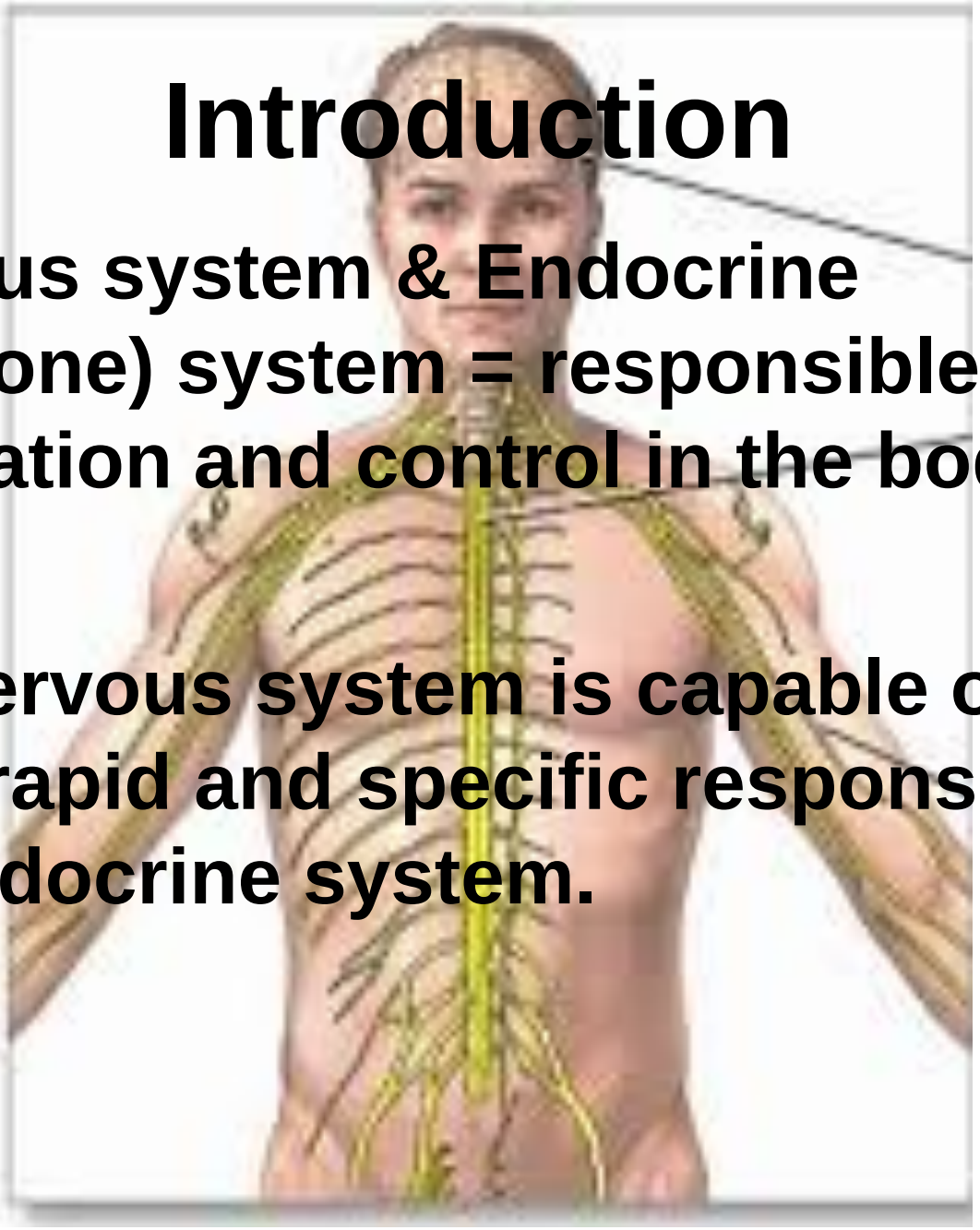
Biology 12

Chapter 17
The Nervous System

Introduction



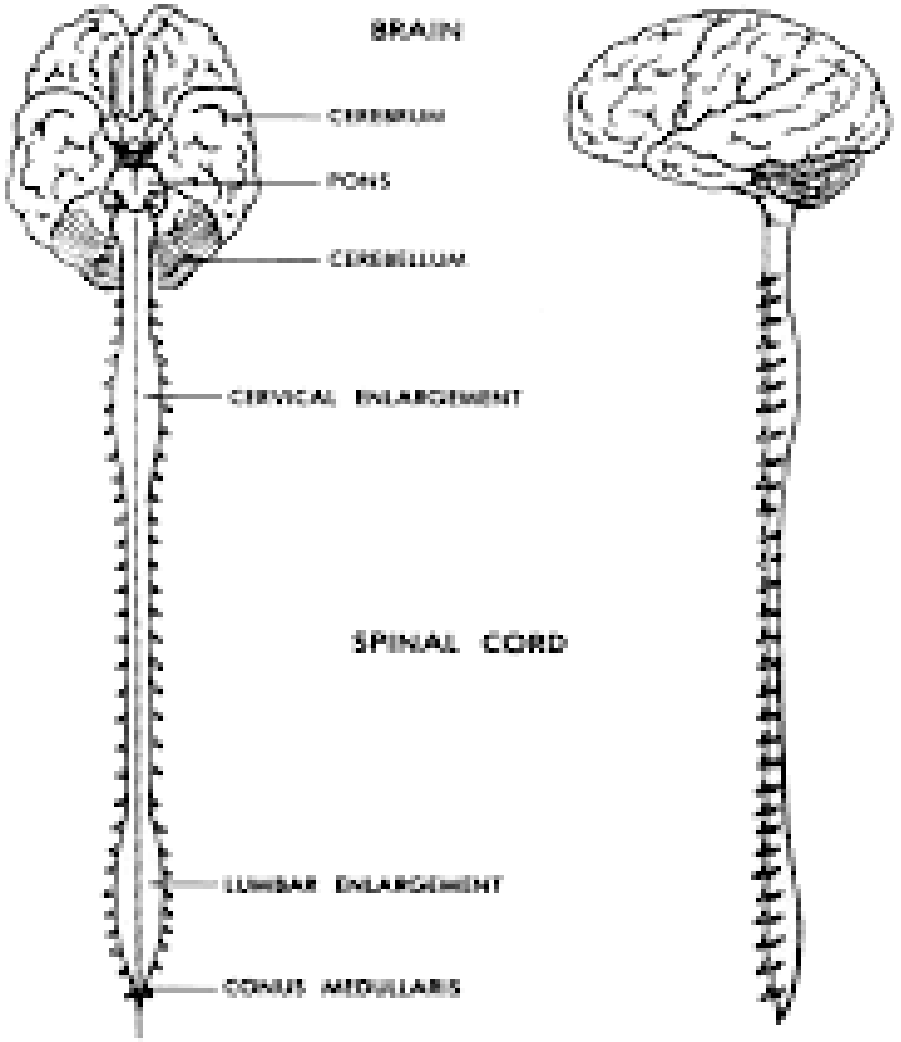
- **Nervous system & Endocrine (hormone) system = responsible for integration and control in the body.**

- **The nervous system is capable of much more rapid and specific responses than the endocrine system.**

17.1- Nervous Tissue

- Two major Divisions
  1. **Central Nervous System (CNS)**

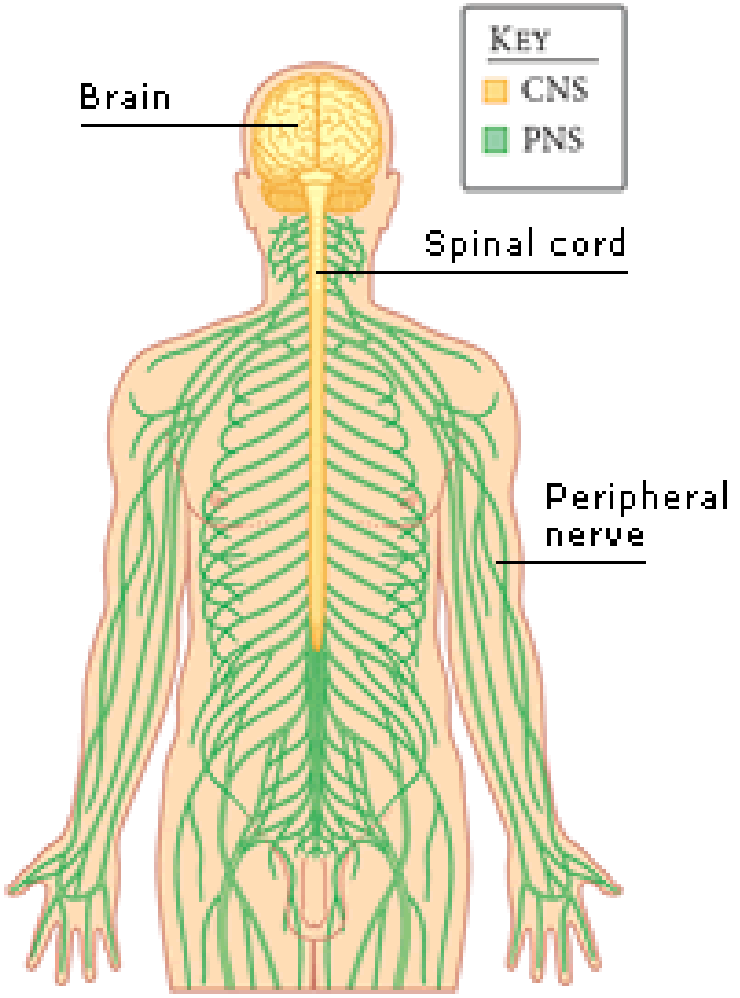
     = Brain and spinal cord (located in midline of body)



