron (shown by the large red arrow) to the spinal cord. From there it is passed via interneurons to motor neurons (blue arrow) that lead to the muscles in the hand and arm.



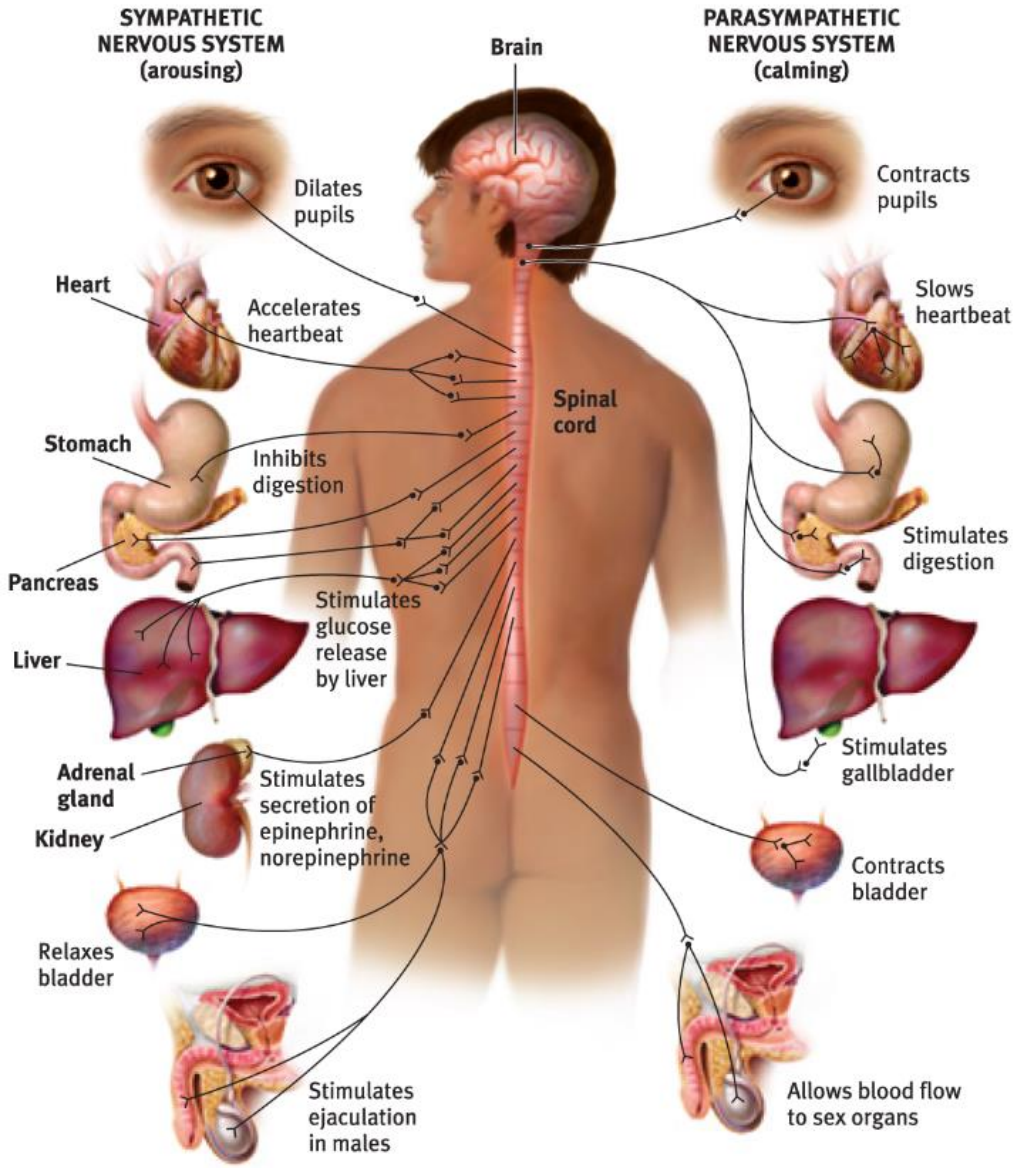
2. Because this reflex involves only the spinal cord, the hand jerks away from the candle flame even before information about the event has reached the brain, where pain is experienced.

The Peripheral Nervous System

- The peripheral nervous system has two parts — **somatic** and **autonomic**.
- **Somatic nervous system** monitors sensory input and triggers motor output, controlling your skeletal muscles (which is why it is also called the skeletal nervous system).
- **Autonomic nervous system (ANS)** controls your glands and the muscles of your internal organs, including those of your heart and digestive system.

Autonomic Nervous System

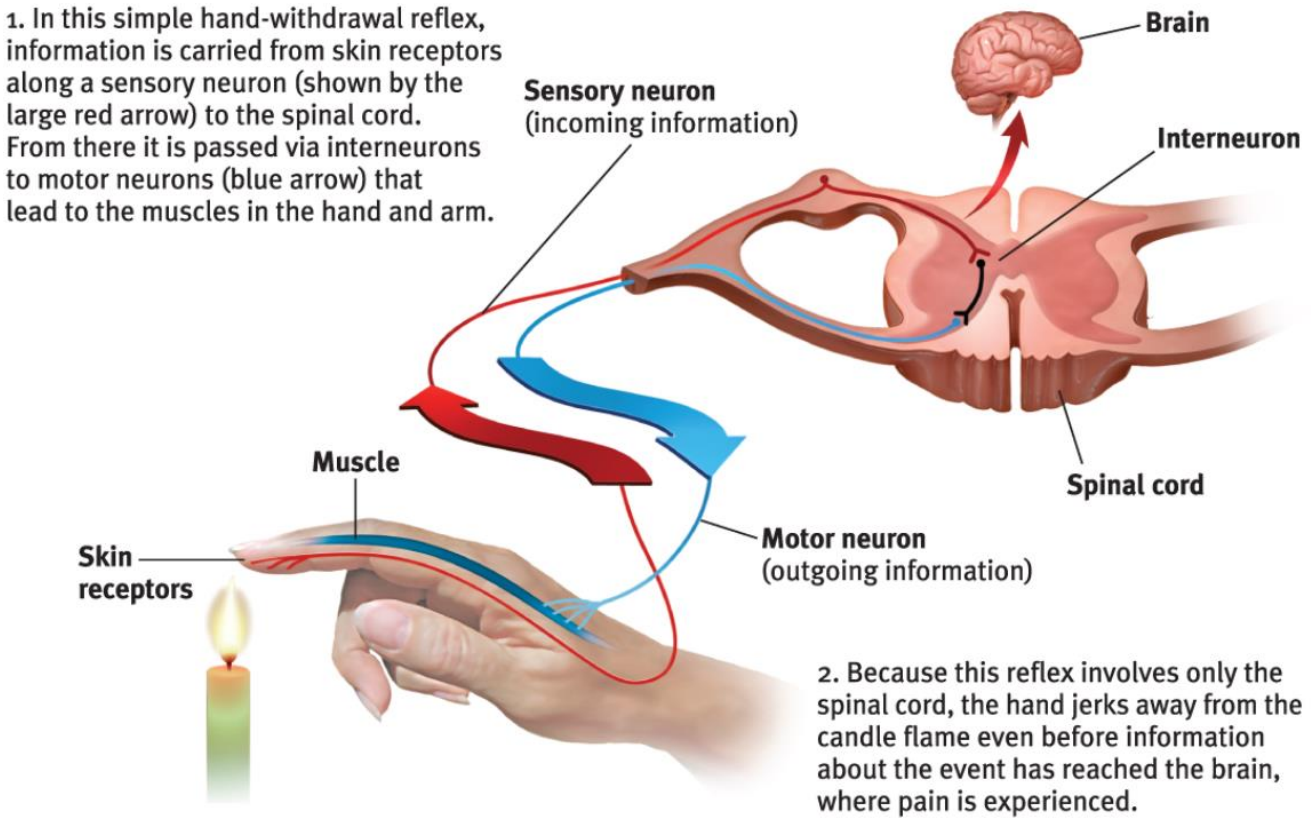
- **Sympathetic nervous system:** fight-or-flight response



- **Parasympathetic nervous system:** rest-and-digest response

Central Nervous System

- **Brain** enables thinking, feeling, and acting; has about 86 billion neurons
- **Spinal Cord** is a two-way highway connecting the peripheral nervous system and the brain.



