Big Idea 3: Living systems store, retrieve, transmit and respond to information essential to life processes.

Enduring understanding 3.E: Transmission of information results in changes within and between biological systems.

Essential knowledge 3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.

a. The neuron is the basic structure of the nervous system that reflects function.

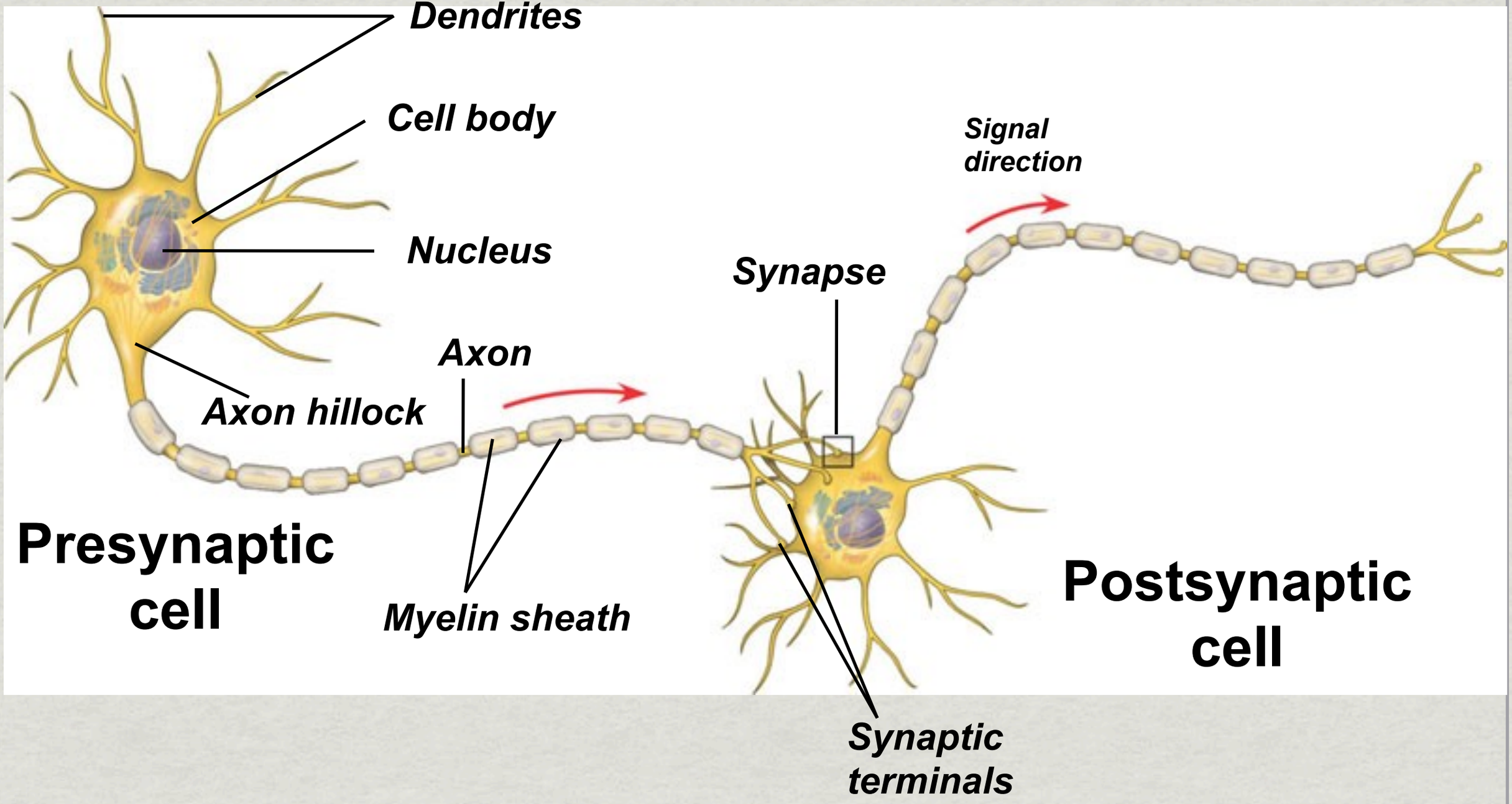
Evidence of student learning is a demonstrated understanding of each of the following:

1. A typical neuron has a cell body, axon and dendrites. Many axons have a myelin sheath that acts as an electrical insulator.
2. The structure of the neuron allows for the detection, generation, transmission and integration of signal information.
3. Schwann cells, which form the myelin sheath, are separated by gaps of unsheathed axon over which the impulse travels as the signal propagates along the neuron.

NEURONS: Function

- **Neurons are the functional units of nervous systems.**
  - **Neurons transmit signals from one location in the body to another .**

NEURON: Structure



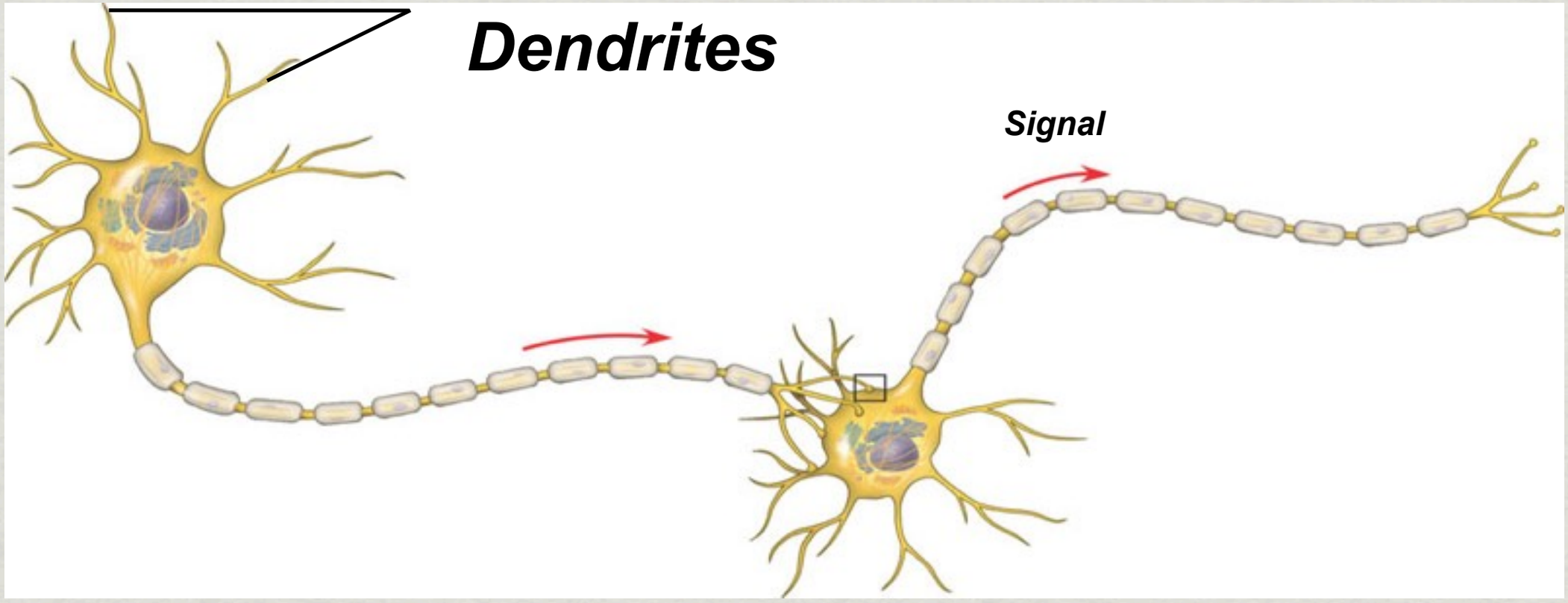
SENSING THE ENVIRONMENT

- **The first step in interacting with the environment is detecting stimuli.**
  - **All stimuli represent forms of energy**
  - The type of stimuli regularly detected include: electromagnetic radiation, pressure, temperature, chemicals

SENSORY RECEPTION

"DETECTION"

- Sensory cells have sensory receptors that detect the stimuli directly. (unicellular and multicellular organisms)

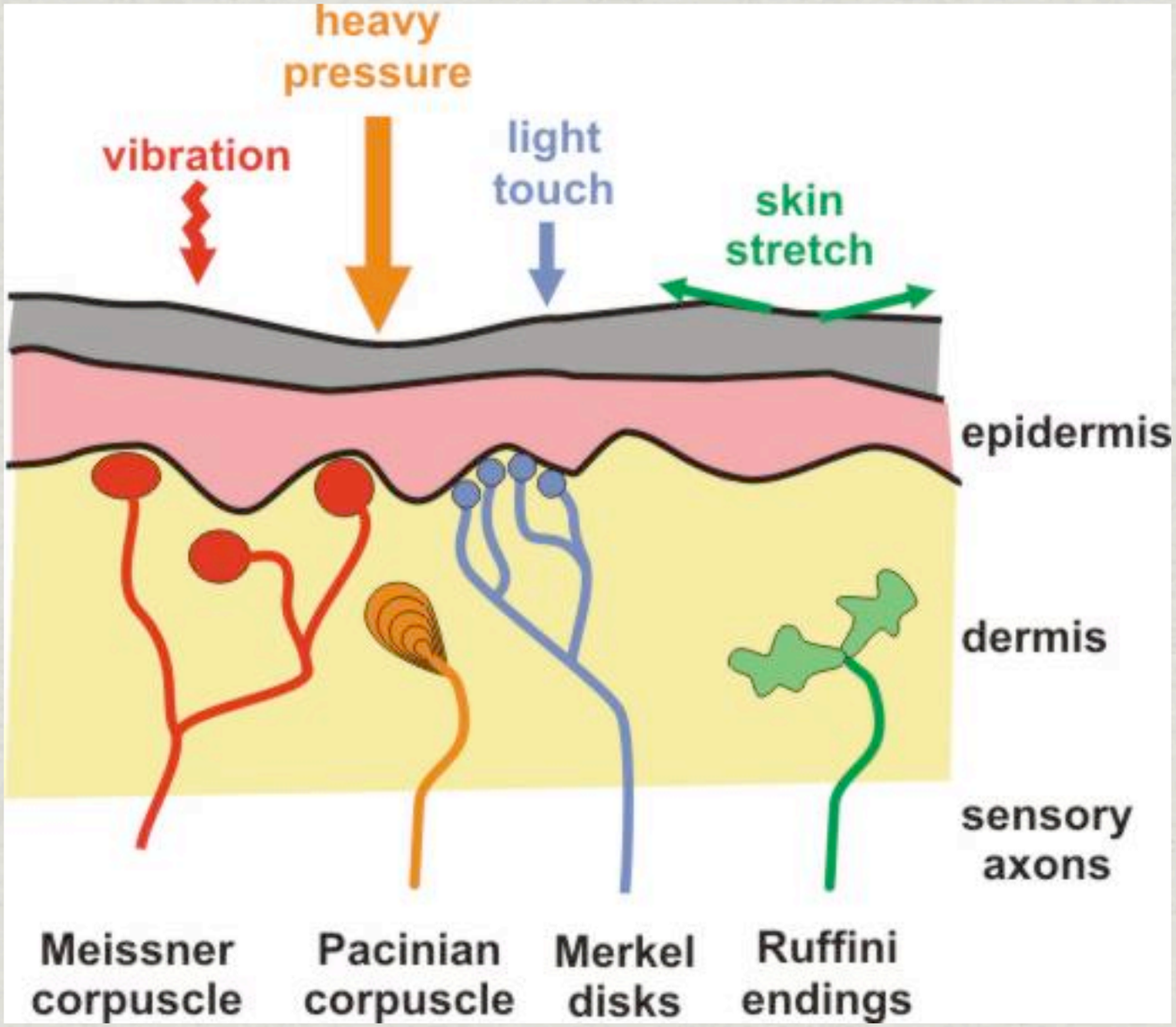


Mechanoreceptors

- pressure, touch, stretch, motion and sound

Mechanoreceptors

- pressure, touch, stretch, motion and sound



Mechanoreceptors

- pressure, touch, stretch, motion and sound

Chemoreceptors

- Transmit information about specific molecules or total solute concentration.
  - oxygen, carbon dioxide, glucose and amino acids.