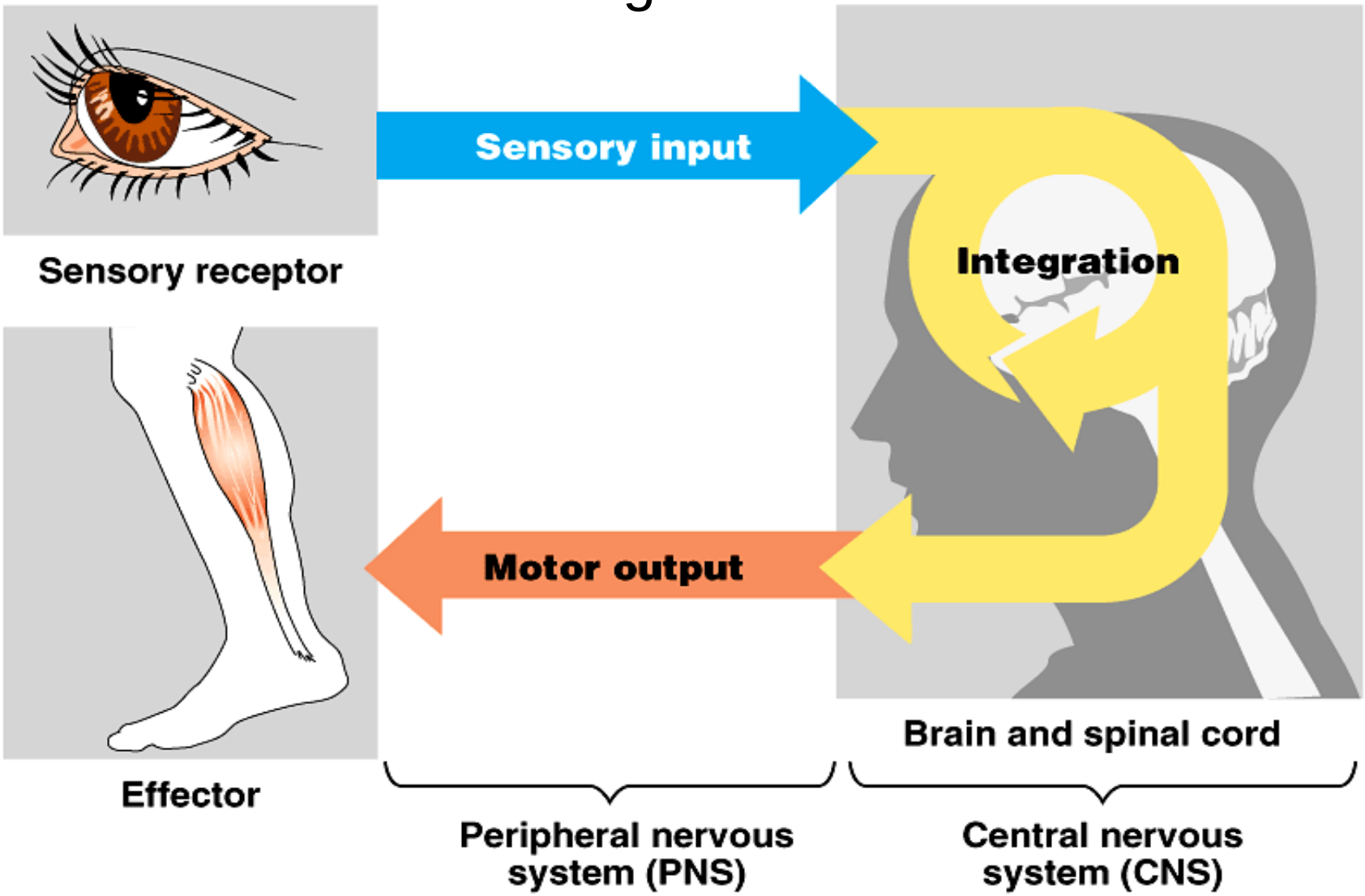
17.1- Nervous Tissue

2. Peripheral Nervous System (PNS)

= Nerves that carry sensory messages to the CNS and motor commands from the CNS to the muscles and glands



The two systems are interconnect and work together



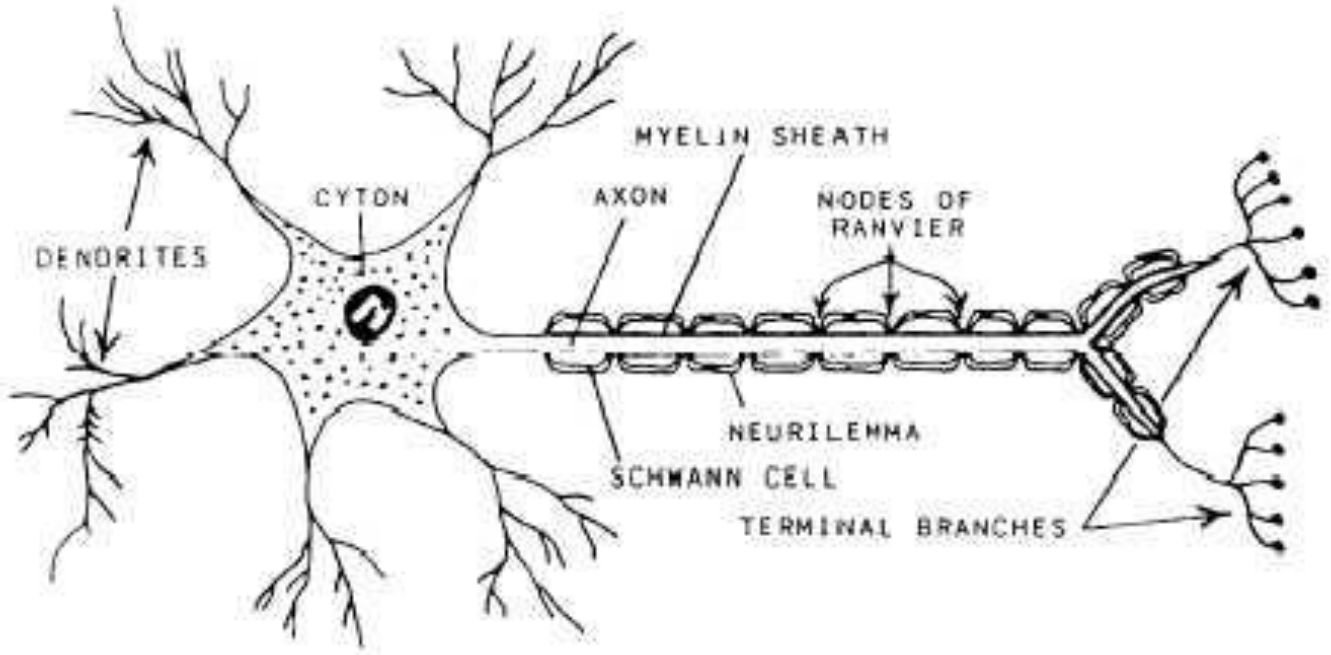
The Neuron

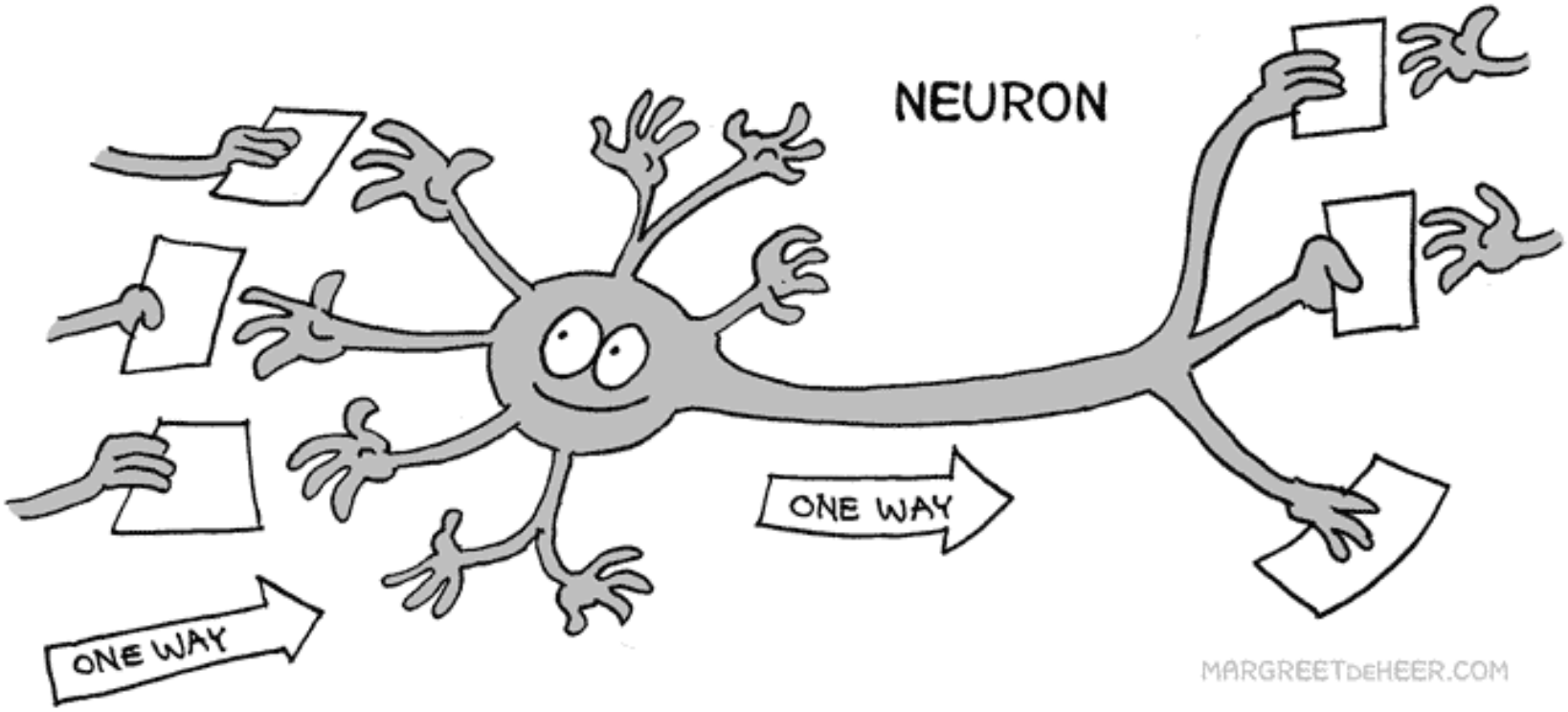
- The neuron is the basic cell of the nervous system.
- Among the most highly specialized cells.