Endocrine System

- the body's "slow" chemical communication system; a set of glands that secrete **hormones** into the bloodstream.
- **Hormones** are chemical messengers that are manufactured by the endocrine glands, travel through the bloodstream, and affect other tissues.

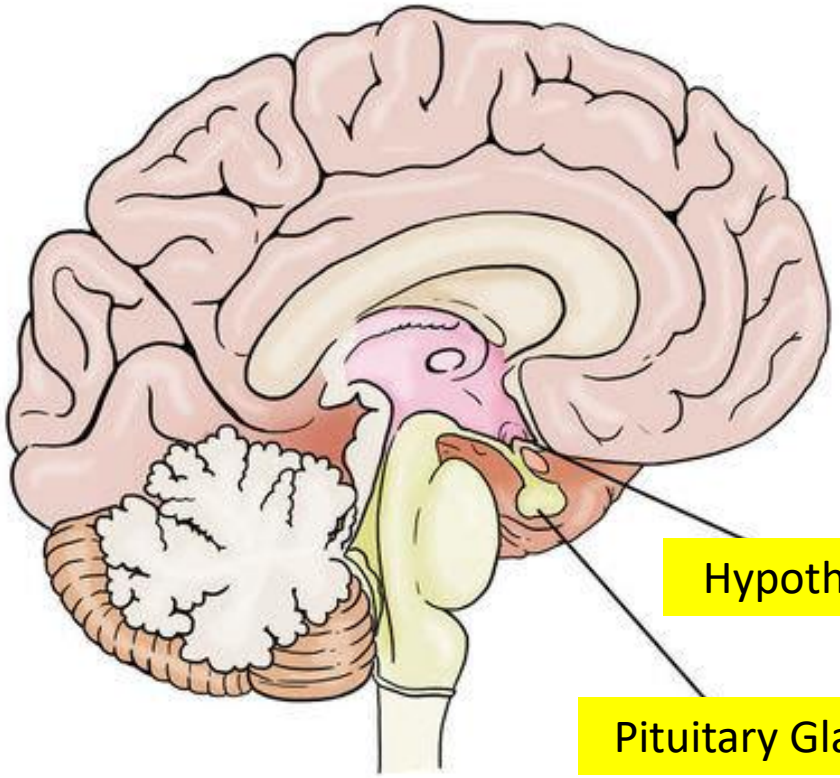
Hormones vs Neurotransmitters

- **Neurotransmitters**
  - produced by the nervous system (in the axial terminal of a neuron)
  - released from the presynaptic nerve terminal in the brain. Then they bind to **specific receptors**, causing changes in the electrical properties of target cells, which can cause various postsynaptic effects (neural impulses).
  - work locally and their actions are very fast.

Dopamine acts as both a neurotransmitter and a hormone.

- **Hormones**
  - usually secreted from the endocrine system and released into the bloodstream, but they act on **distant** target cells
  - Some hormones are chemically identical to neurotransmitters.

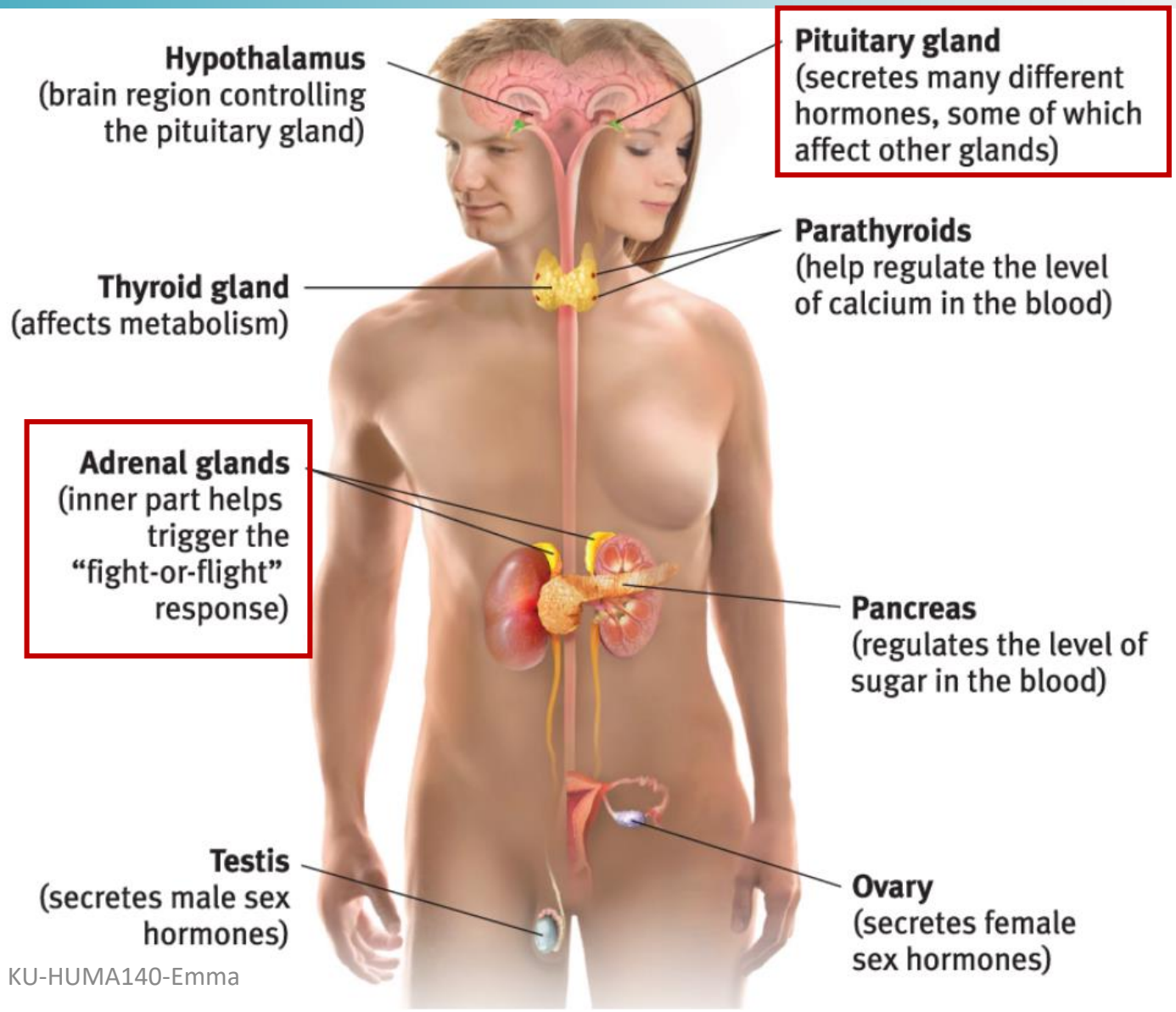
How does brain control the endocrine system