Electromagnetic Receptors

- light, infrared, UV, electricity and magnetism.

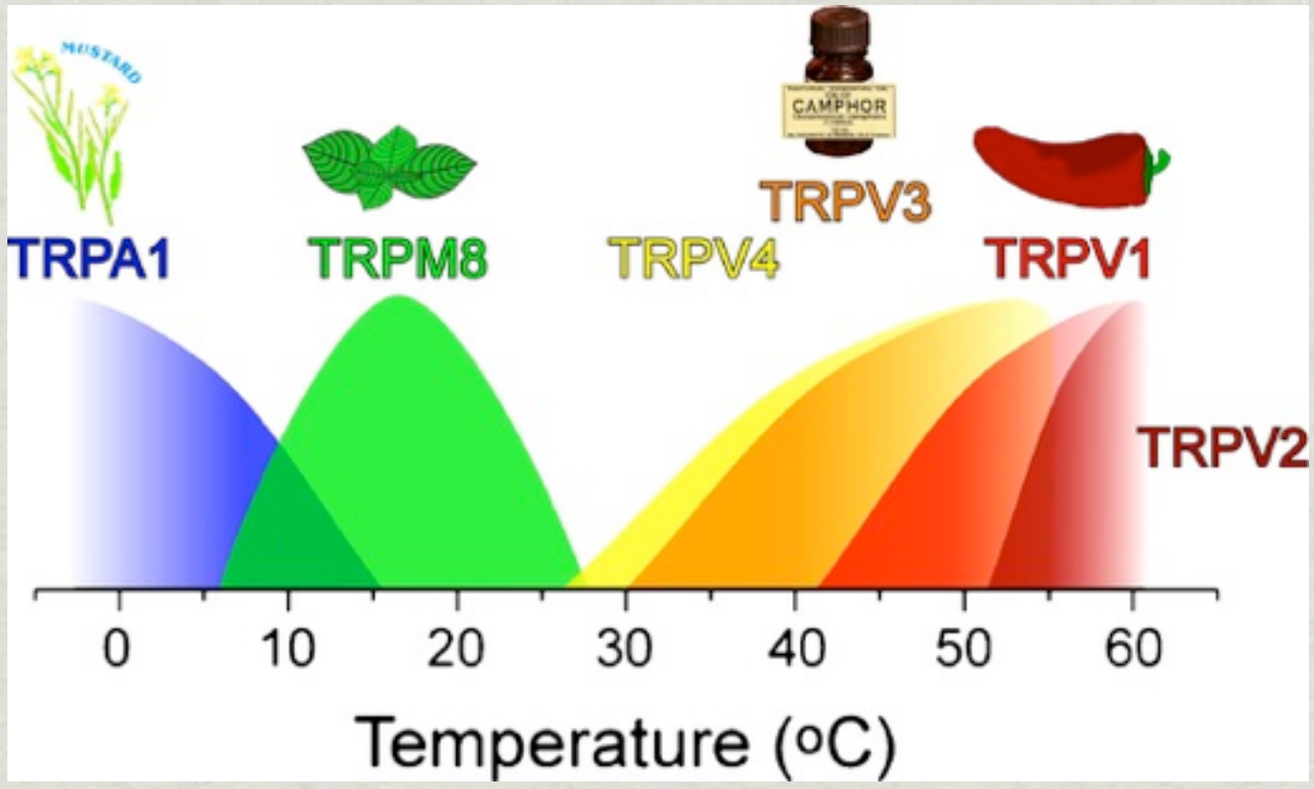
E

M

IR

Thermoreceptors

- Detect heat and cold.
  - Each TRP receptor detects a different temperature range.



Photoreceptors

- Detect wavelengths of visible light: Roy G. Biv
  - Rods and cones detect light in vertebrates.

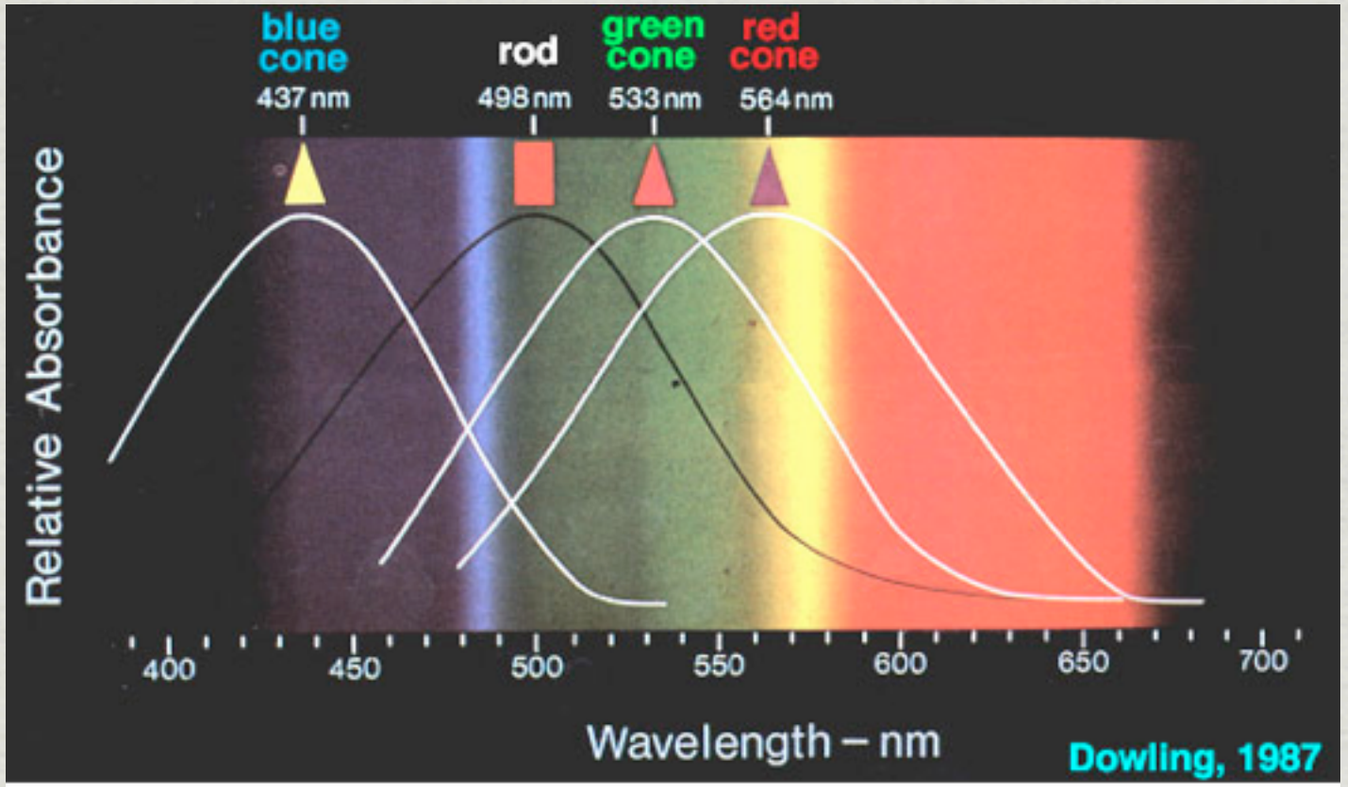


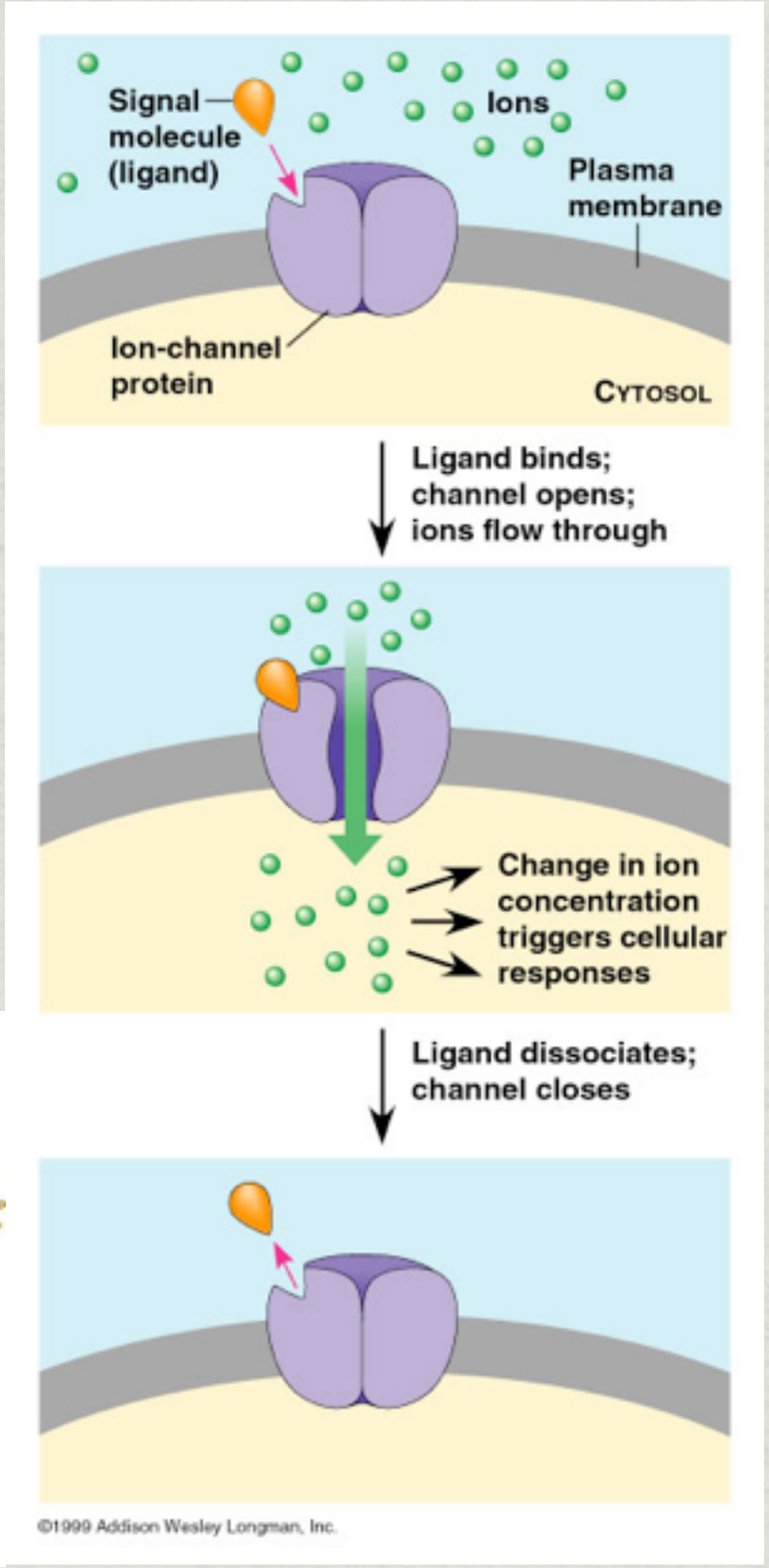
Fig. 14.The peak spectral sensitivities of the the 3 cone types and the the rods in the primate retina (Brown and Wald, 1963). From Dowling's book (1987).