Structure: the neuron is divided into 3 distinct sections:

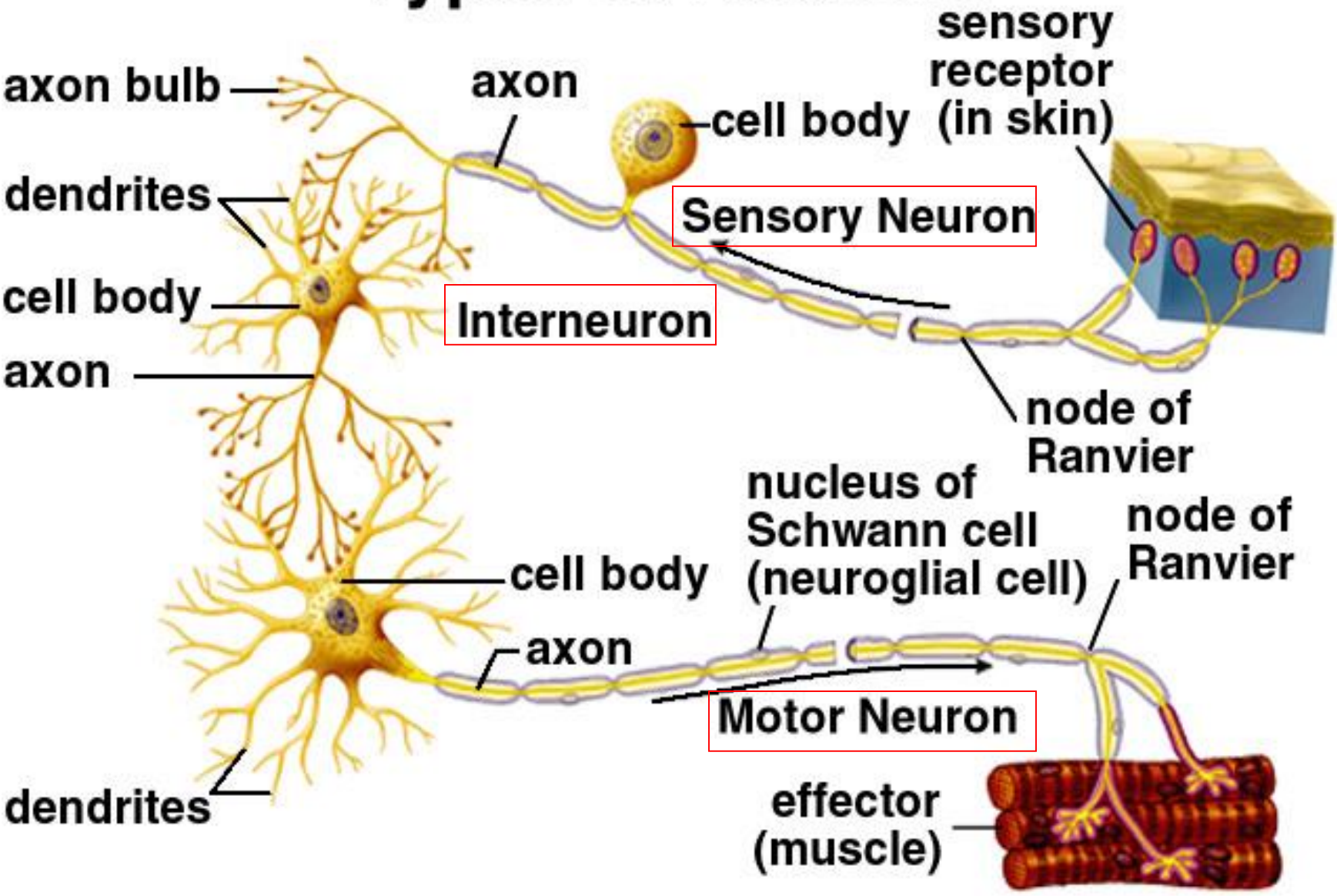
1. **Cell body=** contains nucleus and coordinates cell activities
2. **Dendrites=** carry impulses to cell body
3. **Axons=** carry impulses away from cell body

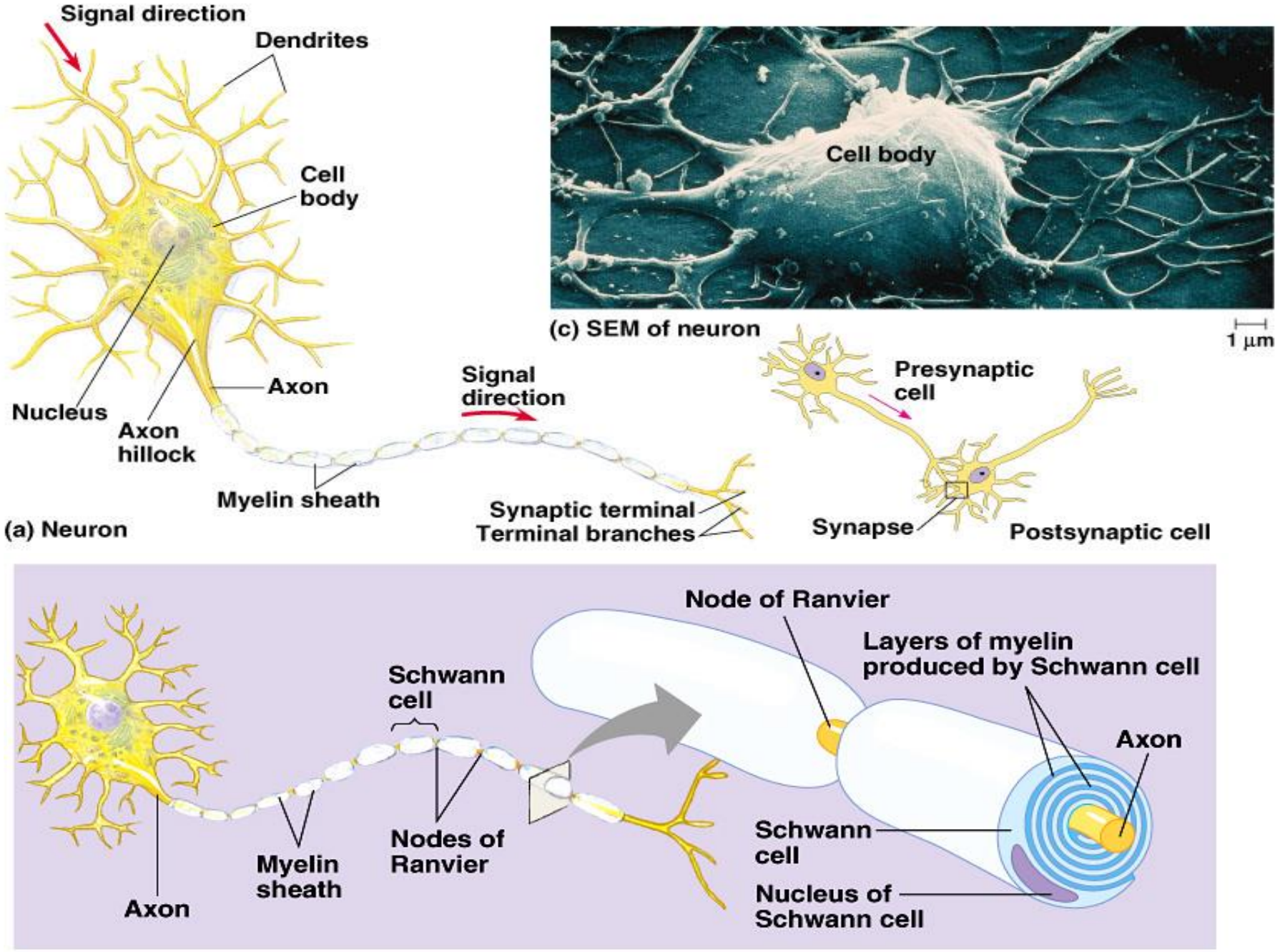
- **Myelin sheath**= is the fatty substance surrounding parts of the neuron
- **Nodes of Ranvier**= gaps where there is no myelin sheath
- **Schwann cells**= make up the myelin sheath