Hypothalamus

Pituitary Gland

- " The master gland"
- Growth hormone
- Oxytocin



Socrative Time!
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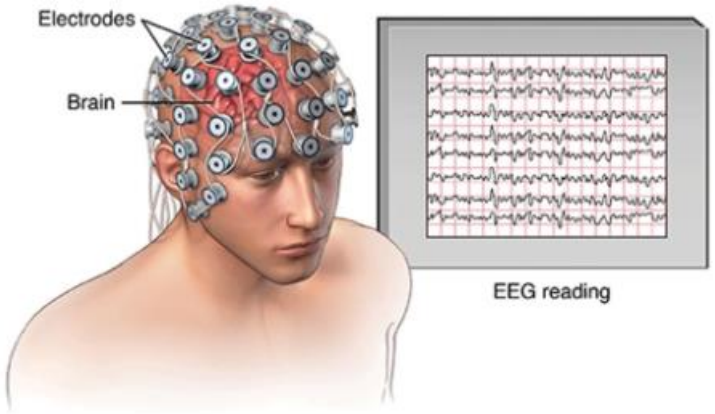
Learning Objective Questions: Week 3

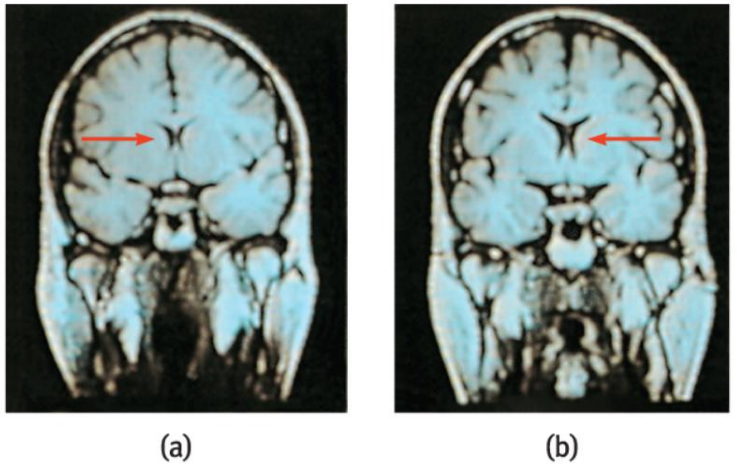
- What are the structures and functions of the limbic system?
- What are the four lobes of the cerebral cortex, and where are they located?
- What are the functions of the motor cortex, somatosensory cortex, and association areas?
- How does brain modify itself after some kinds of damage?
- What is a split brain, and what does it reveal about the functions of our two brain hemispheres?
- What is the circadian rhythm, and what are the stages of our nightly sleep cycle?

Tools of Discovery



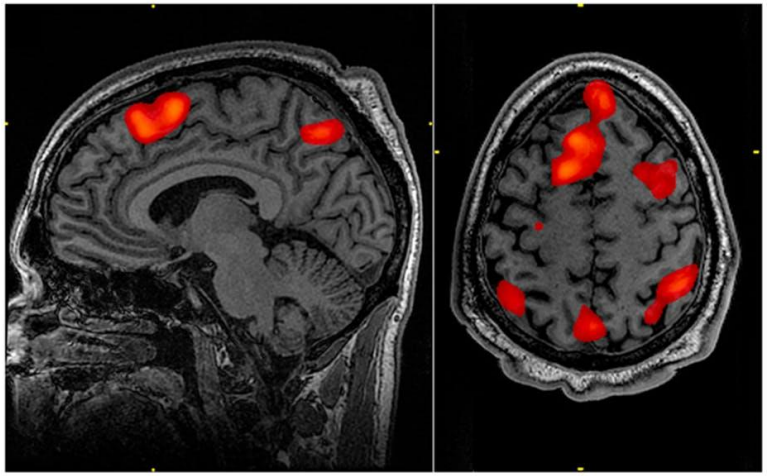
EEG (electroencephalogram)

electrical activity



MRI (Magnetic resonance imaging)

hydrogen density in the blood

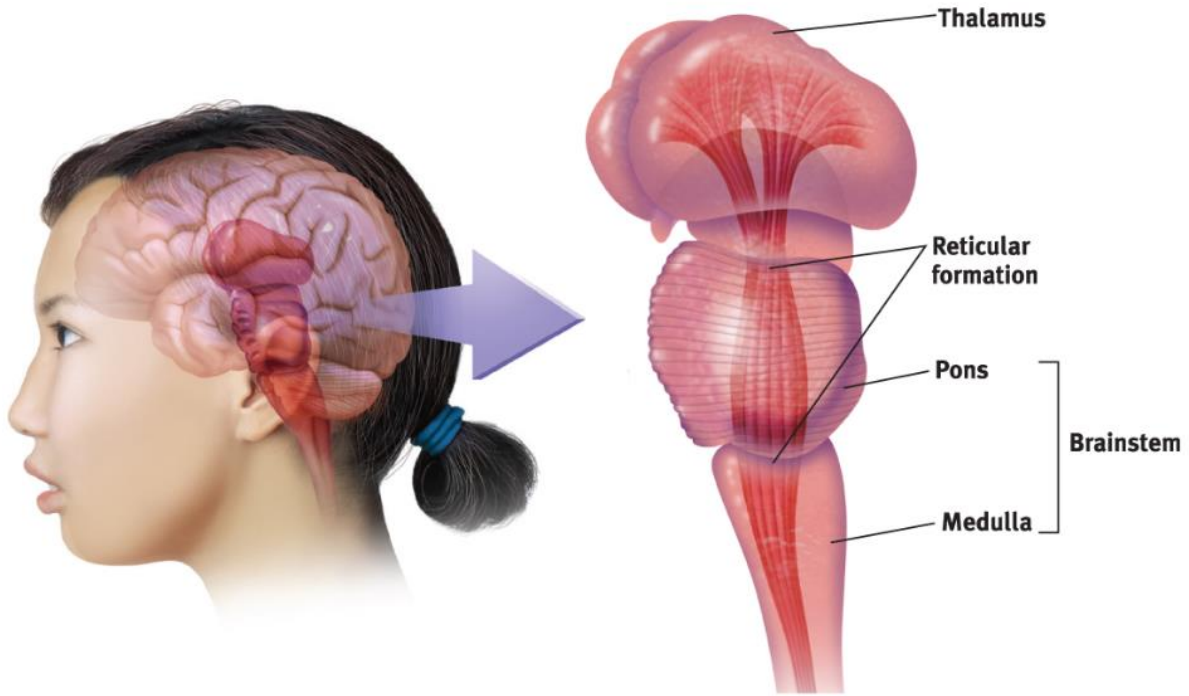


fMRI (functional MRI)

- **MEG (magnetoencephalography):** magnetic fields
- **PET (Positron Emission Tomography):** radioactive sugar

Older Brain Structures

- **The Brainstem**:
  - The oldest part and central core of the brain, beginning where the spinal cord swells as it enters the skull; responsible for automatic survival functions.