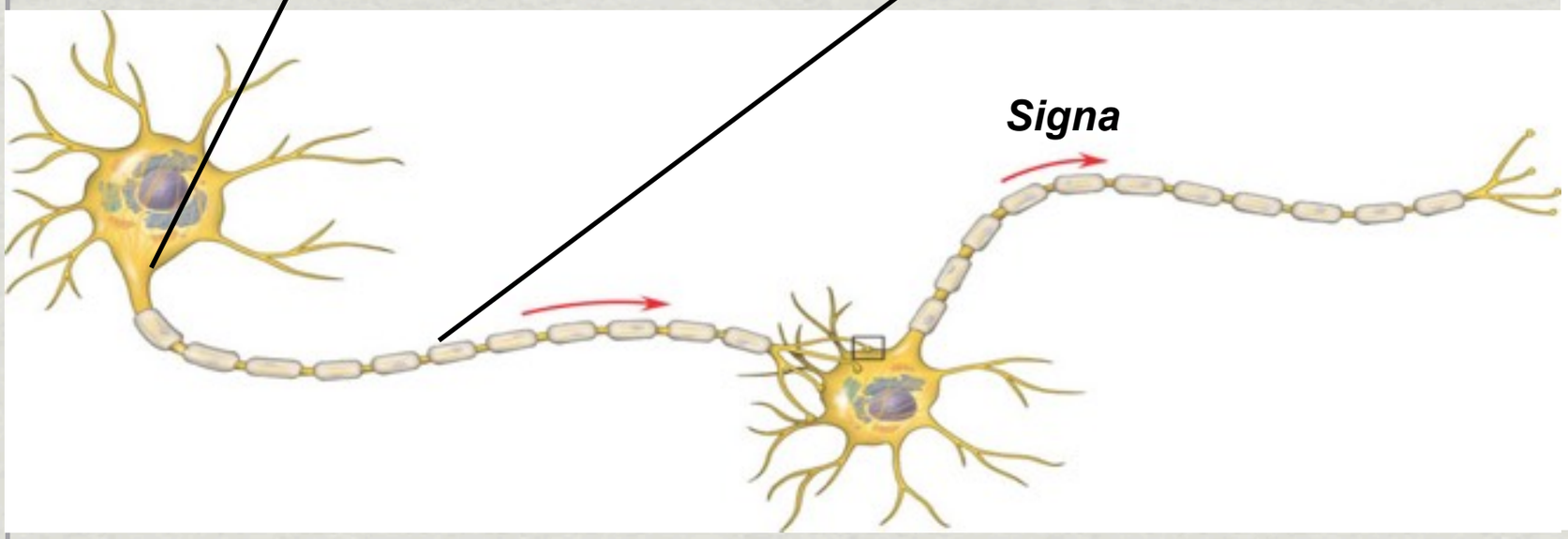
Nociceptors (Pain Receptors)

- Detect extremes: temperature, pressure, heat or chemicals.
  - Many of the other receptors can act as a pain receptors in cases of extreme stimuli.

SENSORY TRANSDUCTION

- The conversion of a physical or chemical stimulus to change in membrane potential of the cell with the sensory receptor.
  - This is necessary for both unicellular and multicellular organisms



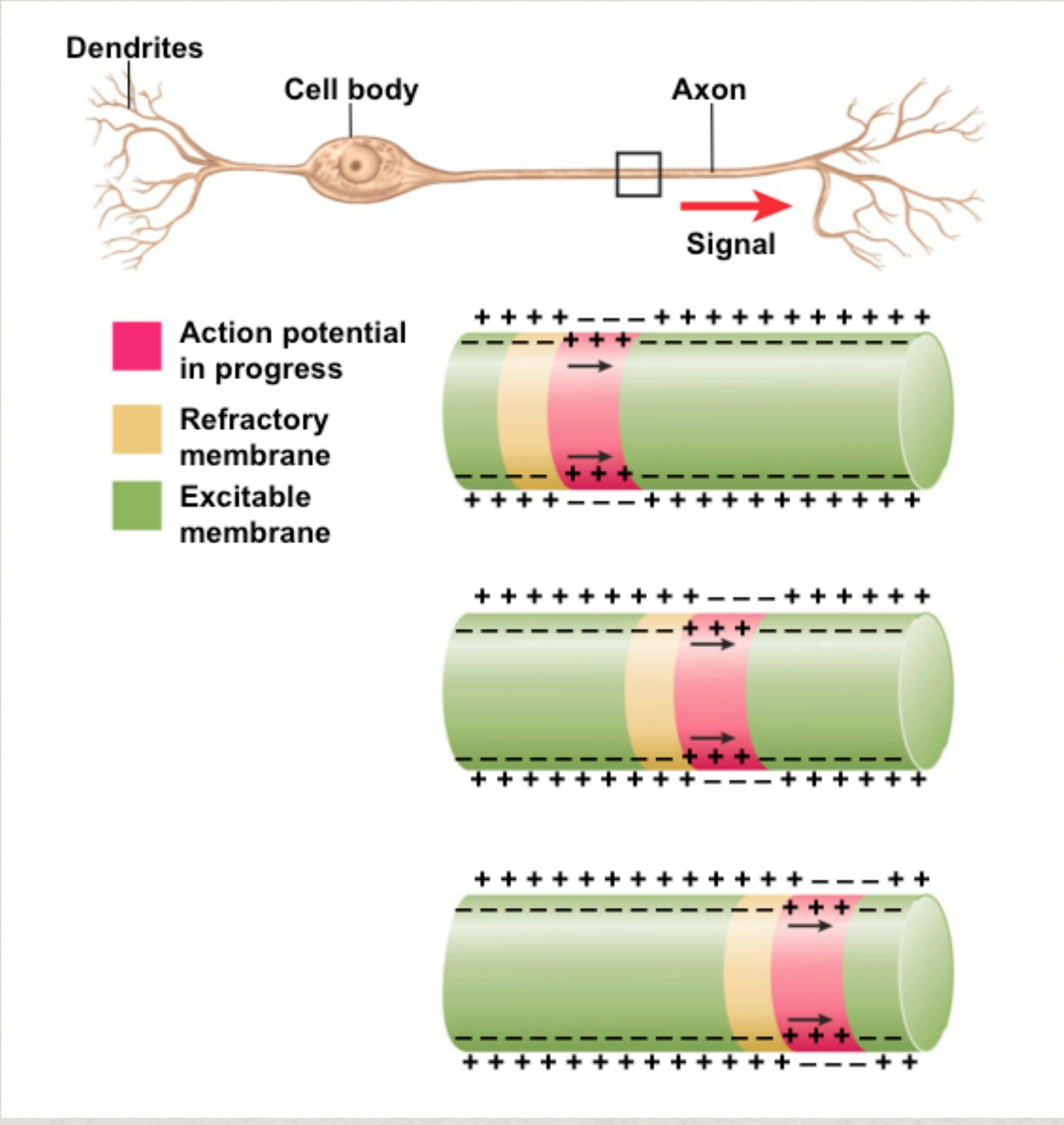


SENSORY TRANSMISSION

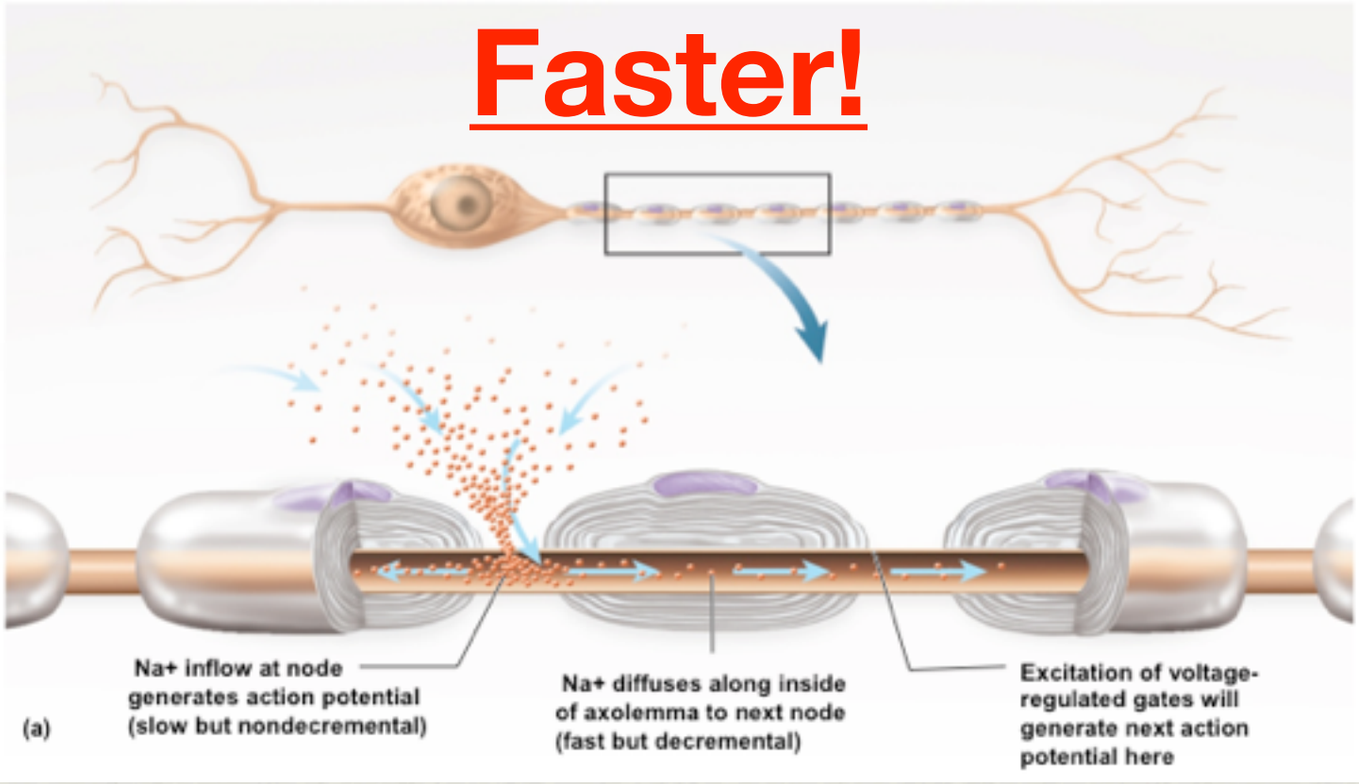
- Changing the membrane potential of the sensory cell initiates the action potential (electrical impulse) to the central nervous system.