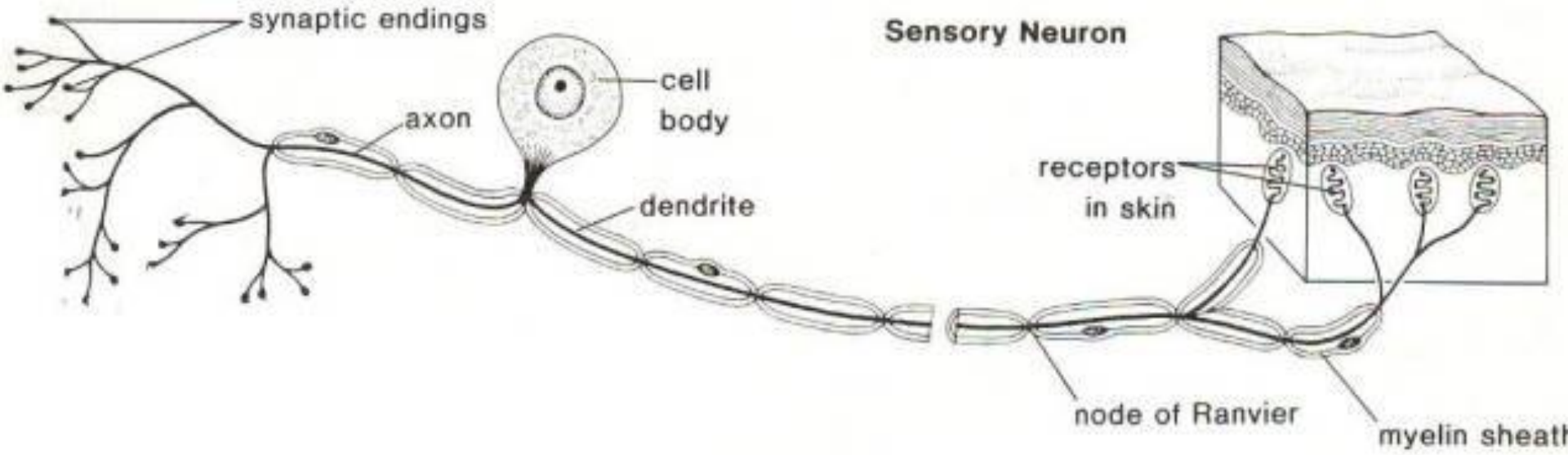



NEURON
ONE WAY
ONE WAY
MARGREETDEHEER.COM

Types of Neurons

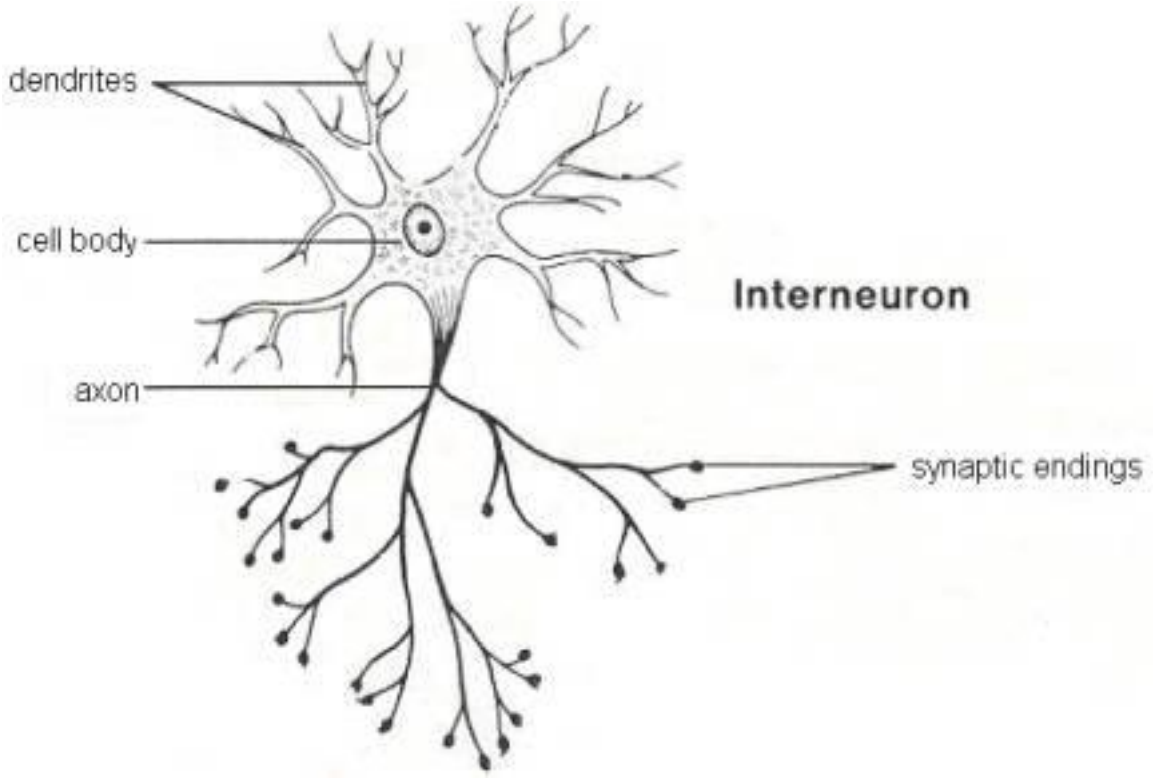



Signal direction
Dendrites
Cell body
Nucleus
Axon hillock
Axon
Signal direction
Myelin sheath
Synaptic terminal
Terminal branches
(a) Neuron
Cell body
(c) SEM of neuron
1 µm
Presynaptic cell
Synapse
Postsynaptic cell
Node of Ranvier
Layers of myelin produced by Schwann cell
Schwann cell
Axon
Myelin sheath
Nodes of Ranvier
Schwann cell
Nucleus of Schwann cell
Axon



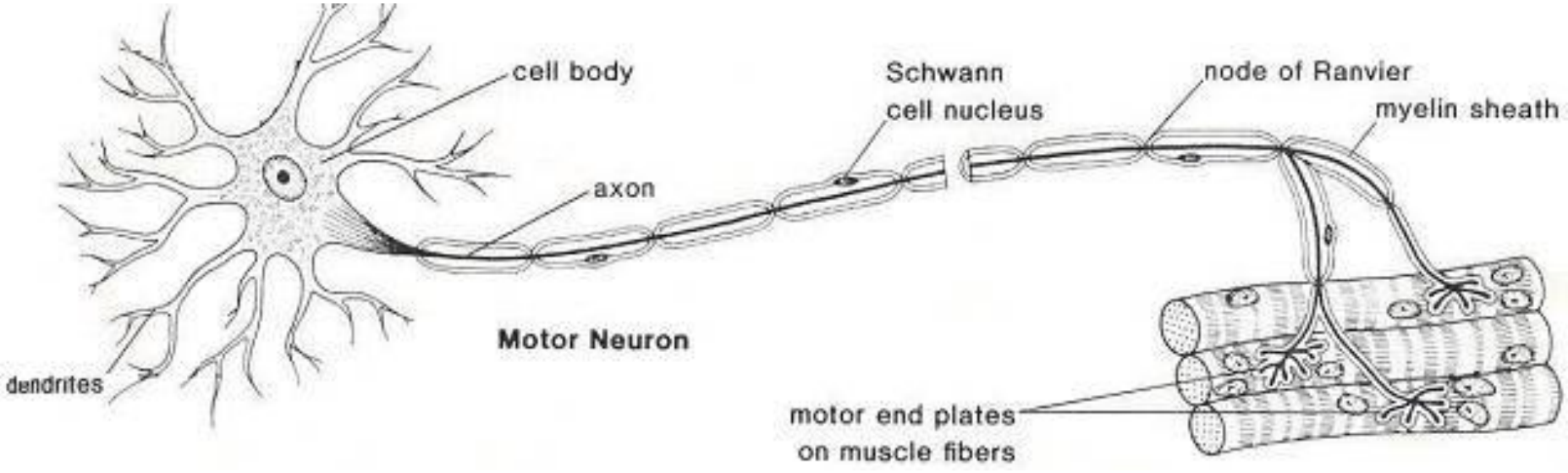
Sensory Neuron:

Relays messages from receptors to the brain or spinal cord



Interneuron (relay neuron):

- Relays message from sensory neuron to motor neuron
- Found in the brain and spinal cord



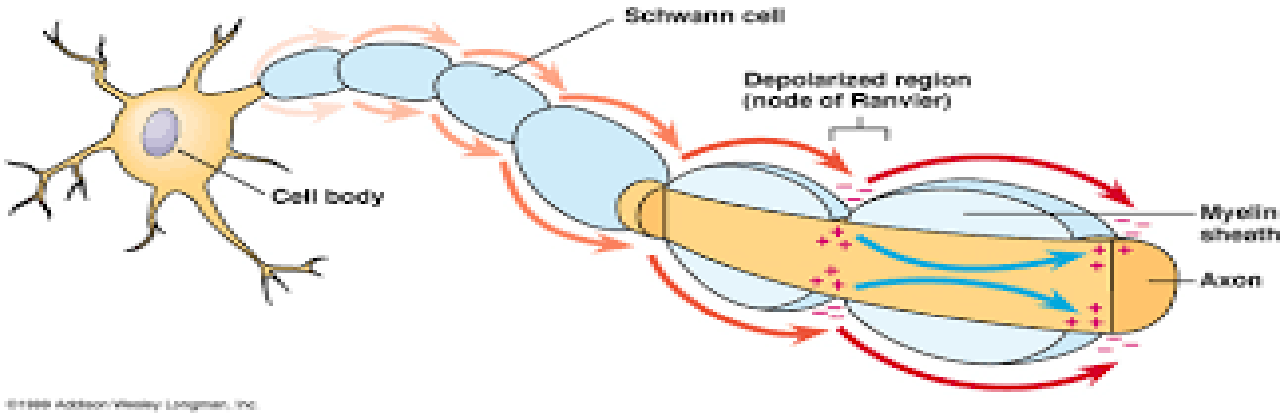
Motor Neuron:

Relays messages from the brain or spinal cord to the muscles and organs

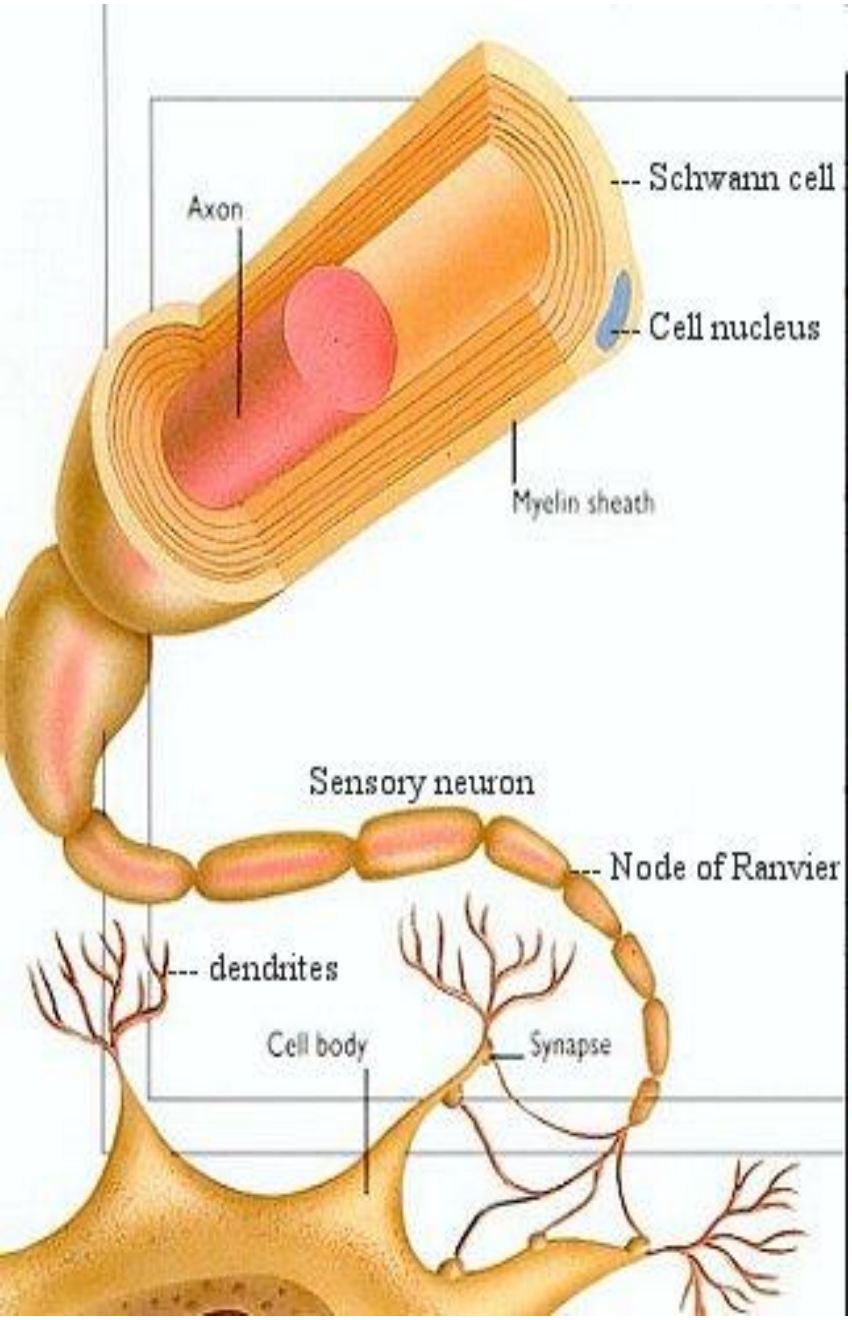
NEURONS

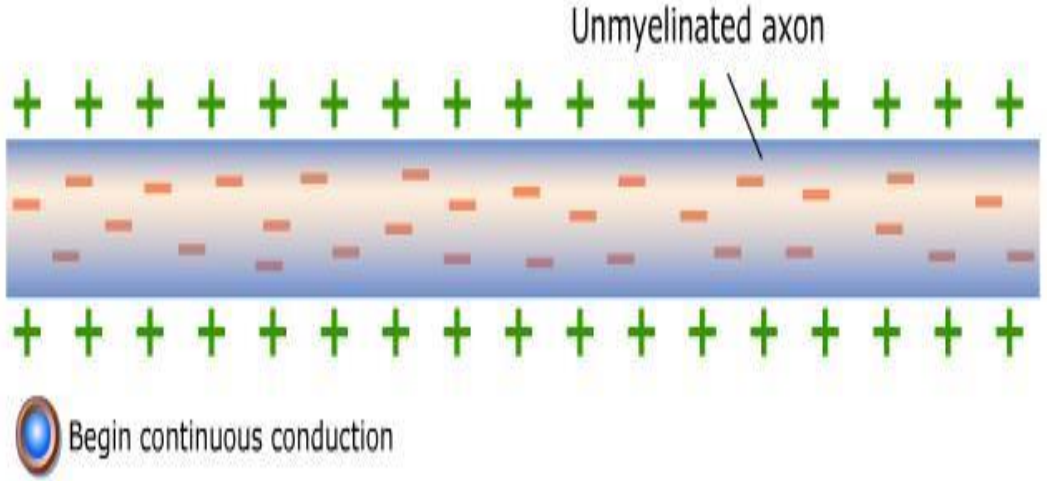
TYPE OF NEURON	DESCRIPTION	FUNCTION
Sensory Neuron	• contain special receptors to detect stimuli • Long myelinated dendrites • Short axons • Cell body outside the spinal cord contained in ganglion	Carry impulses toward the CNS
Interneurons (connector or association neurons)	• entire neuron is found inside the spinal cord • your brain is made up of all interneurons	connect the sensory and motor neurons
Motor Neurons	• short dendrites • long myelinated axons • end of motor neurons are motor end plates attached to muscles	Carry message from the brain and spinal cord to muscles and cells

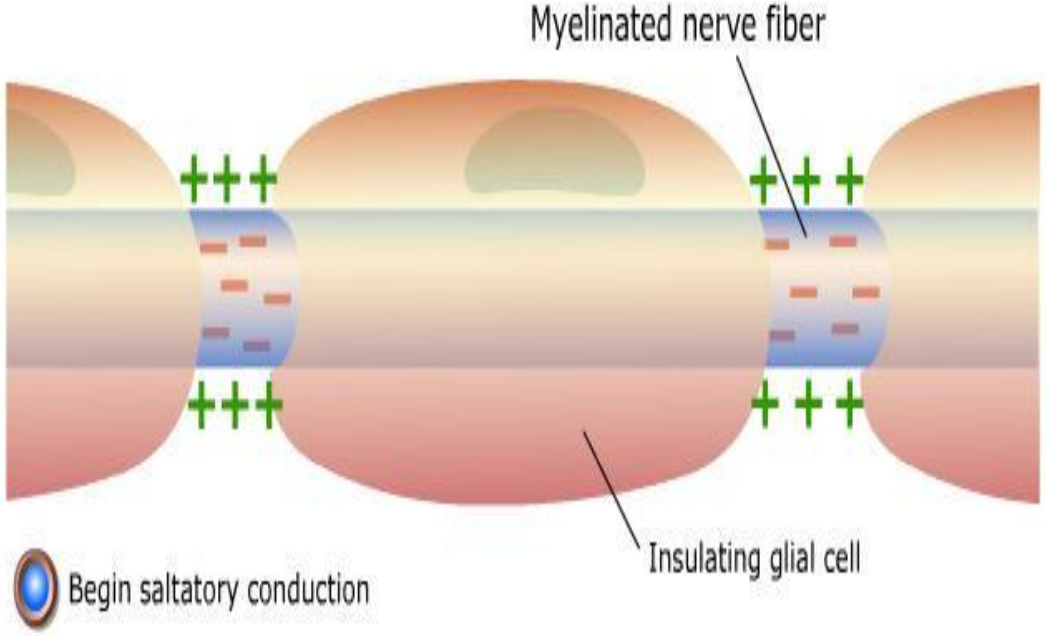
- **<u>Nervous Impulses</u>** - impulses move at 200 meters/second in peripheral (myelinated) nerves – but only 20 m/sec in non-myelinated interneurons.



- Saltatory conduction - In peripheral nerves - nervous impulse “jumps” from node to node **skipping the insulated regions** under the myelin sheath (sensory and motor nerves).


Axon
--- Schwann cell
--- Cell nucleus
Myelin sheath
Sensory neuron
--- Node of Ranvier
--- dendrites
Cell body
Synapse


Unmyelinated axon
Begin continuous conduction

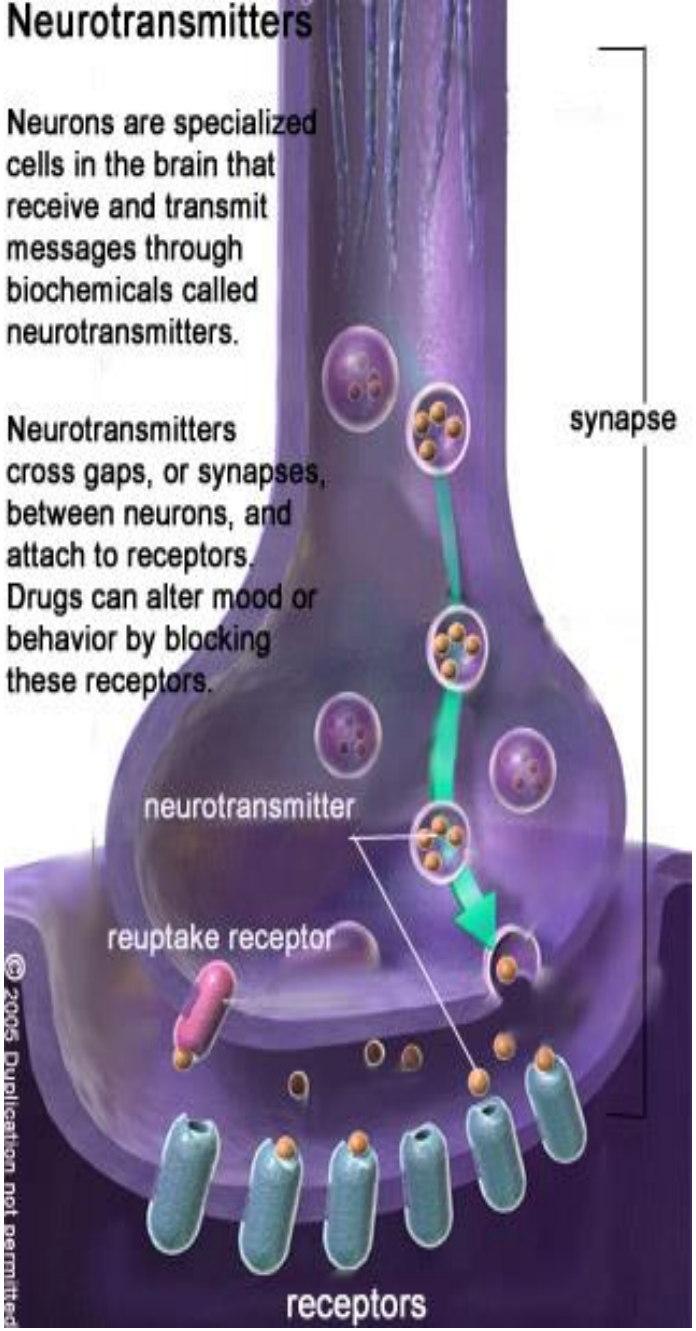

Myelinated nerve fiber
Insulating glial cell
Begin saltatory conduction

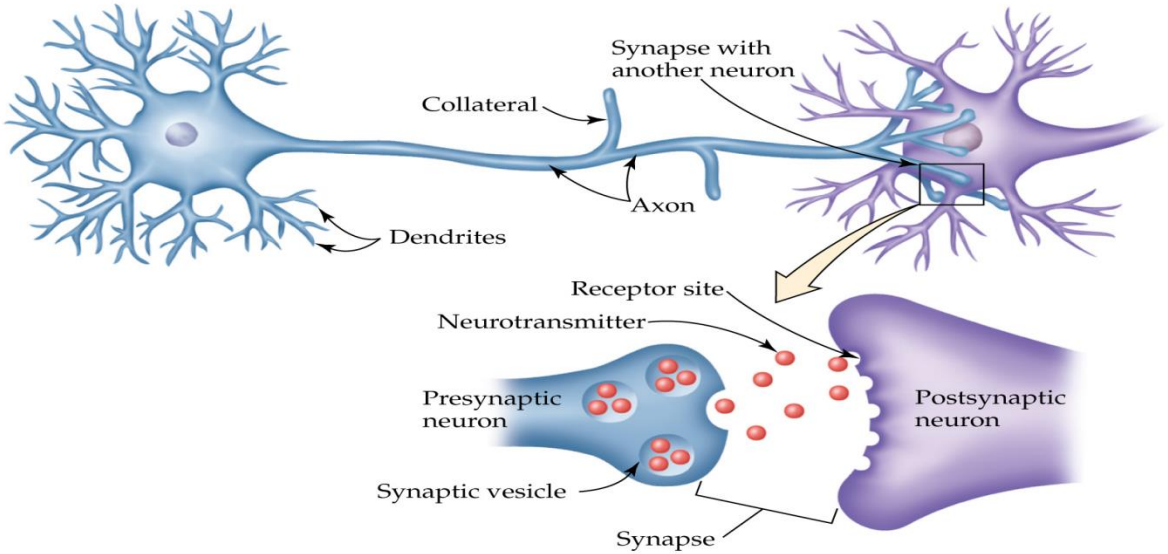
- Nerve conduction is “**All or None**” - if the threshold stimulus is achieved, the impulse will go the entire length of the neuron.