- Pons: coordinate movements and control sleep
- Medulla: heartbeat and breathing

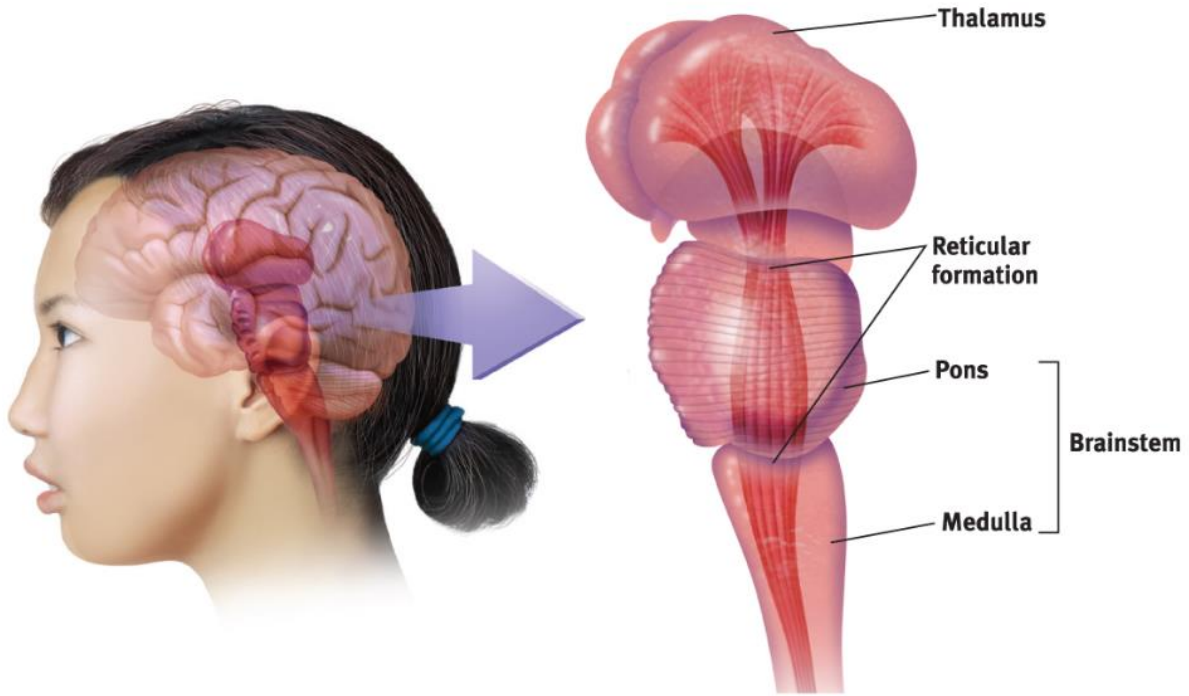
Older Brain Structures

- The brainstem is a crossover point. Here, you'll find a peculiar sort of cross-wiring, with most nerves to and from each side of the brain connecting to the body's opposite side. Thus, the right brain controls the left side of the body, and vice versa

Andrew Swift

Older Brain Structures

- **The Reticular Formation and Thalamus**



Older Brain Structures

- **The Cerebellum**:
  - the “little brain” at the rear of the brainstem; functions include processing sensory input, coordinating movement output and balance, and enabling nonverbal learning and memory.

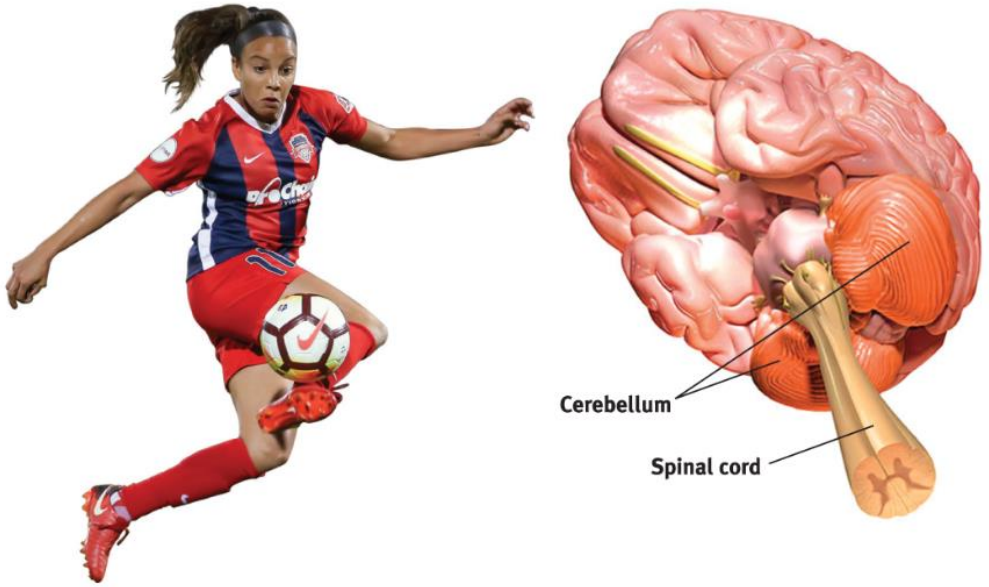
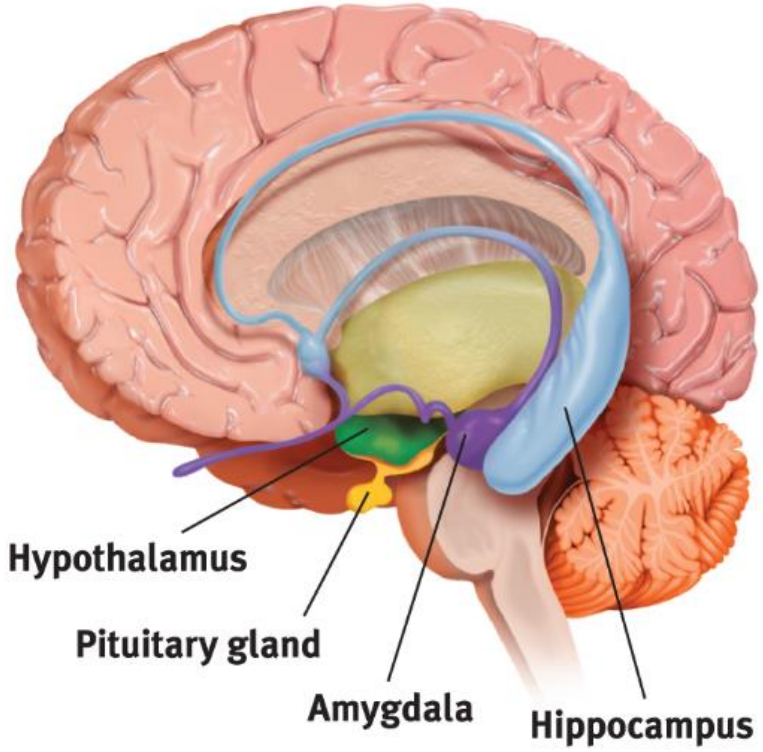


FIGURE 2.13 The brain’s organ of agility
Hanging at the back of the brain, the cerebellum coordinates our voluntary movements, as when USA women’s soccer player Mallory Pugh controls the ball.

The Limbic System

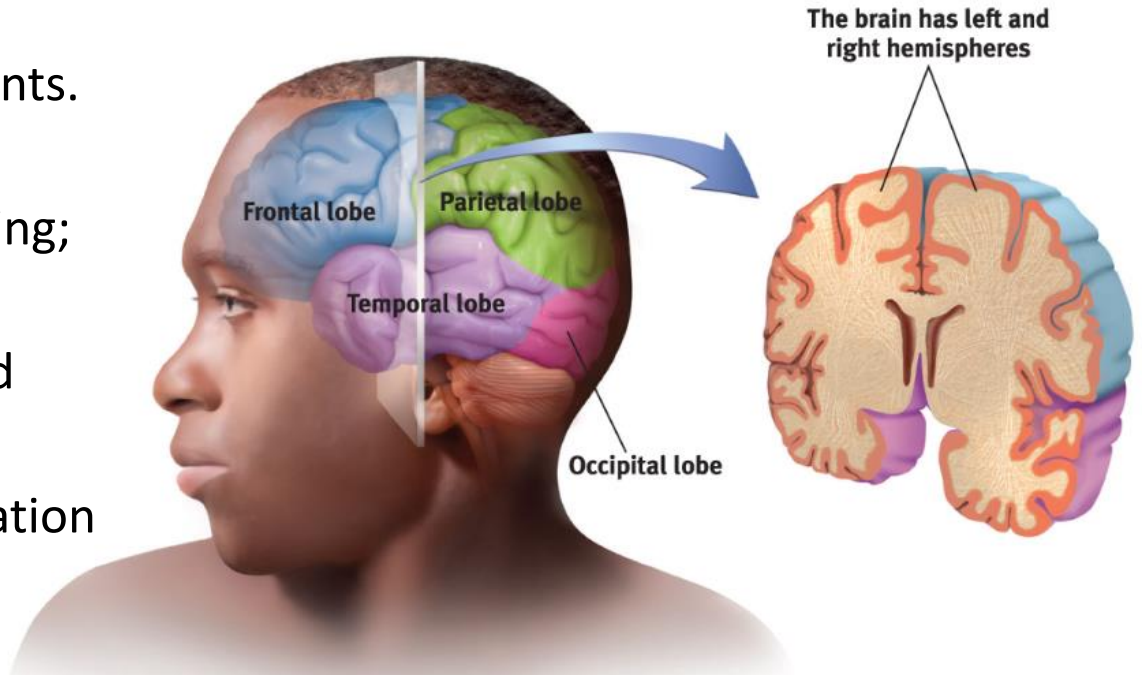
- **The limbic system** is the neural system (including the amygdala, hypothalamus, and hippocampus) located below the cerebral hemispheres; associated with emotions and drives.