Neuron: (action potential conduction)

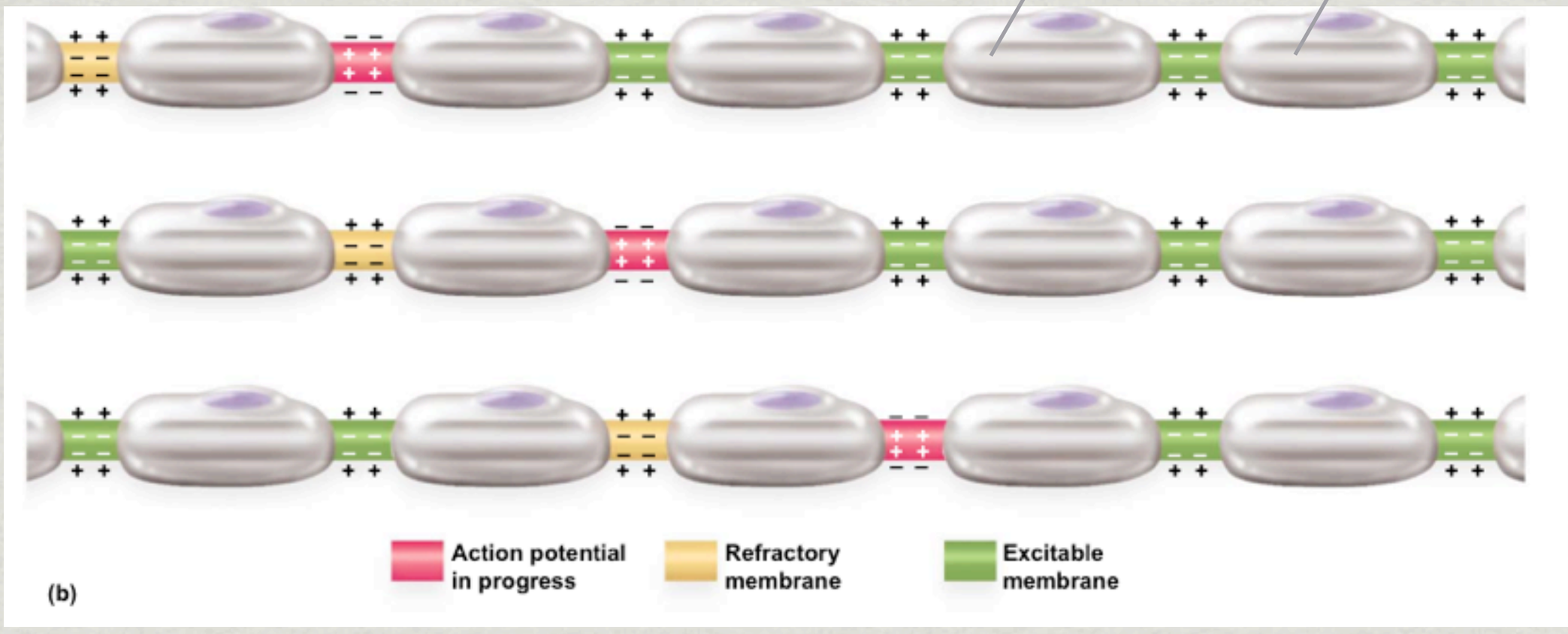
This example shows a neuron that is NOT myelinated!



Faster!



SCHWANN CELLS



Essential knowledge 3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.

b. Action potentials propagate impulses along neurons.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Membranes of neurons are polarized by the establishment of electrical potentials across the membranes.
2. In response to a stimulus, Na^+ and K^+ gated channels sequentially open and cause the membrane to become locally depolarized.
3. Sodium/Potassium pumps, powered by ATP, work to maintain membrane potential.

INFORMATION PROCESSING

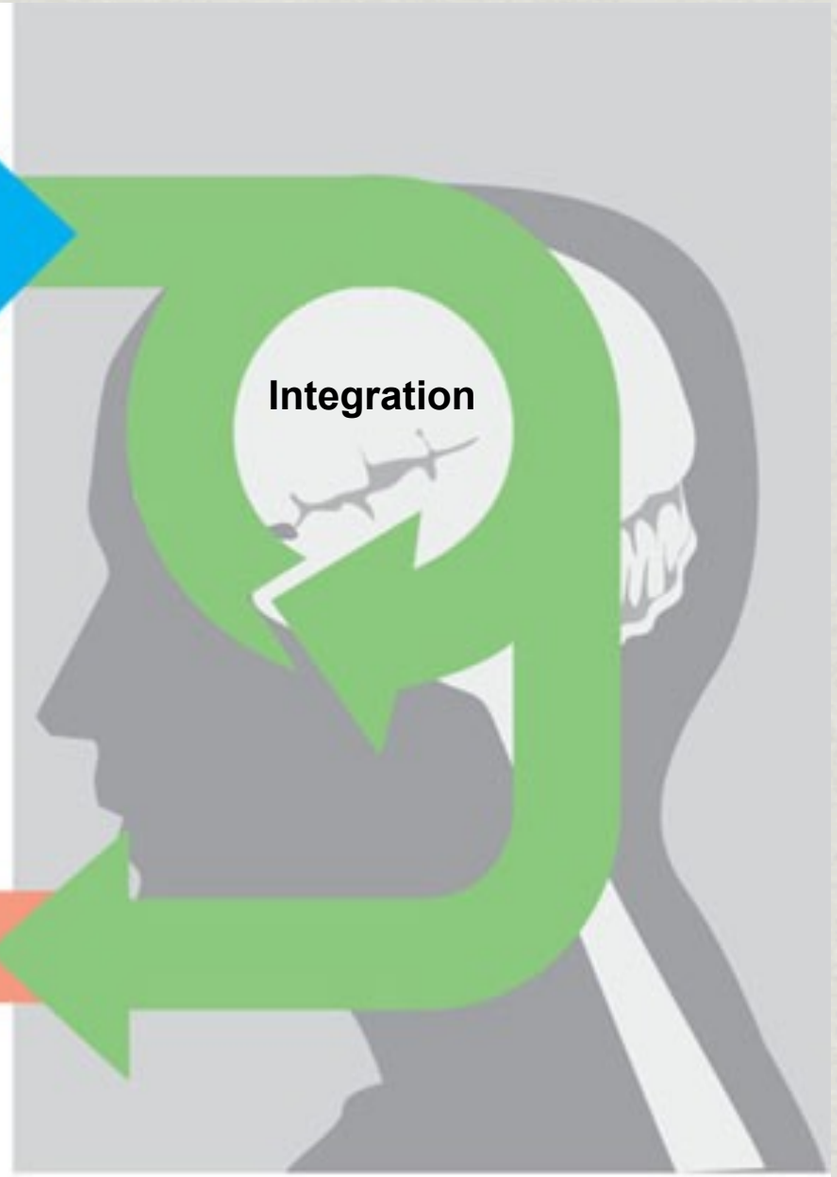
Sensor

Effector

Sensory input

IN GENERAL

Motor output



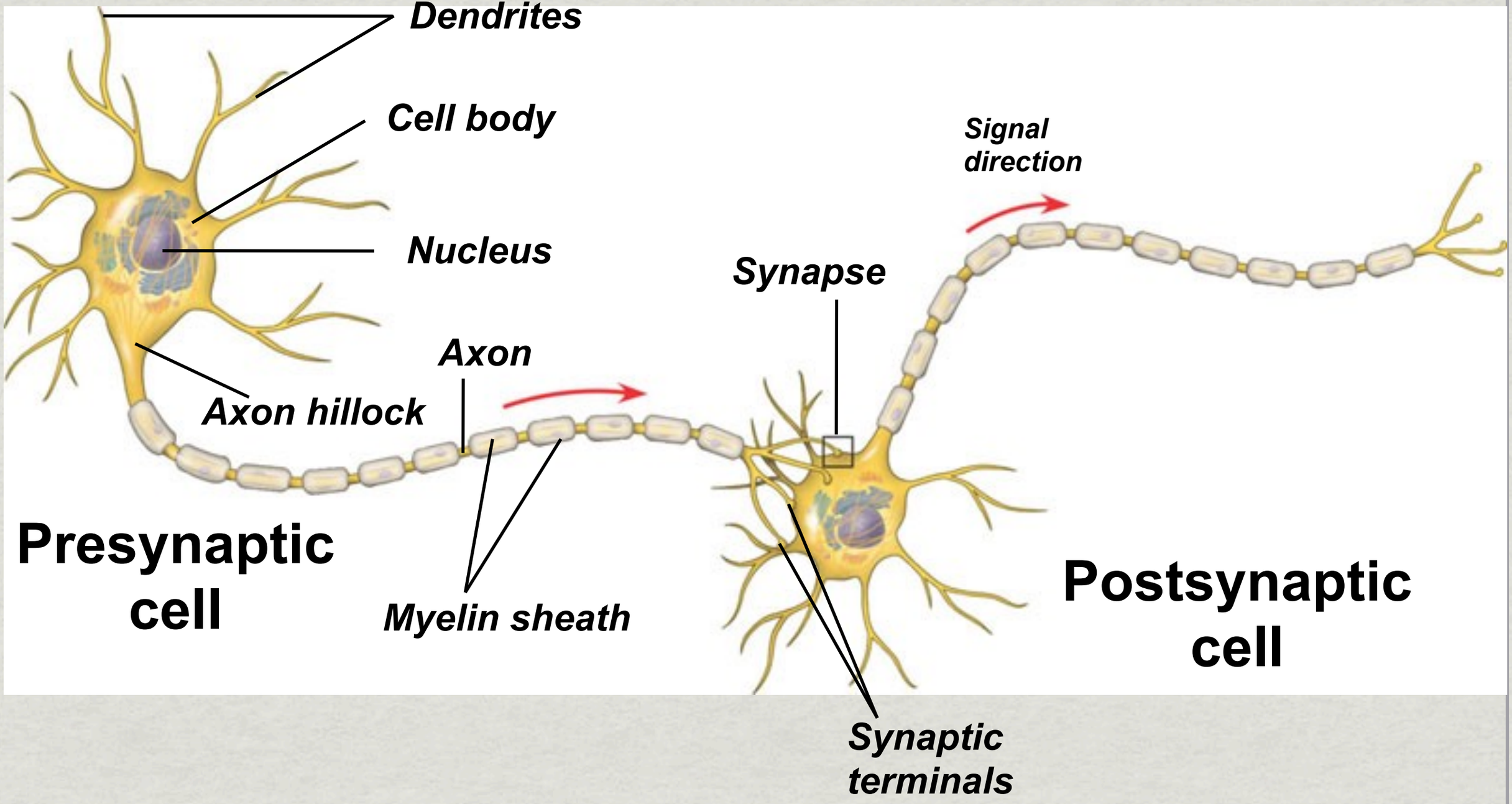
Peripheral nervous system (PNS)

Central nervous system (CNS)