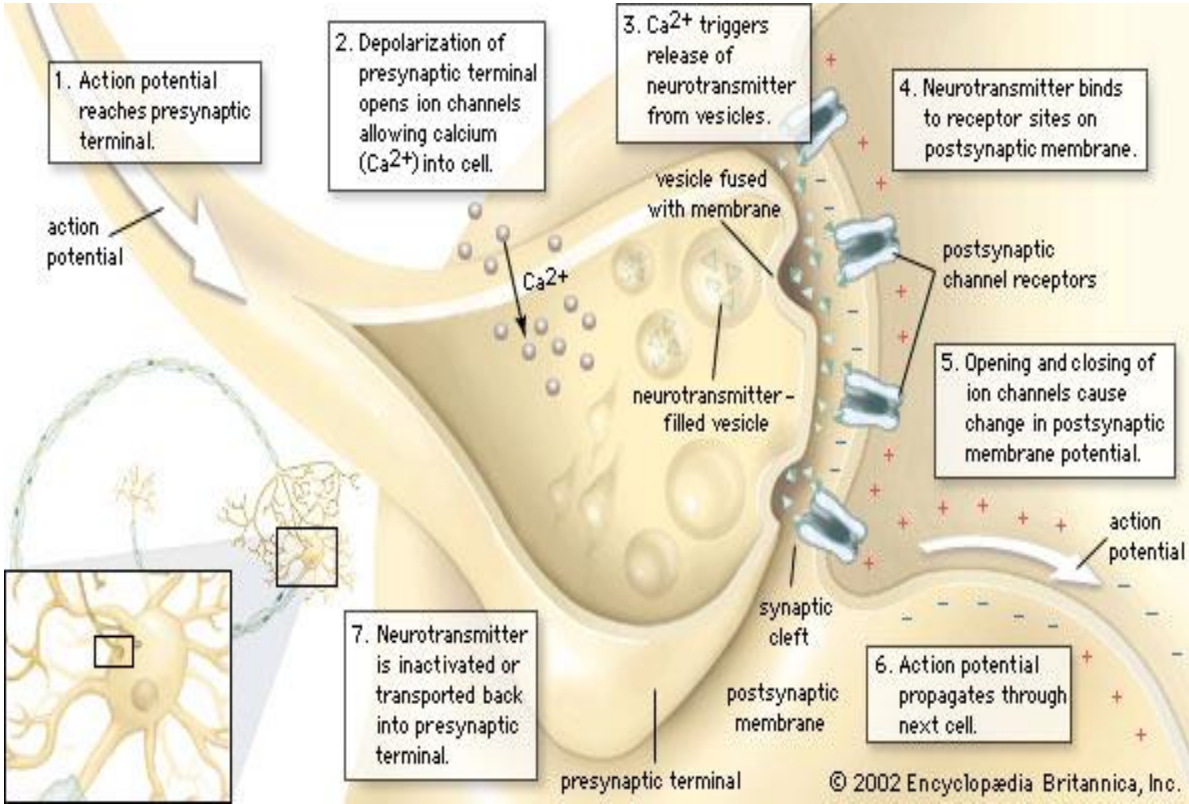
Neurotransmitters

Neurons are specialized cells in the brain that receive and transmit messages through biochemicals called neurotransmitters.

Neurotransmitters cross gaps, or synapses, between neurons, and attach to receptors. Drugs can alter mood or behavior by blocking these receptors.