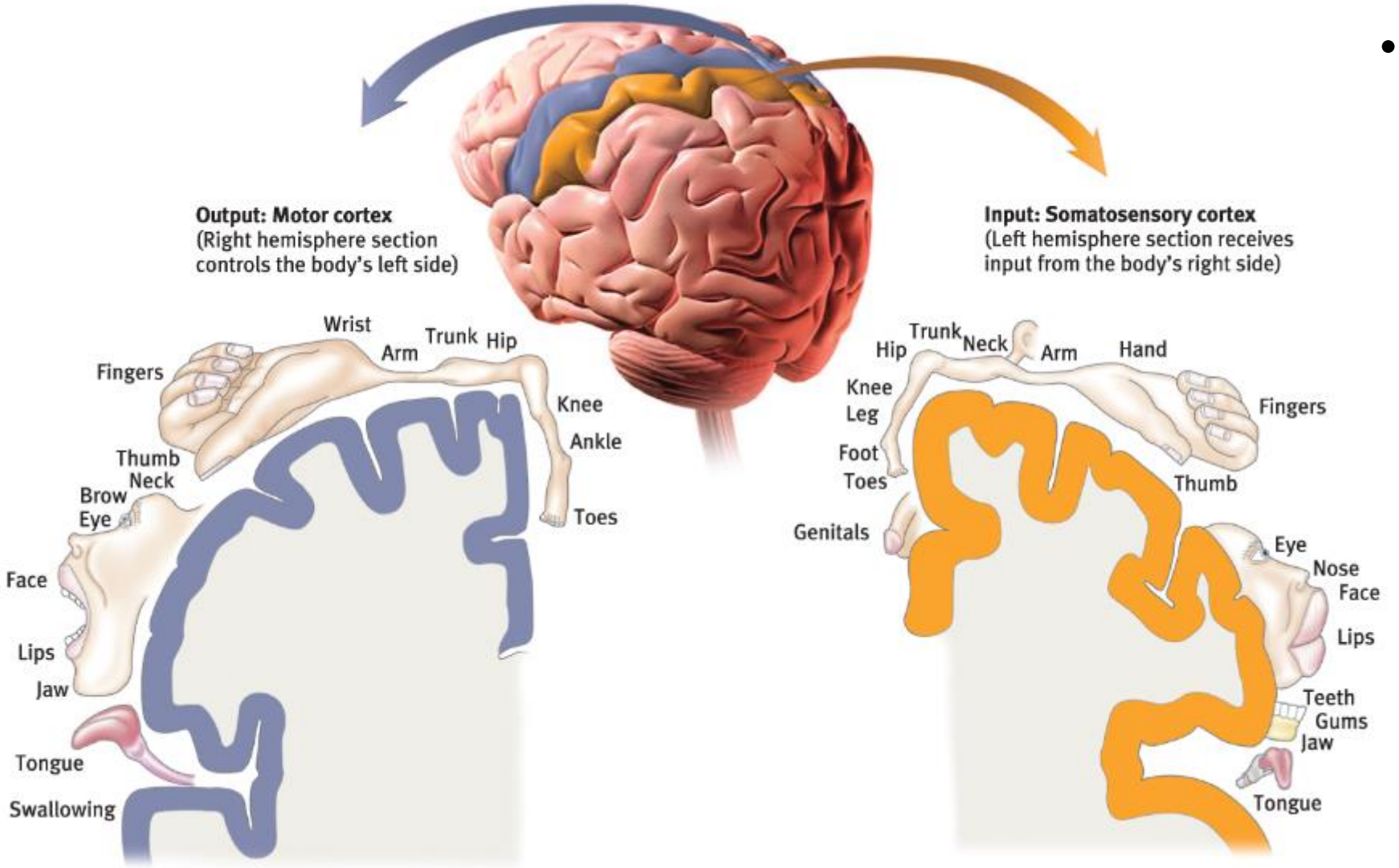
- **Amygdala**: aggression and fear
- **Hypothalamus**: helps govern the endocrine system via pituitary gland; regulates hunger, thirst, reward, and sexual behavior.
- **Hippocampus**: processes conscious, explicit memories of facts and events.

The Cerebral Cortex

- **The cerebral cortex** is a thin layer of interconnected neurons covering the cerebral hemispheres; the body's ultimate control and information-processing center.
  - **Frontal:** involved in speaking and muscle movements and in making plans and judgments.
  - **Temporal:** includes areas that receive information from the ears; language processing; object processing.
  - **Parietal:** receives sensory input for touch and body position; navigation.
  - **Occipital:** includes areas that receive information from the visual fields.