NEURONS: Structure & Function

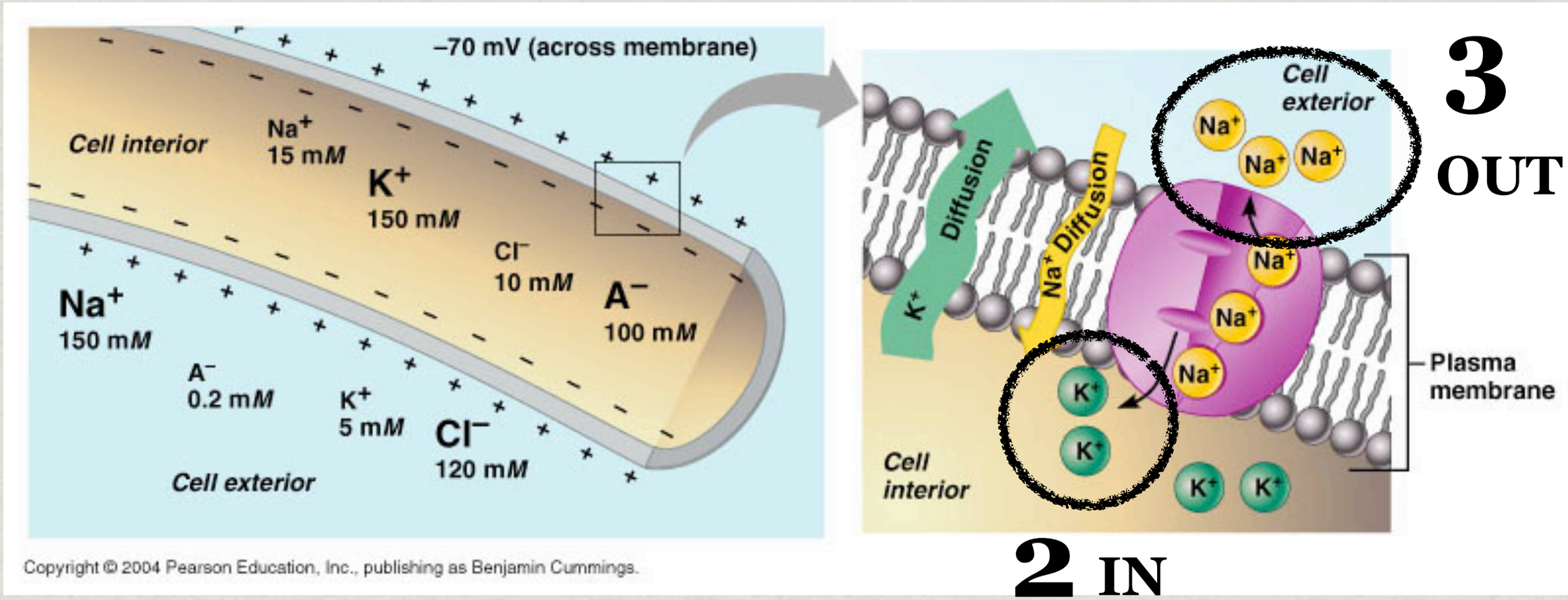
- **Neurons are the functional units of nervous systems.**
  - **Neurons transmit signals from one location in the body to another .**

NEURON: Structure



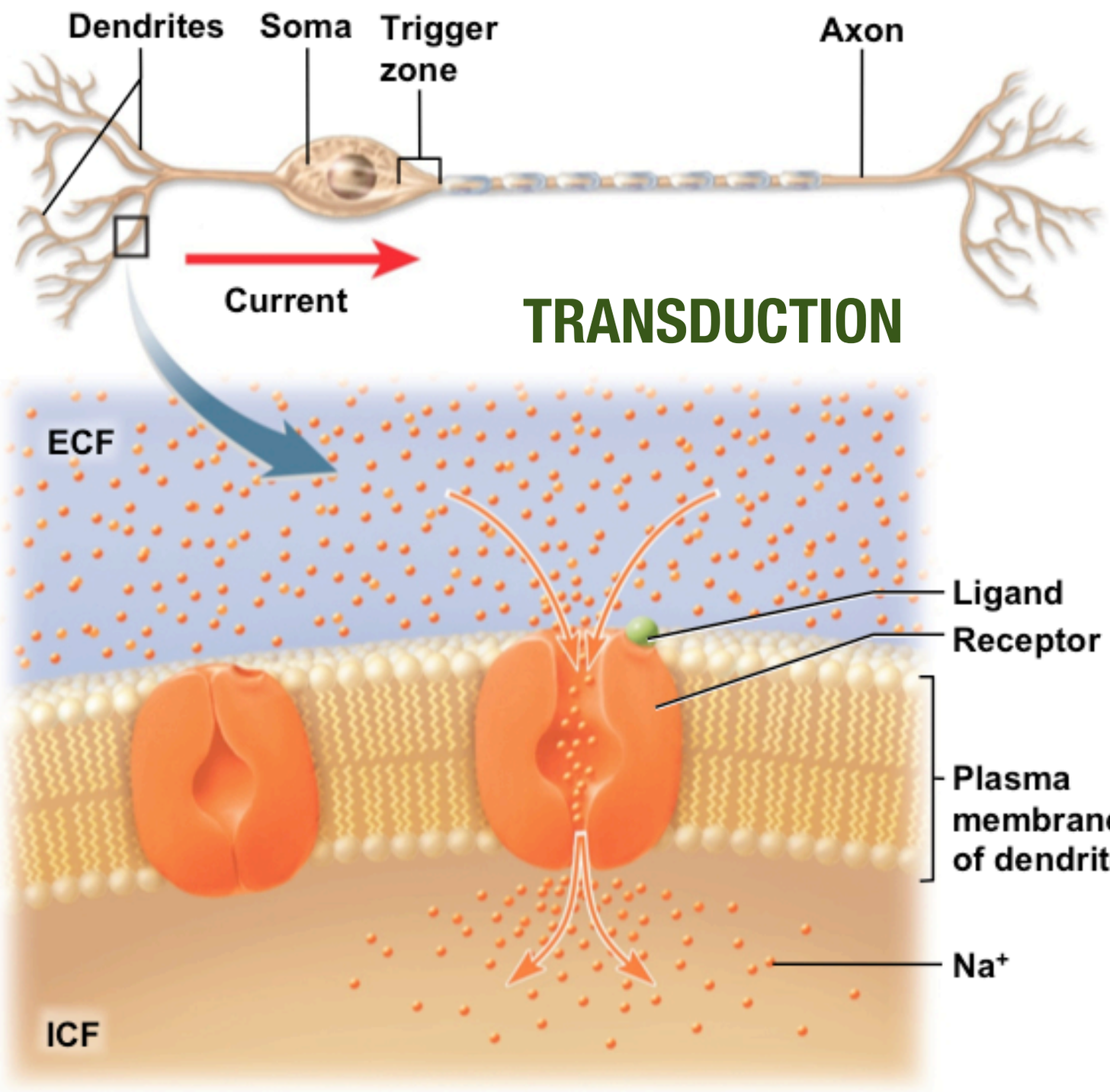
NEURON: Function (resting potentials)

- **Every cell has a voltage or membrane potential across its membrane.**
- **Every cell is negatively charged inside relative to outside.**
- **Ion pumps/channels create & maintain resting potential**
- **Resting potentials exist in a neuron when it is NOT sending impulses**



THE UNEQUAL TRANSPORT OF NA+ AND K+ RESULTS IN THE VOLTAGE ON THE LEFT

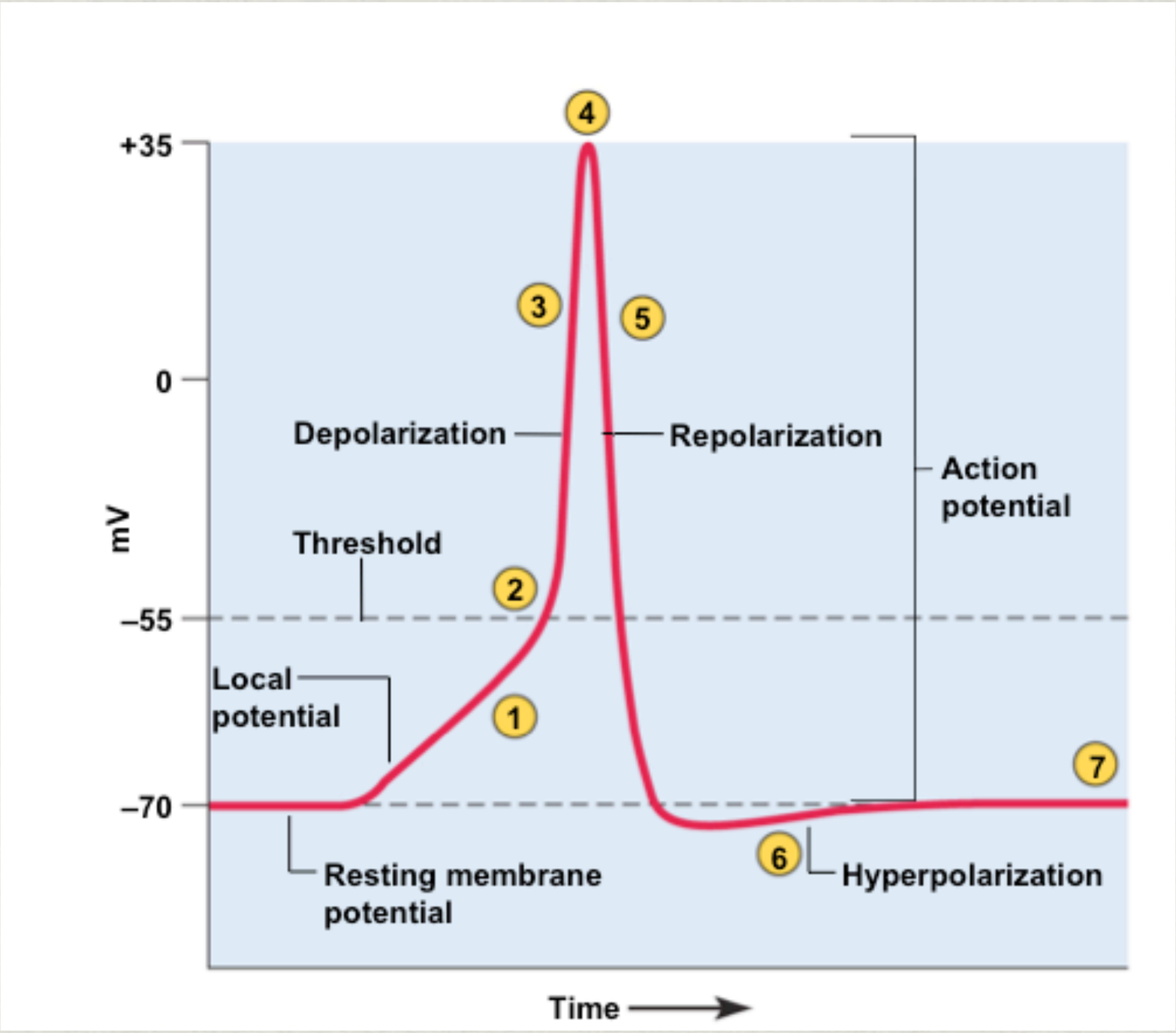
Excitation of a neuron by a chemical stimulus