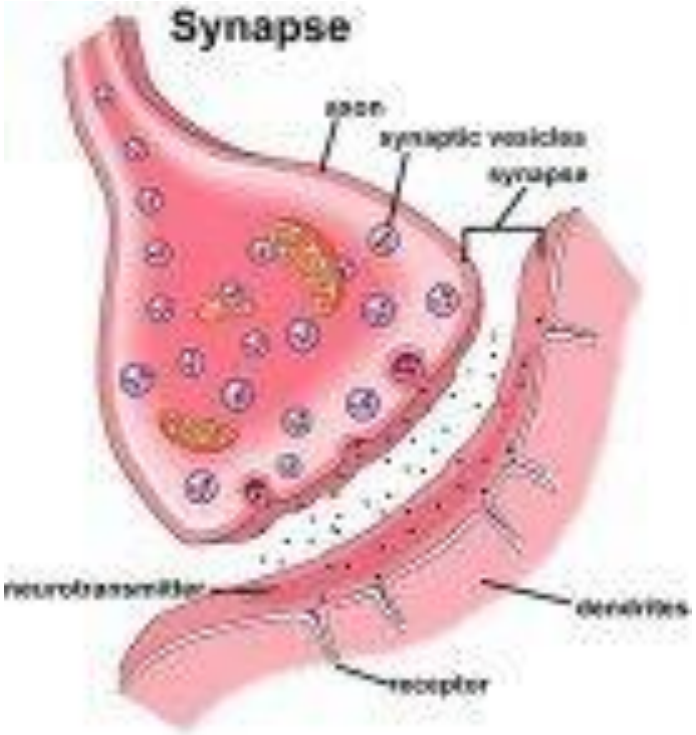




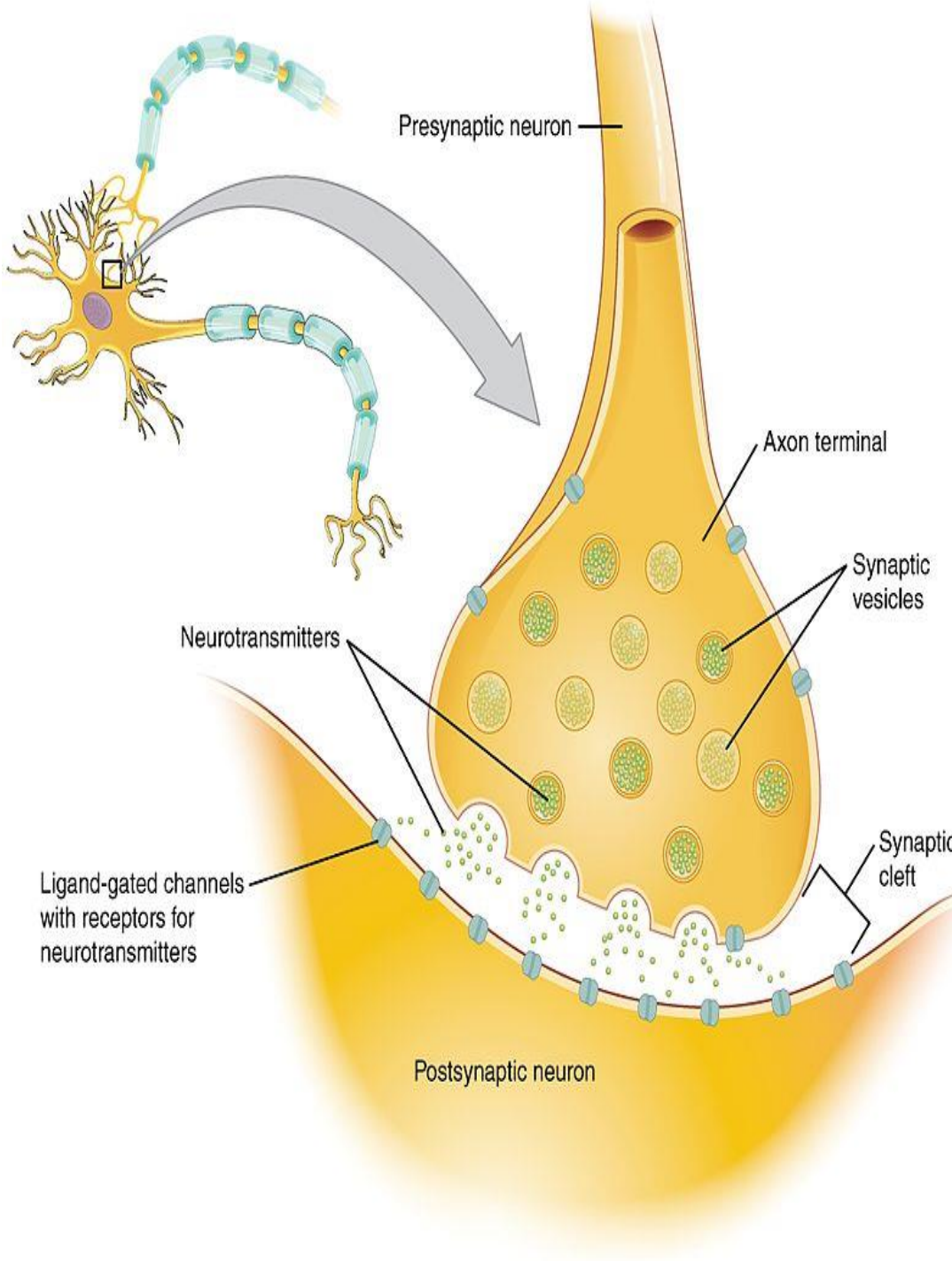
- synapse

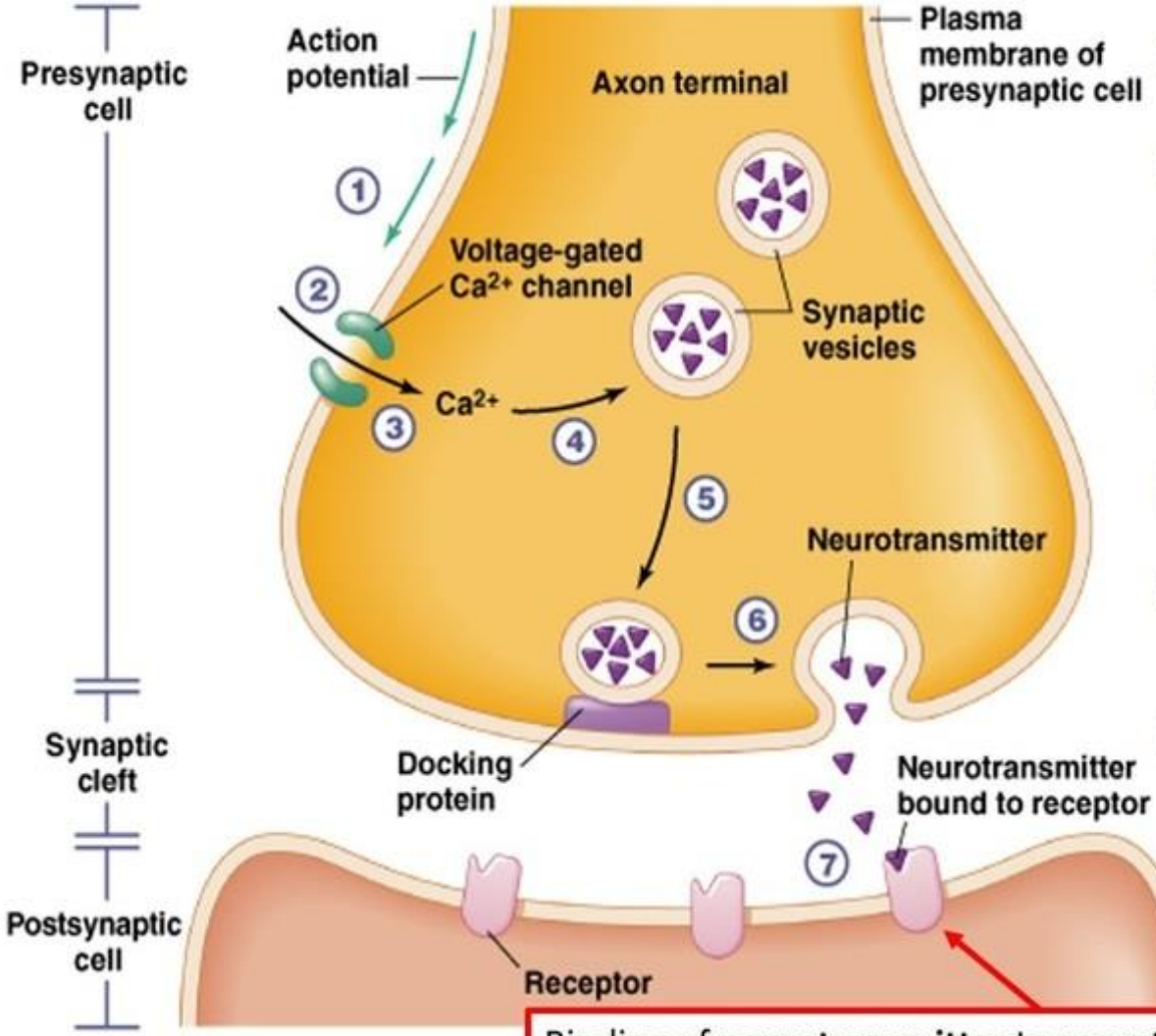
The Neural Synapse

- The junction point between a nerve and any other structure is called a <u>synapse.</u>



- In between the two is a space called the <u>synaptic cleft.</u>
- In the pre-synaptic region - are synaptic vesicles containing <u>neurotransmitter</u> molecules.



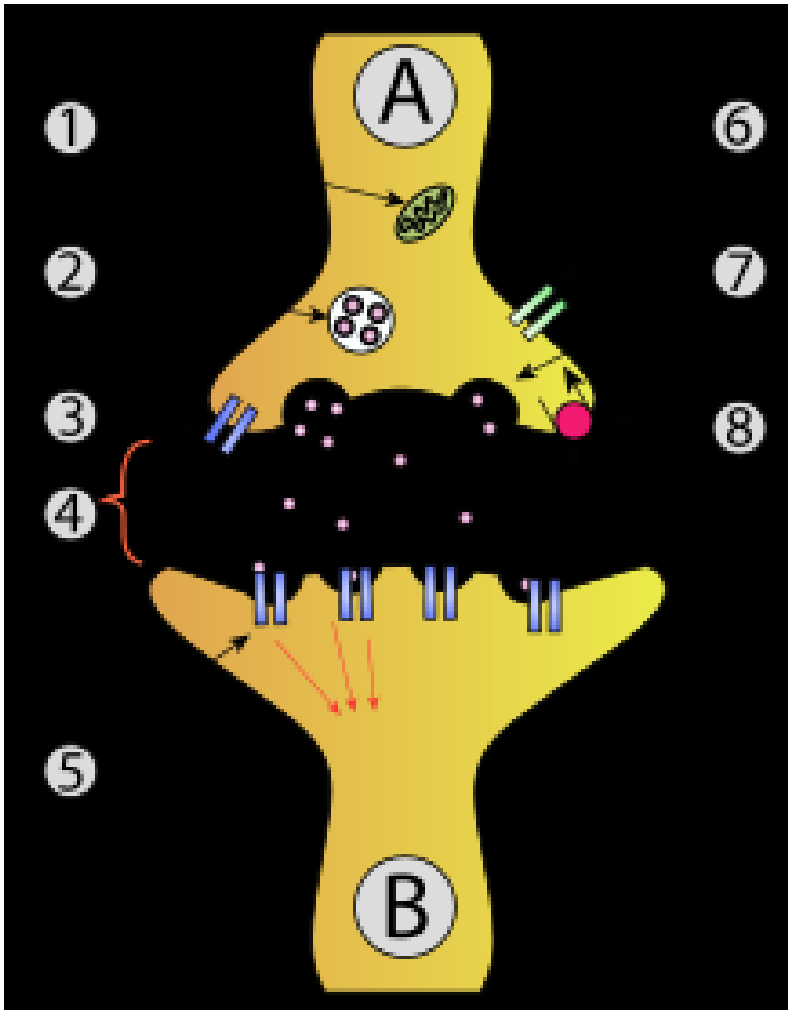


1. Action potentials arrive at axon terminal.
2. Voltage-gated Ca^{2+} channels open.
3. Ca^{2+} enters the cell.
4. Ca^{2+} signals to vesicles.
5. Vesicles move to the membrane.
6. Docked vesicles release neurotransmitter by exocytosis.
7. Neurotransmitter diffuses across the synaptic cleft and binds to receptors.

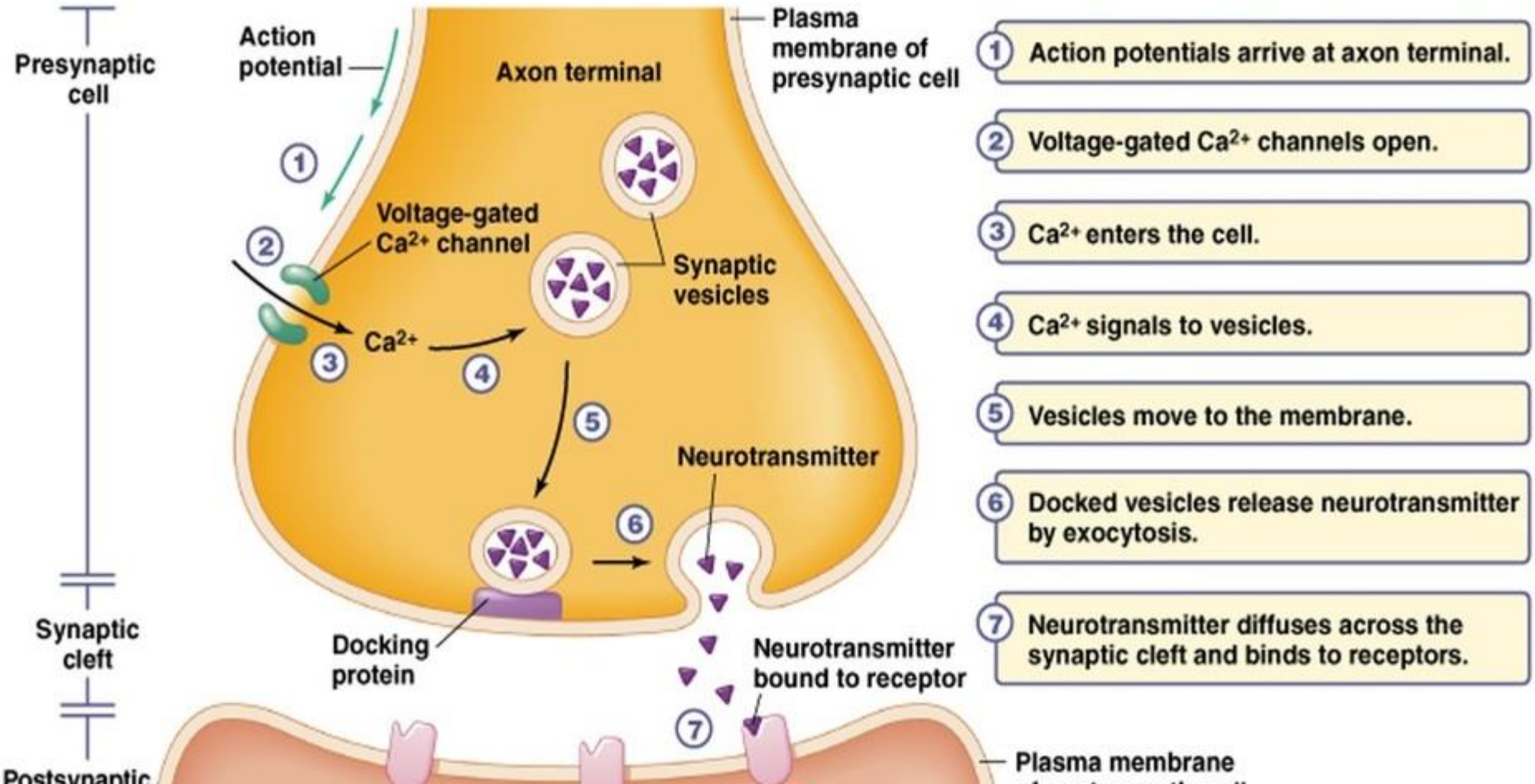
Binding of **neurotransmitter** to **receptor** allows the **"ligand-gated" Na+ ion channel** to **open** in the **post-synaptic membrane** allowing **Na+ ions** to diffuse (by facilitated diffusion) from the **synaptic cleft into** the **post-synaptic bulb.** If enough Na+ ions move into pre-synaptic bulb then another action potential will be activated at the **"axon hillock"**