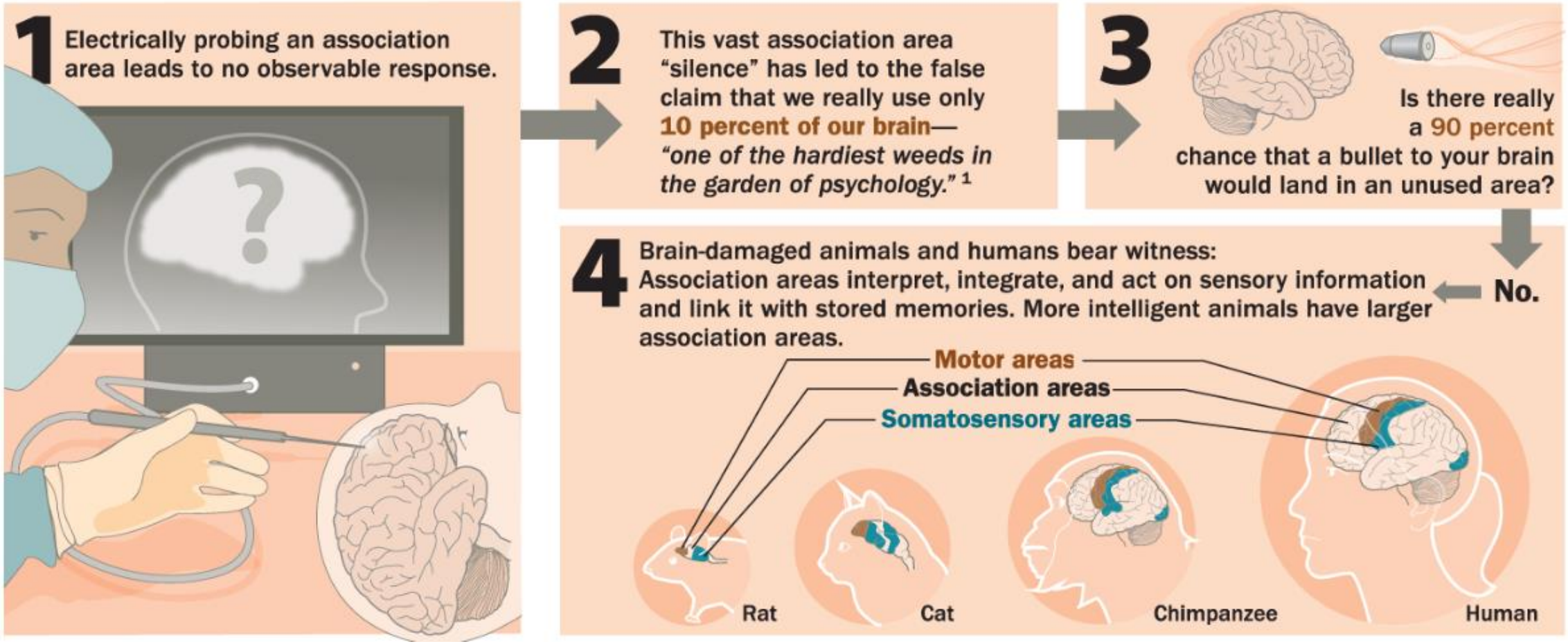
Motor Cortex and Somatosensory Cortex



- The brain devotes more tissue to sensitive areas and to areas requiring precise control. So, your fingers have a greater representation in the cortex than does your upper arm.

Association Areas

- cerebral cortex areas involved primarily in higher mental functions, such as learning, remembering, thinking, and speaking.



Association Areas

- the prefrontal cortex enables judgment, planning, social interactions, and processing of new memories

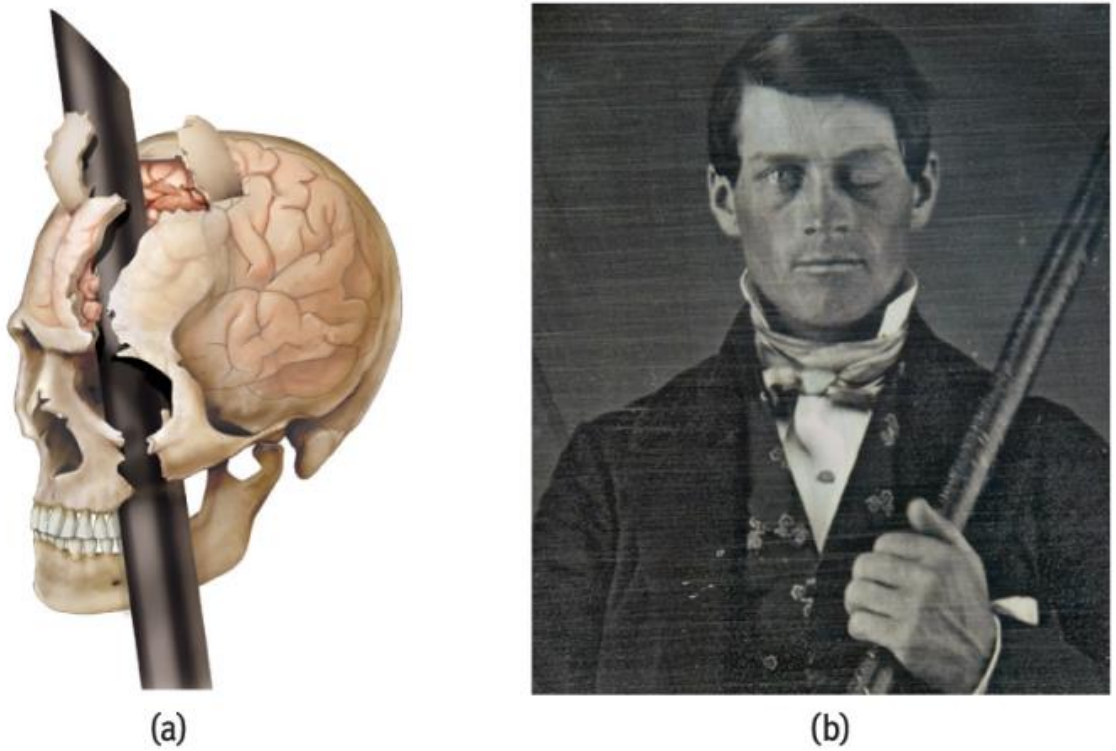
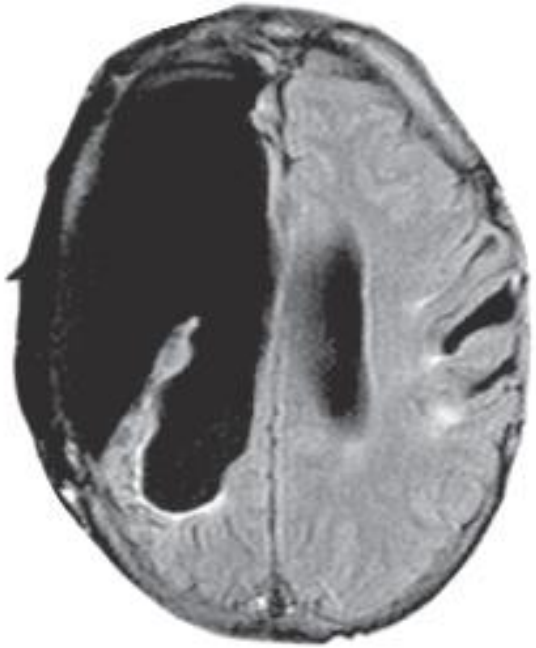


FIGURE 2.20 A blast from the past (a) Phineas Gage's skull was kept as a medical record. Using measurements and modern neuroimaging techniques, researchers have reconstructed the probable path of the rod through Gage's brain (Van Horn et al., 2012). (b) This photo shows Gage after his accident. (The image has been reversed to show the features correctly. Early photos, including this one, were actually mirror images.)

Responses to Damage

- **Neural Plasticity:** the brain's ability to change, especially during childhood, by reorganizing after damage or by building new pathways based on experience.



This 6-year old girl had surgery to end her life-threatening seizures. Although most of an entire hemisphere was removed, her remaining hemisphere compensated by putting other areas to work.

Responses to Damage

- **Neurogenesis:** The formation of new neurons.
- Neurogenesis is crucial when an embryo is developing, but also continues in certain brain regions after birth and throughout our lifespan.

nature medicine

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Published: November 1998

Neurogenesis in the adult human hippocampus

Peter S. Eriksson, Ekaterina Perfilieva, Thomas Björk-Eriksson, Ann-Marie Alborn, Claes Nordborg, Daniel A. Peterson & Fred H. Gage

Nature Medicine **4**, 1313–1317 (1998) | Cite this article

122k Accesses | **4512** Citations | **647** Altmetric | Metrics

Blindsight

- People with cerebral blindness have normal eyes but suffer from partial or total loss of vision due to damage of the visual part of the cortex: the **occipital lobe**. Some people with cerebral blindness may still respond to visual stimuli that they do not consciously perceive. This phenomenon is called **blindsight**.

- https://www.youtube.com/watch?v=pZBwLNYzgO4

Prosopagnosia

- Prosopagnosia, also known as face blindness, means you cannot recognize people's faces. Face blindness often affects people from birth and is usually a problem a person has for most or all of their life. It can have a severe impact on everyday life.