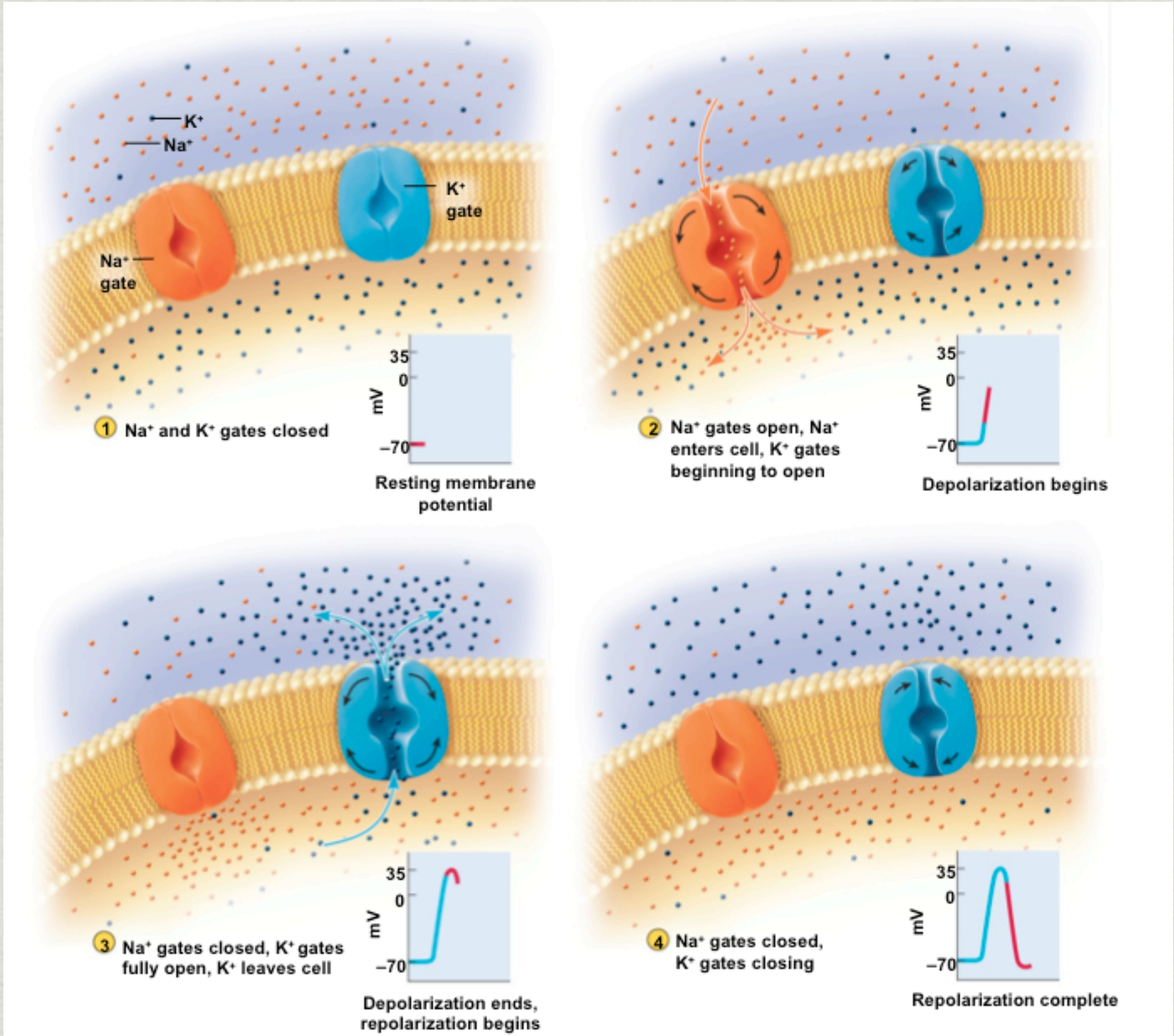
Neuron: FUNCTION (action potentials)

- **Action potentials exist in a neuron when it IS sending impulses.**
- **Results in a rapid & dramatic change in ion concentrations.**
- **Voltage gated channels are responsible for action potentials.**

REVIEW- (action potentials)



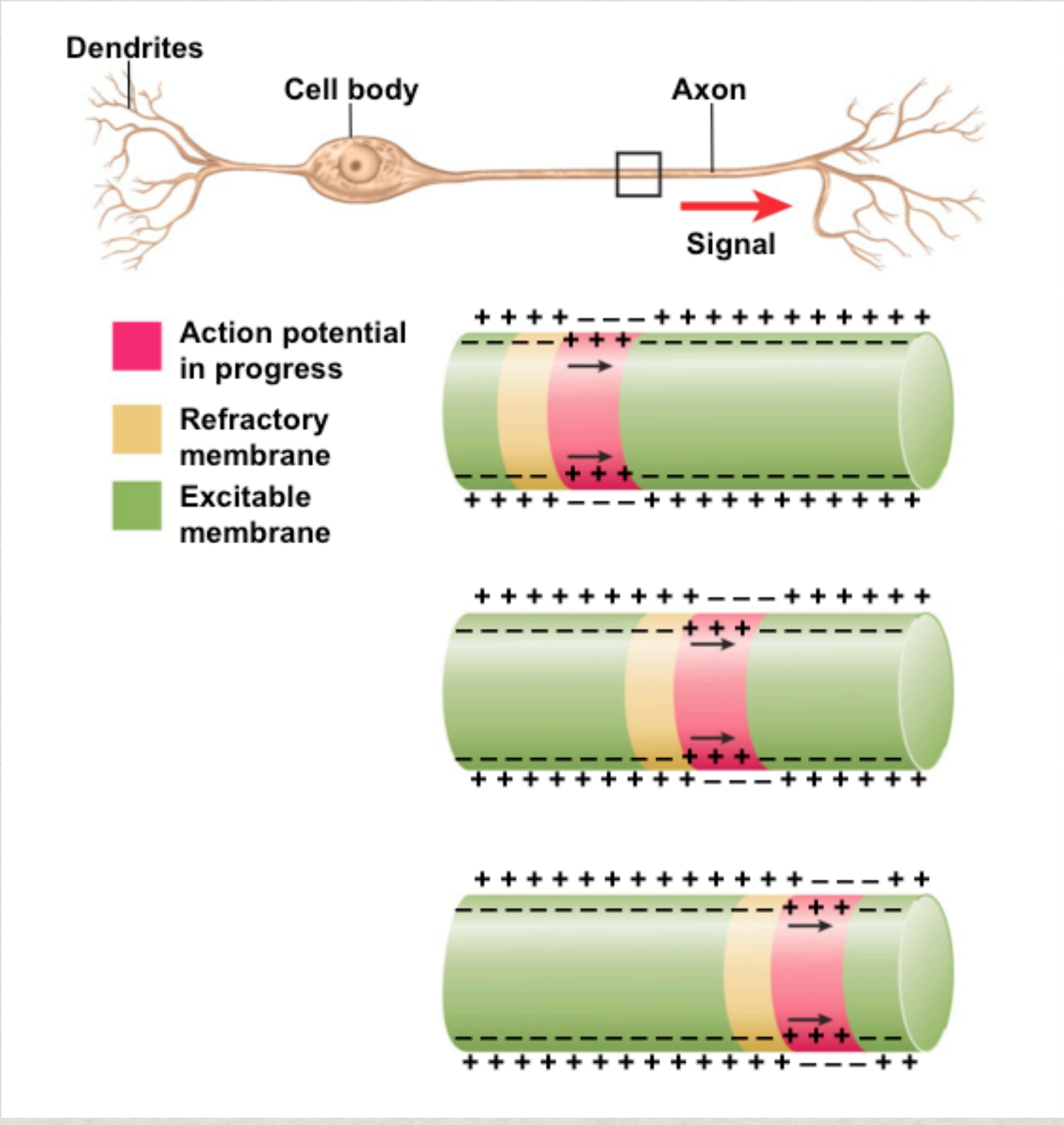
Remember the Na+/K+ pumps work continuously but they are not pictured here



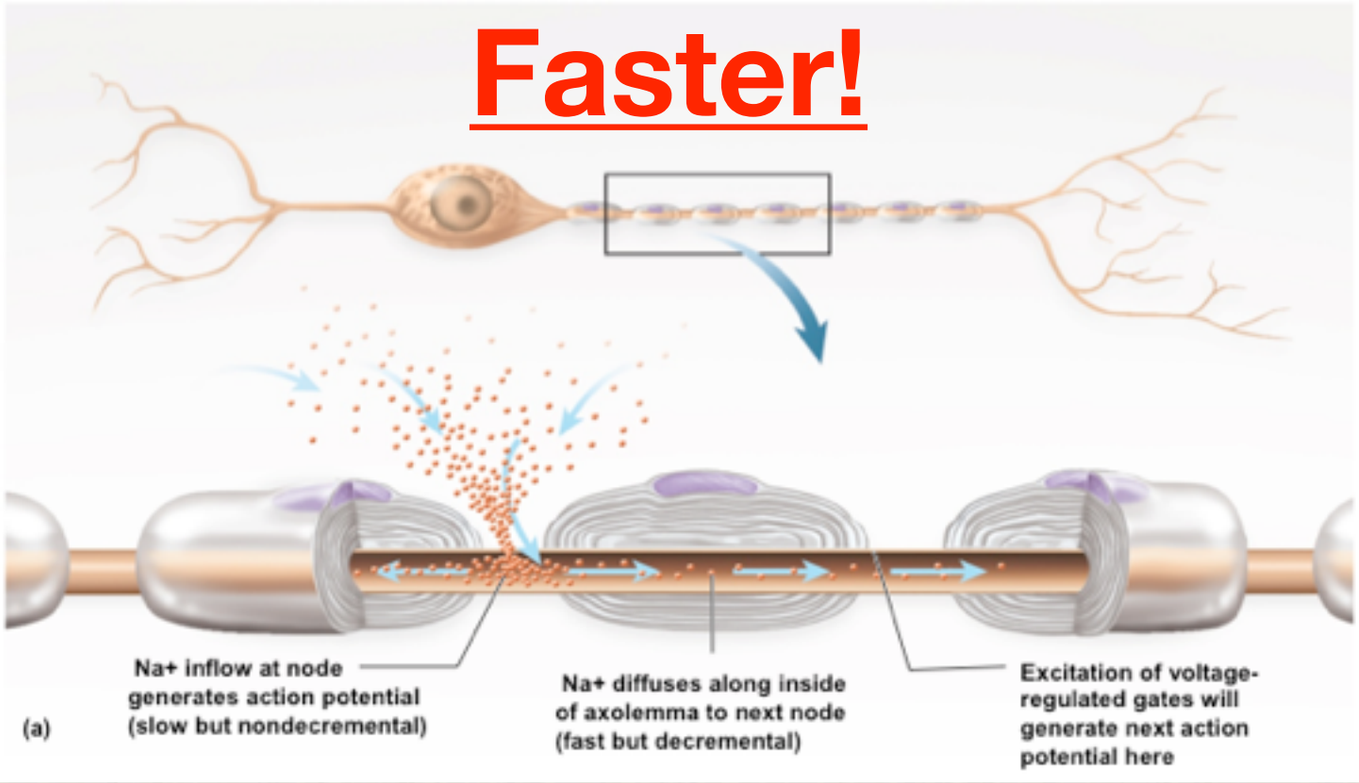
A cool fact: the human body spends 33% of its total energy to run the Na+/K+ pumps

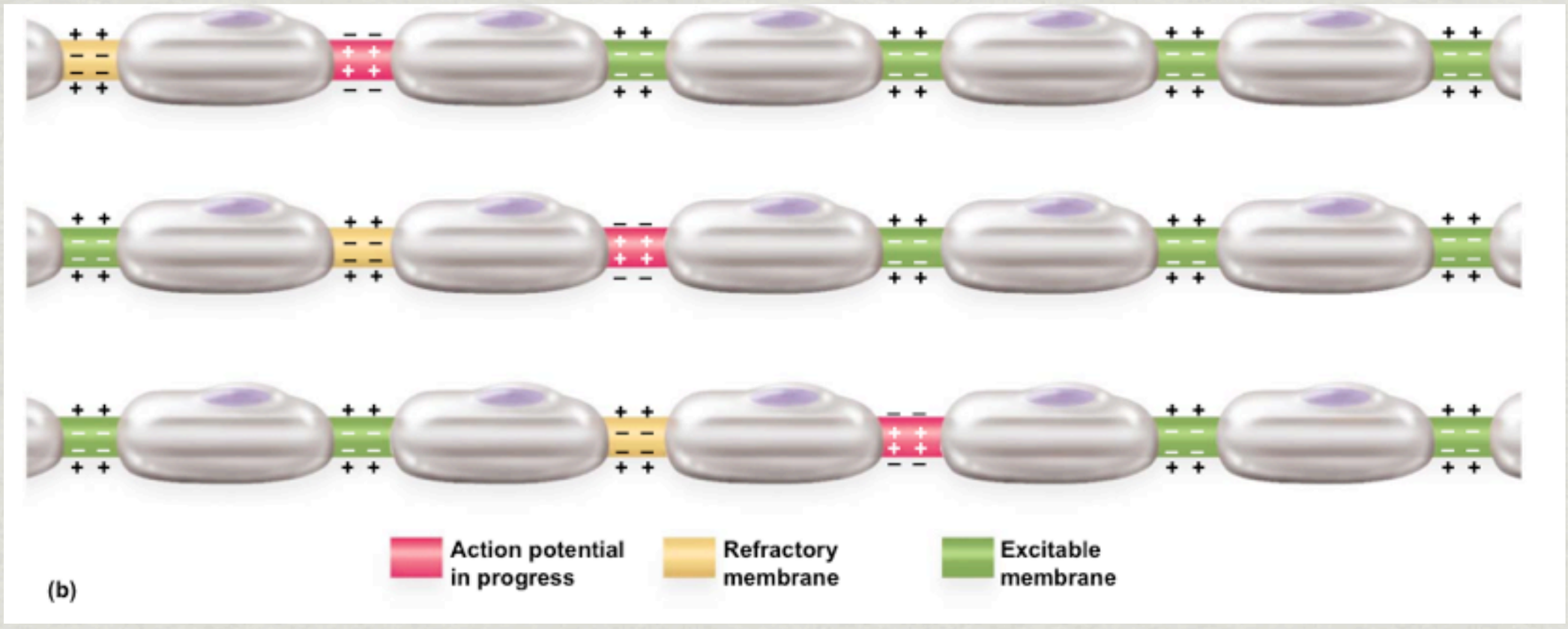
Neuron: (action potential conduction)

This example shows a neuron that is NOT myelinated!



Faster!


Na+ inflow at node
generates action potential
(slow but nondecremental)
Na+ diffuses along inside
of axolemma to next node
(fast but decremental)
Excitation of voltage-
regulated gates will
generate next action
potential here
(a)


Action potential
in progress
Refractory
membrane
Excitable
membrane
(b)

Essential knowledge 3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.

c. Transmission of information between neurons occurs across synapses.

Evidence of student learning is a demonstrated understanding of each of the following:

1. In most animals, transmission across synapses involves chemical messengers called neurotransmitters.

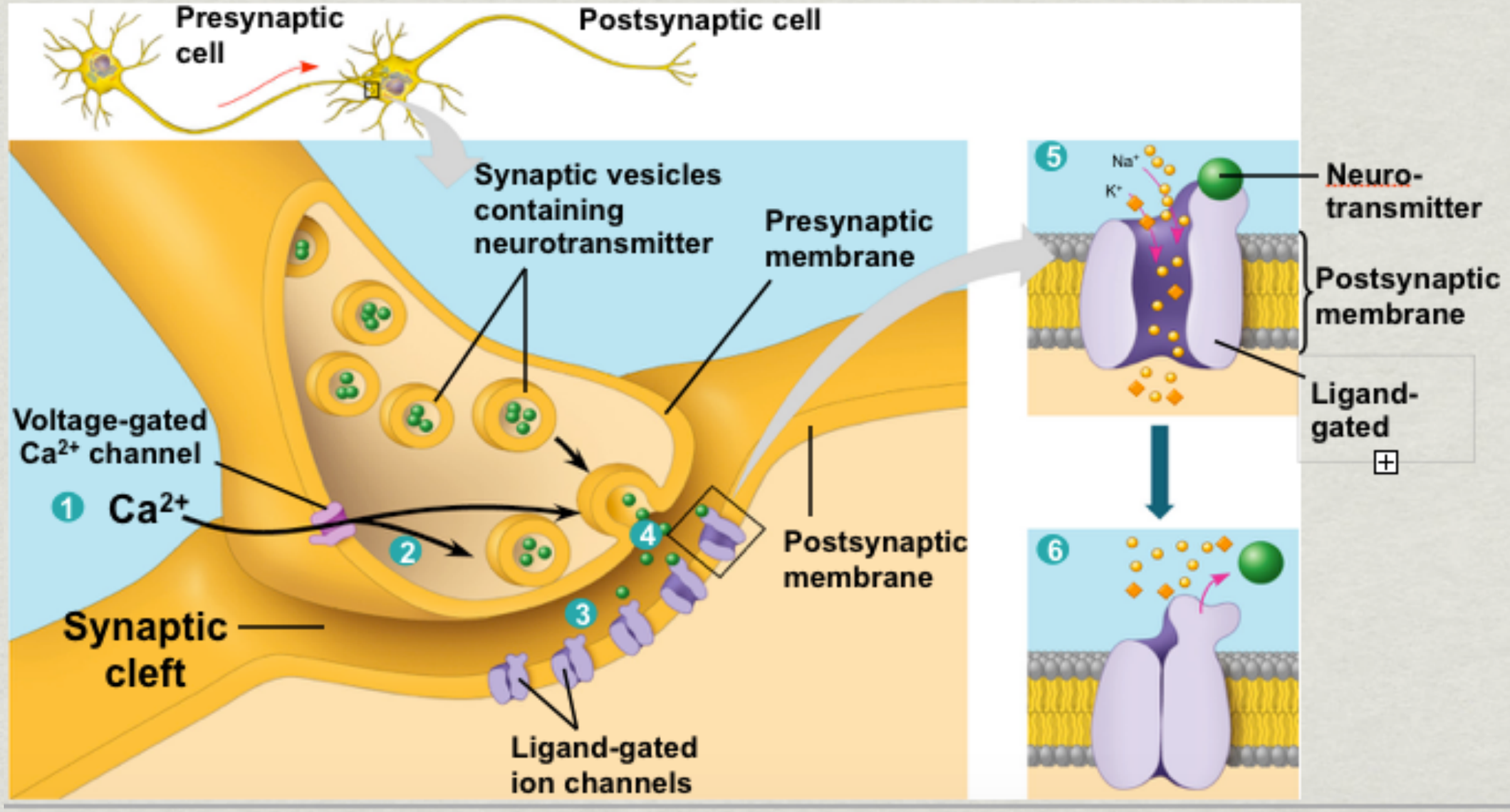
To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Acetylcholine
- Epinephrine
- Norepinephrine • Dopamine
- Serotonin
- GABA

Neuron: FUNCTION (synaptic transmission)

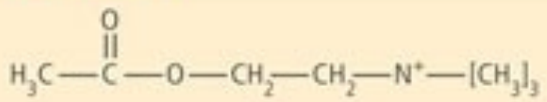
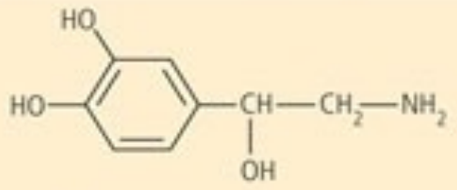
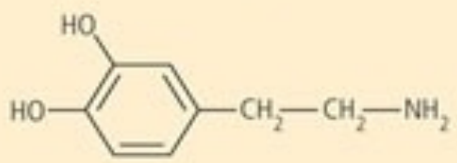
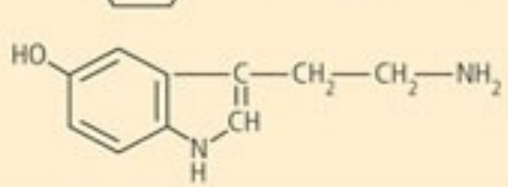
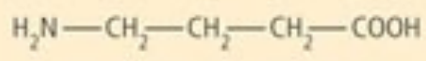
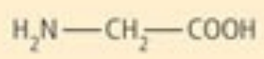
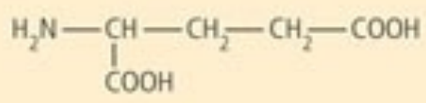
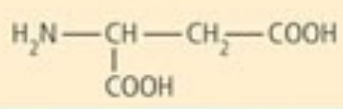
- Nerve cells communicate with other cells at synapses.
  - Effector cells include other nerves, muscles or glands
- Electric synapse.
- Chemical synapse.

Neuron: FUNCTION (synaptic transmission)



Neurotransmitters

Table 48.1 Major Neurotransmitters

Neurotransmitter	Structure	Functional Class	Secretion Sites
Acetylcholine		Excitatory to vertebrate skeletal muscles; excitatory or inhibitory at other sites	CNS; PNS; vertebrate neuromuscular junction
Biogenic Amines			
Norepinephrine		Excitatory or inhibitory	CNS; PNS
Dopamine		Generally excitatory; may be inhibitory at some sites	CNS; PNS
Serotonin		Generally inhibitory	CNS
Amino Acids			
GABA (gamma aminobutyric acid)		Inhibitory	CNS; invertebrate neuromuscular junction
Glycine		Inhibitory	CNS
Glutamate		Excitatory	CNS; invertebrate neuromuscular junction
Aspartate		Excitatory	CNS
Neuropeptides (a very diverse group, only two of which are shown)			
Substance P	Arg—Pro—Lys—Pro—Gln—Gln—Phe—Phe—Gly—Leu—Met	Excitatory	CNS; PNS
Met-enkephalin (an endorphin)	Tyr—Gly—Gly—Phe—Met	Generally inhibitory	CNS

Essential knowledge 3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.

2. Transmission of information along neurons and synapses results in a response.

3. The response can be stimulatory or inhibitory.

Main Idea

- ***Sensing and consequently <u>Responding</u> to the environment is an absolute necessity for all organisms.***

- responses occur at the cellular level, but this unit will focus on responses at the organismal level.

Locomotion

- ***For many organisms, Responding to environmental stimuli often involves moving to or away from a stimulus***.
  - *Locomotion*- is the ability to move place to place, the act of self propulsion.