- https://www.youtube.com/watch?v=koxUs49scJw

The Divided Brain

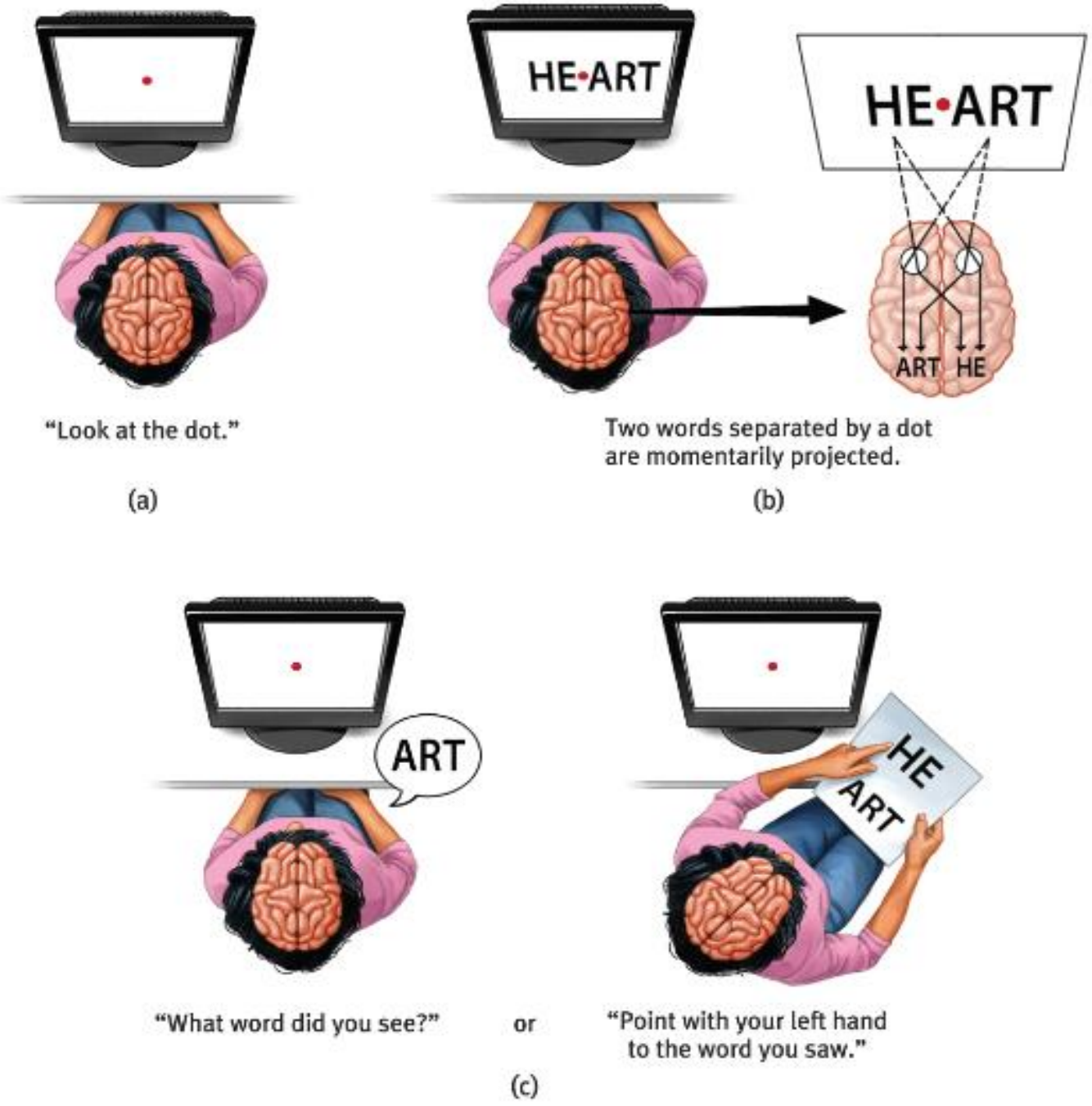
- **Corpus Callosum**: a large band of neural fibers connecting the two brain hemispheres and carrying messages between them.

(a)

(b)

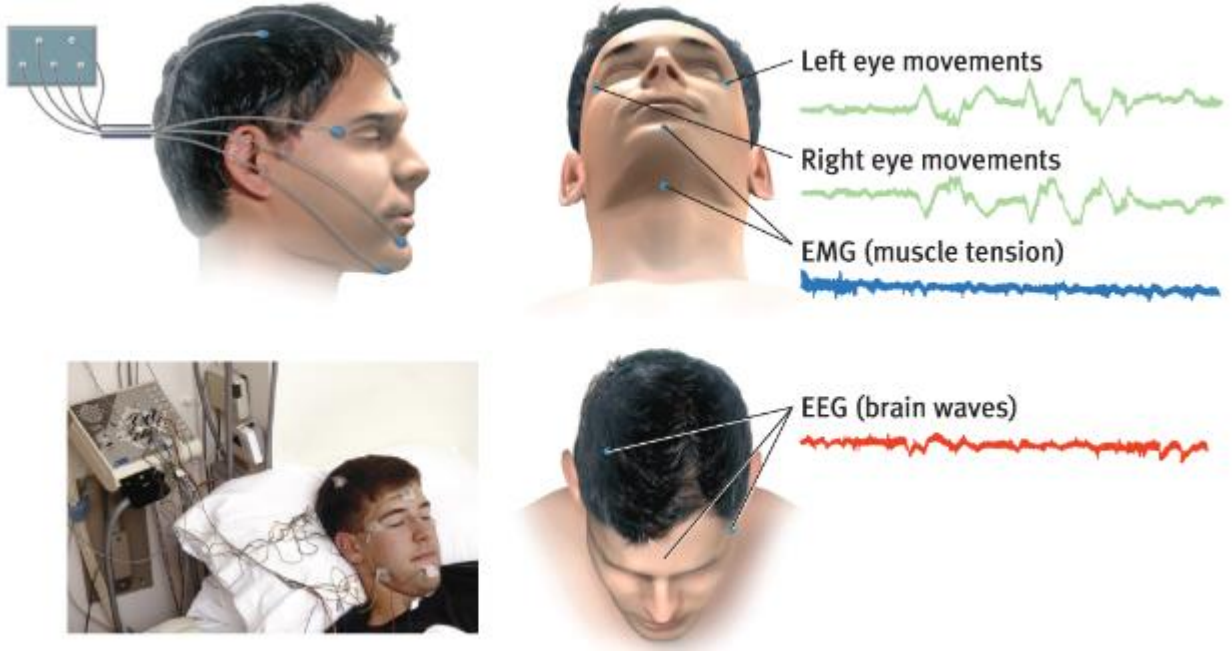
The Divided Brain

- **Split Brain**: a condition resulting from surgery that separates the brain's two hemispheres by cutting the fibers (mainly those of the corpus callosum) connecting them.