Growth

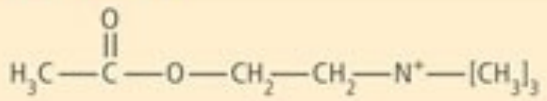
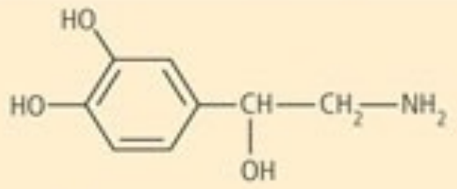
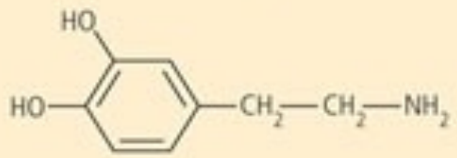
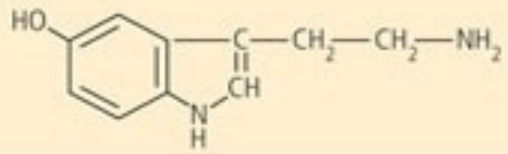
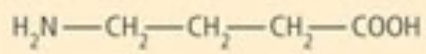
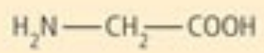
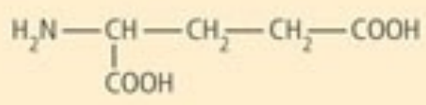
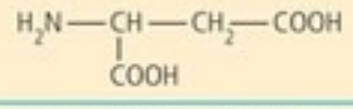
- ***For some organisms growing towards or away from a stimulus is the best they can do.***
  - ***I am using a liberal interpretation of "moving" to include <u>self propulsion</u> as well as <u>growth</u>.***

Locomotion & Growth

- *Motile Organisms*- have the ability to move place to place.
- *Sessile Organisms*- do not have the ability to move place to place, they are anchored to a substrate for most of their life.
    - Even sessile organisms can move in emergencies, or can move to new sites for food or at least had a motile stage in their life.

Neurotransmitters

Table 48.1 Major Neurotransmitters

Neurotransmitter	Structure	Functional Class	Secretion Sites
Acetylcholine		Excitatory to vertebrate skeletal muscles; excitatory or inhibitory at other sites	CNS; PNS; vertebrate neuromuscular junction
Biogenic Amines			
Norepinephrine		Excitatory or inhibitory	CNS; PNS
Dopamine		Generally excitatory; may be inhibitory at some sites	CNS; PNS
Serotonin		Generally inhibitory	CNS
Amino Acids			
GABA (gamma aminobutyric acid)		Inhibitory	CNS; invertebrate neuromuscular junction
Glycine		Inhibitory	CNS
Glutamate		Excitatory	CNS; invertebrate neuromuscular junction
Aspartate		Excitatory	CNS
Neuropeptides (a very diverse group, only two of which are shown)			
Substance P	Arg—Pro—Lys—Pro—Gln—Gln—Phe—Phe—Gly—Leu—Met	Excitatory	CNS; PNS
Met-enkephalin (an endorphin)	Tyr—Gly—Gly—Phe—Met	Generally inhibitory	CNS

Essential knowledge 3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.

d. Different regions of the vertebrate brain have different functions.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

- Vision, Hearing, Muscle movement, Abstract thought and emotions, Neuro-hormone production, Forebrain (cerebrum), midbrain (brainstem) and hindbrain (cerebellum) and Right and left cerebral hemispheres in humans

✘✘ The types of nervous systems, development of the human nervous system, details of the various structures and features of the brain parts, and details of specific neurologic processes are beyond the scope of the course and the AP Exam.

Human Brain & Spinal Cord

- The brain provides integrative power that underlies the complex behavior of vertebrates.
- The spinal cord integrates simple processes and conveys information to and from the brain

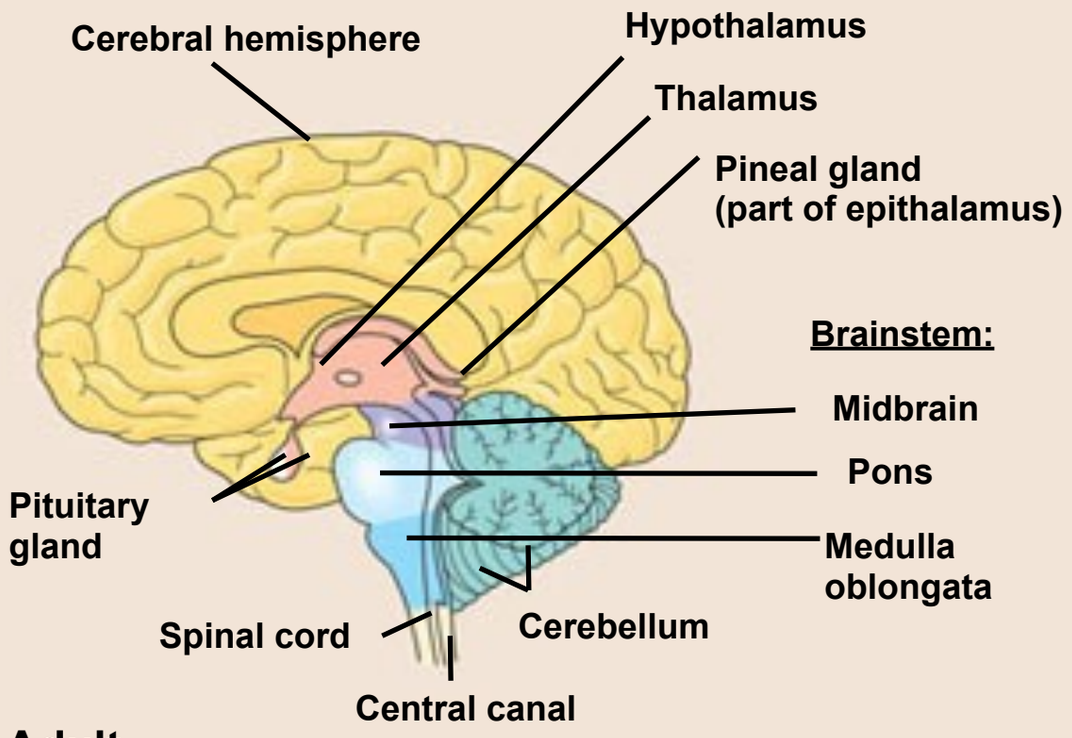
Cerebrum (cerebral hemispheres; includes cerebral cortex, white matter, basal nuclei)

Diencephalon (thalamus, hypothalamus, epithalamus)

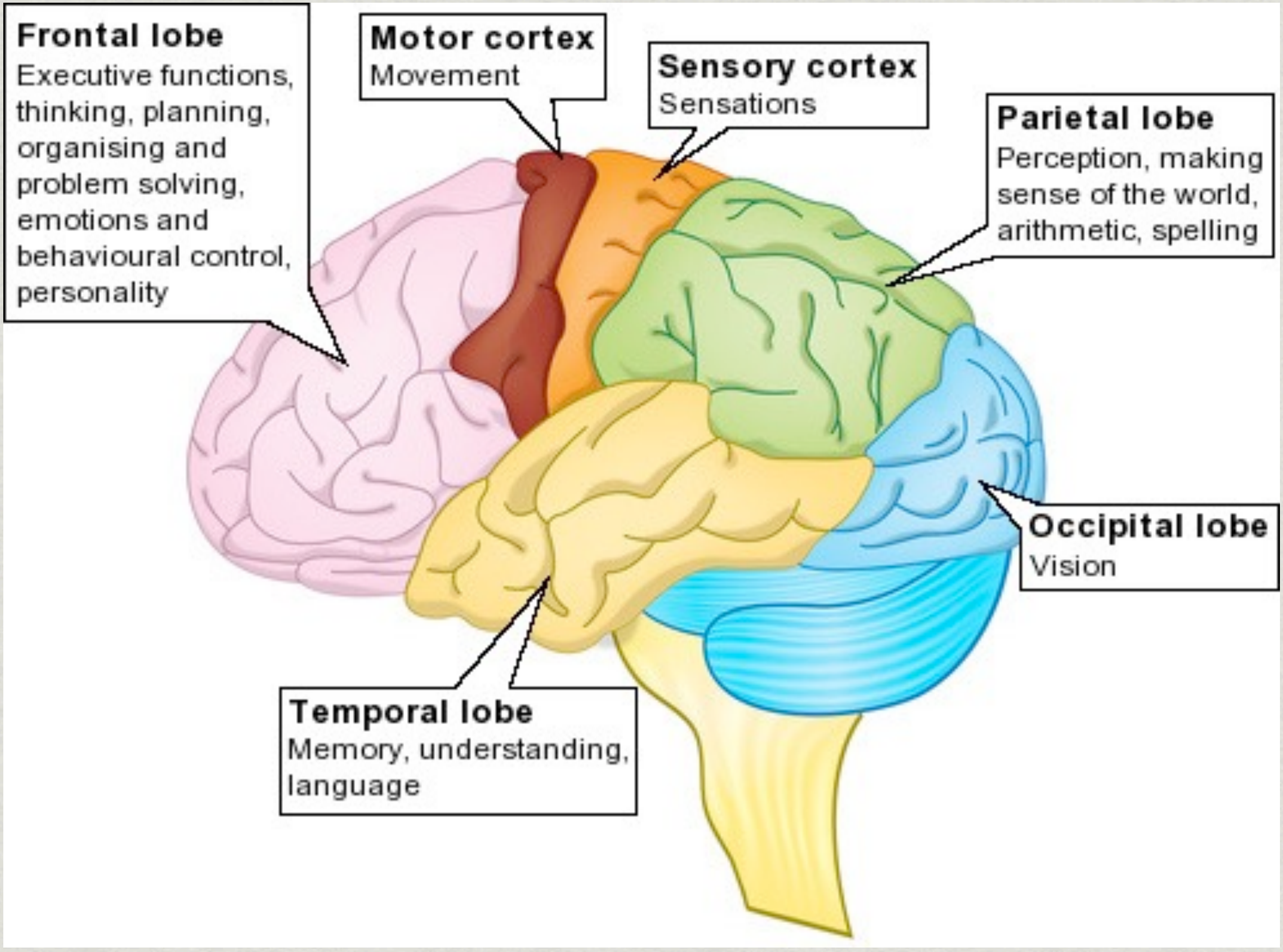
Midbrain (part of brainstem)

Pons (part of brainstem), cerebellum

Medulla oblongata (part of brainstem)



Adult


Frontal lobe
Executive functions, thinking, planning, organising and problem solving, emotions and behavioural control, personality
Motor cortex
Movement
Sensory cortex
Sensations
Parietal lobe
Perception, making sense of the world, arithmetic, spelling
Occipital lobe
Vision
Temporal lobe
Memory, understanding, language

Learning Objectives:

LO 3.43 The student is able to construct an explanation, based on scientific theories and models, about how nervous systems detect external and internal signals, transmit and integrate information, and produce responses. [See SP 6.2, 7.1]

LO 3.44 The student is able to describe how nervous systems detect external and internal signals. [See SP 1.2]

LO 3.45 The student is able to describe how nervous systems transmit information. [See SP 1.2]

LO 3.46 The student is able to describe how the vertebrate brain integrates information to produce a response. [See SP 1.2]

Learning Objectives:

LO 3.47 The student is able to create a visual representation of complex nervous systems to describe/explain how these systems detect external and internal signals, transmit and integrate information, and produce responses. [See SP 1.1]

LO 3.48 The student is able to create a visual representation to describe how nervous systems detect external and internal signals. [See SP 1.1]

LO 3.49 The student is able to create a visual representation to describe how nervous systems transmit information. [See SP 1.1]

LO 3.50 The student is able to create a visual representation to describe how the vertebrate brain integrates information to produce a response. [See SP 1.1]