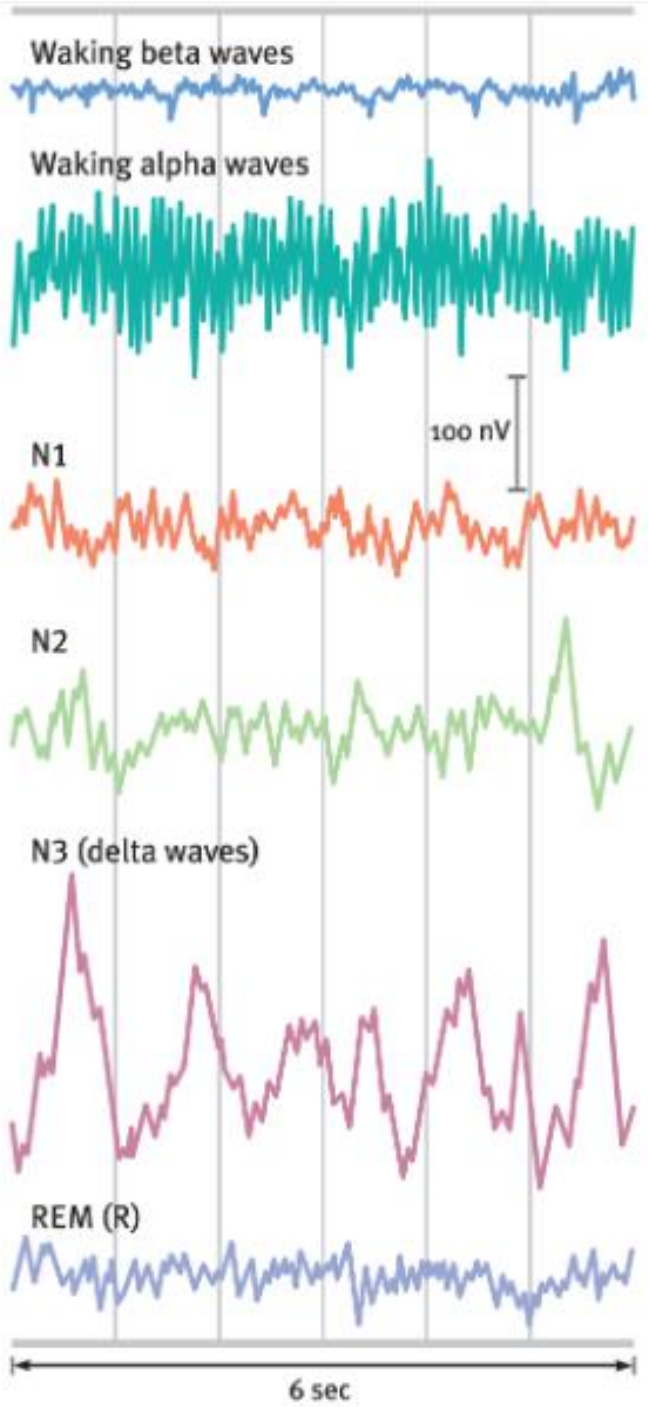
Sleep and Dreams

- **Circadian Rhythm**: our internal biological clock; regular bodily rhythms (for example, of temperature and wakefulness) that occur on a 24-hour cycle.
- **Sleep Stages:** the sleeping brain is active and has its own biological rhythm; about every 90 minutes, we cycle through distinct sleep stages.

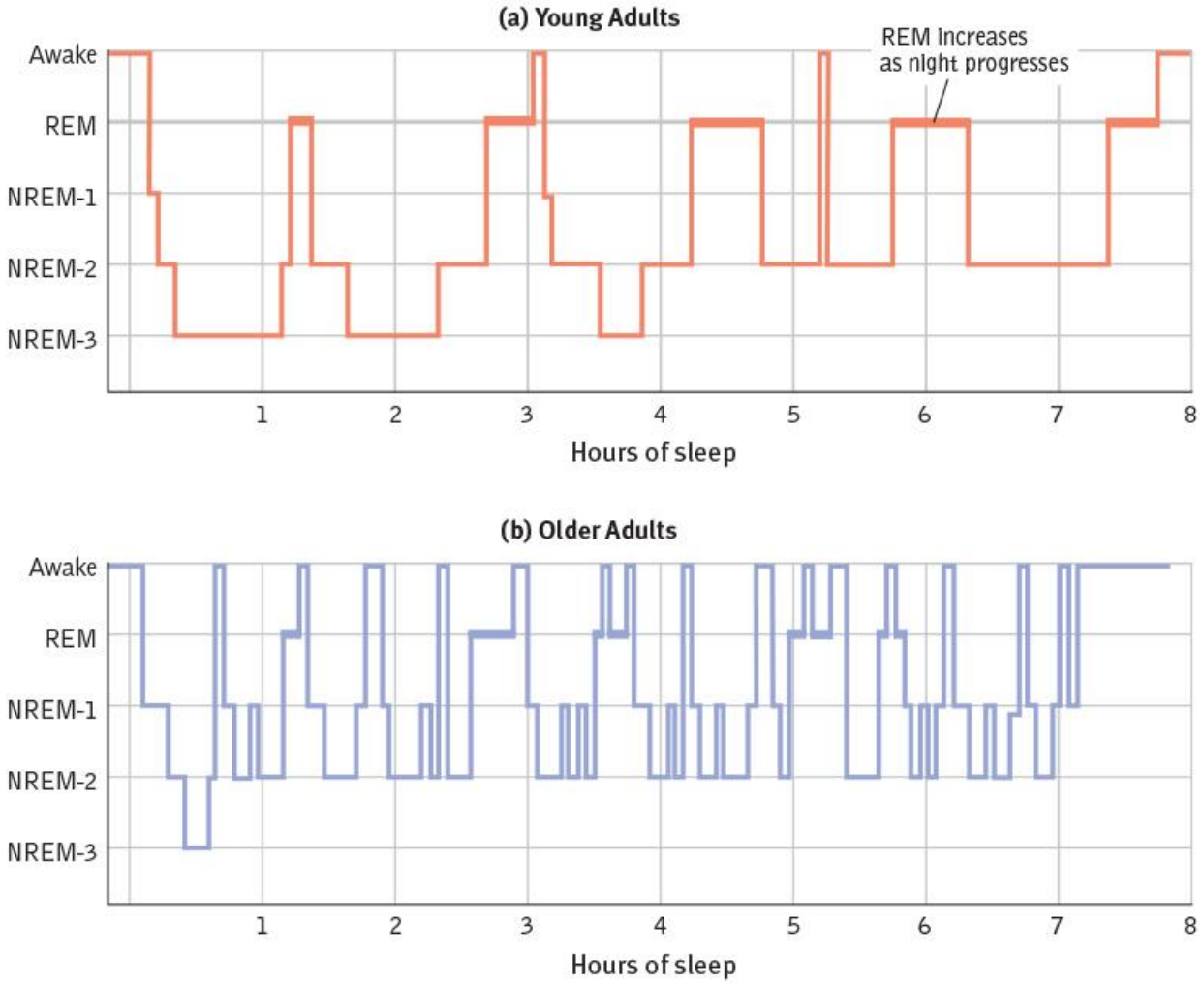


Sleep Stages

Stages	Waveband	Characteristics
Stage 1 (N1)	Theta	• Transition from wakefulness to sleep • Lose responsiveness to stimuli • Drifting thoughts & images
Stage 2 (N2)	Theta (along with sleep spindle and K Complex)	• Gradual decreases in: heart rate, respiration, body temperature, & muscle tension • Difficult to be awaken
Stage 3 and Stage 4 (N3)	Delta	• Slow wave sleep (SWS) • Decrease in: heart rate, respiration, body temperature, & muscle tension • Deepest stage of sleep • Most difficult to be awaken • May sleepwalk, sleep talk or night terror
REM	Alpha/Beta	• Eyes move rapidly • Body is very aroused • Voluntary muscles are paralyzed



Sleep Stages



- People pass through a multistage sleep cycle several times each night. As the night goes on, the periods of deep sleep diminish and REM sleep increases.
- As people age, sleep becomes more fragile, with awakenings more common (Kamel & Gammack, 2006; Neubauer, 1999).

Sleep Disorders

Sleep Disorders	Symptoms
Insomnia	Difficulty falling asleep and then maintaining that sleep.
Sleep apnea	Stop breathing multiple times during sleep.
REM sleep behavior disorder	Sudden and intense movement during sleep.
Narcolepsy	Lack of voluntary control over the onset of sleep
Parasomnias	Abnormal movements or behaviors during sleep, including night terrors and sleepwalking.

Socrative Time!
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The end.