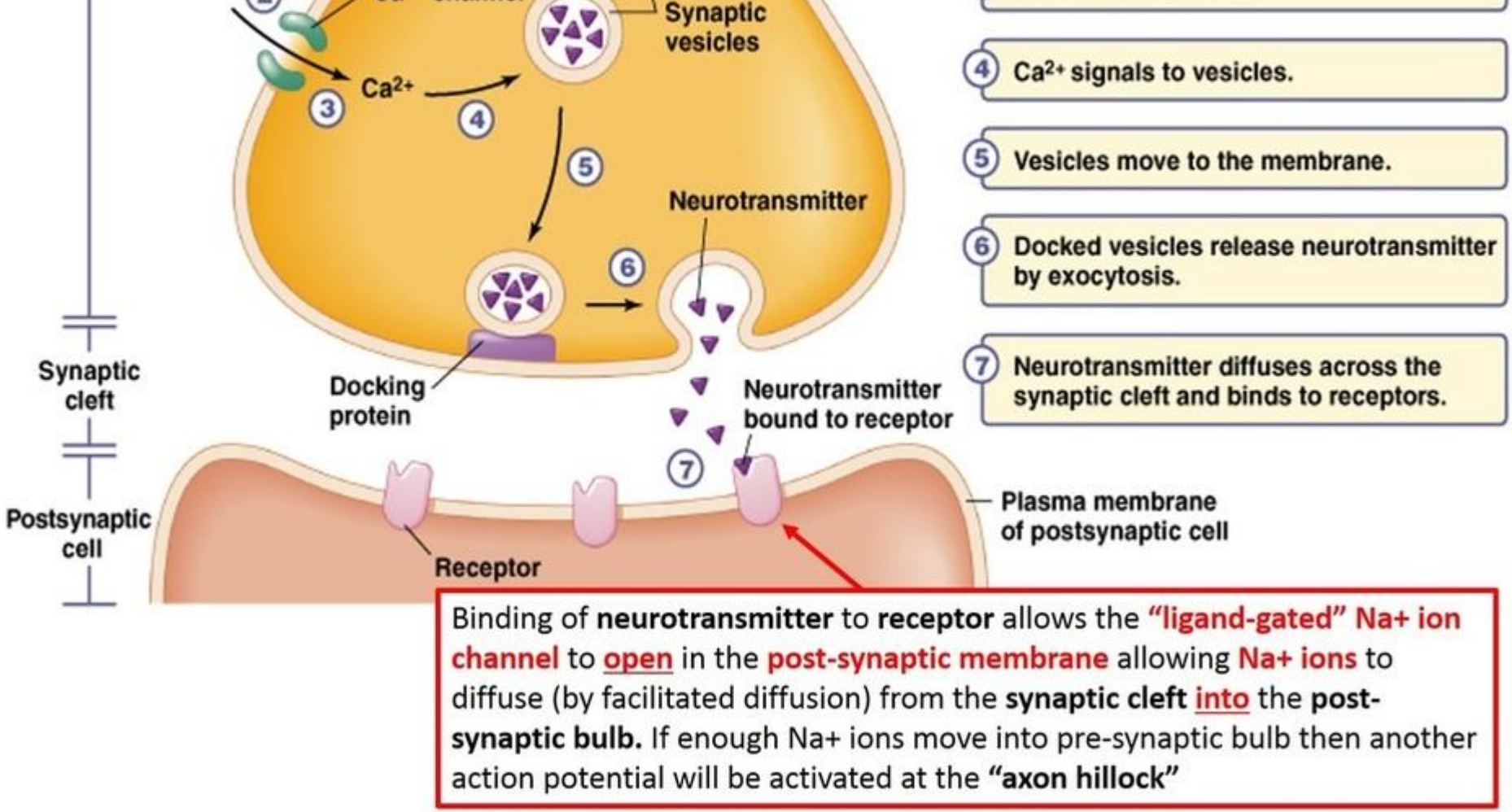
The Neural Synapse

1. When the impulse reaches the synaptic knob, **Ca^{+2}** floods into the knob from the extra cellular environment.
2. This Calcium influx causes the synaptic vesicles to move to the presynaptic membrane and fuse to it.



3. This ruptures the **vesicles** and **neurotransmitter** floods into the **synaptic cleft.**





4. The neurotransmitter diffuses across the cleft and **binds to receptor proteins** on the post synaptic membrane.

5. This opens the sodium gates that allows **sodium to flood in**, initiating the nerve impulse in the second cell.

6. Enzymes quickly break down the attached neurotransmitter to end the transfer.

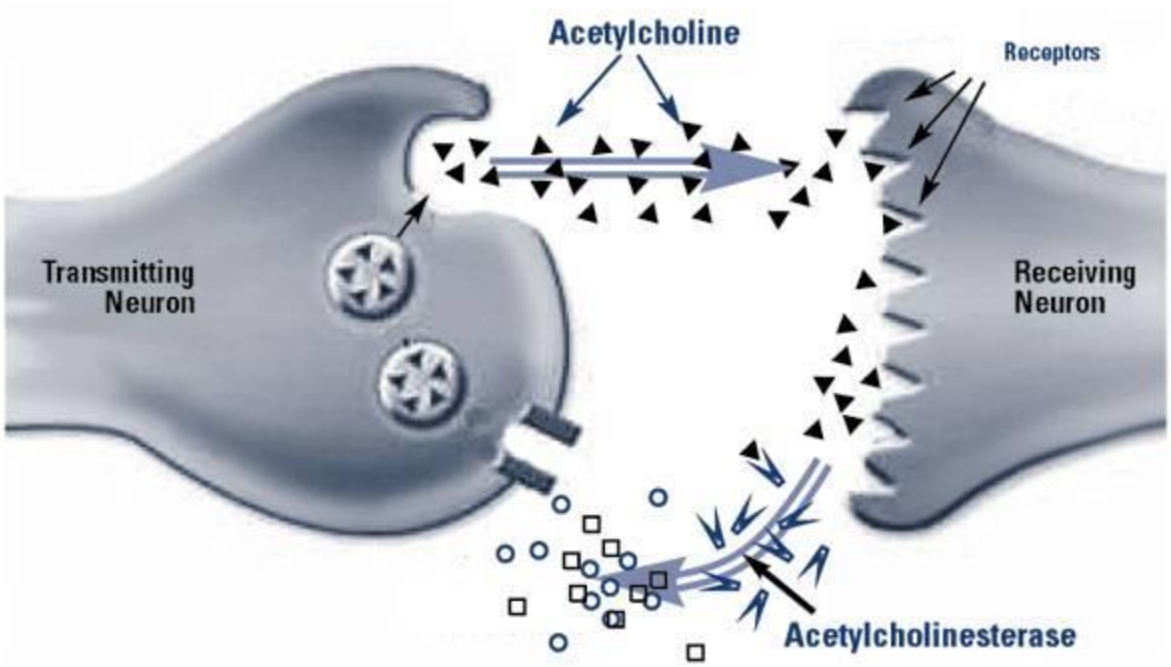


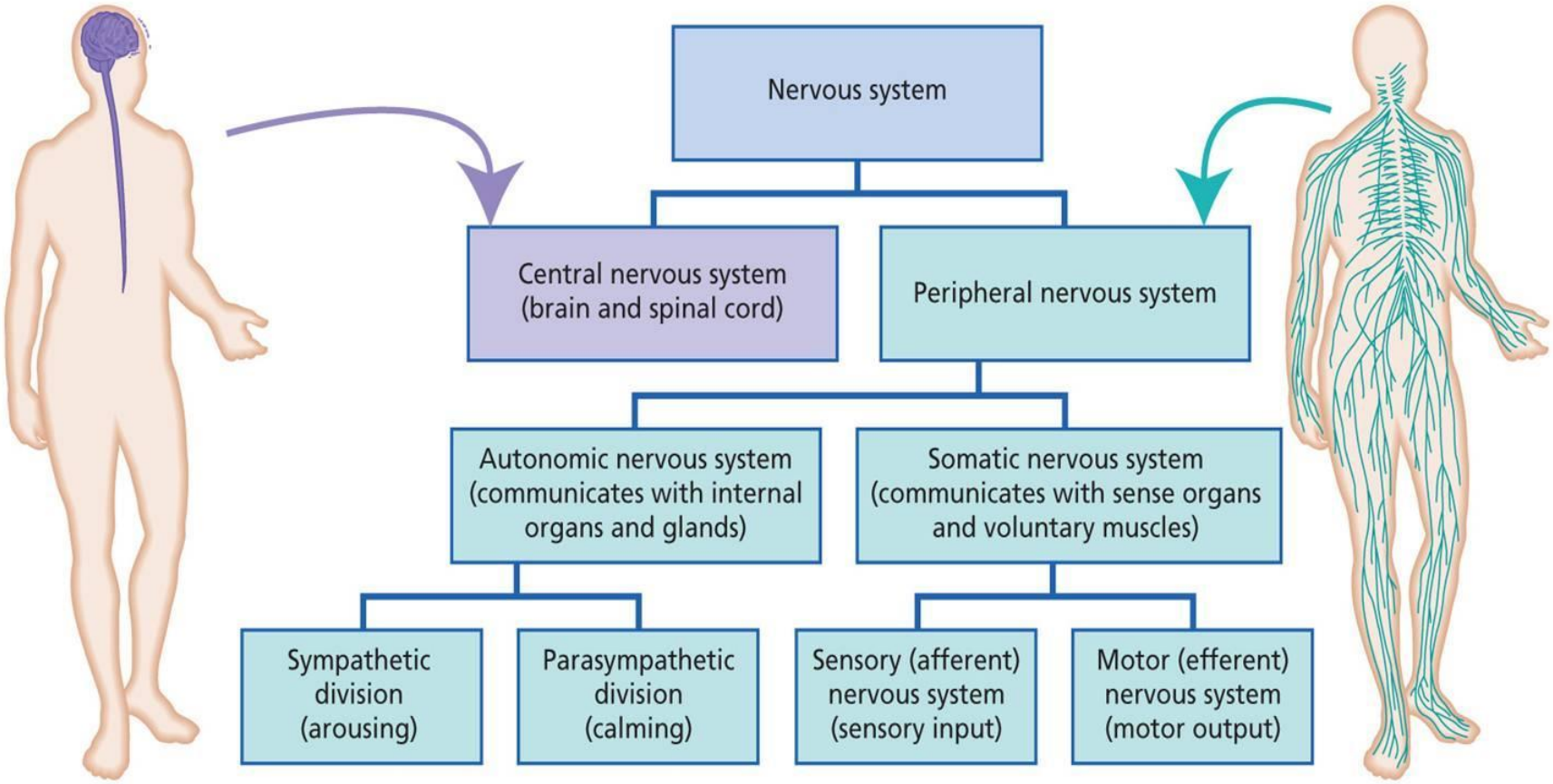
Fig. 1. After signalling, acetylcholine is released from receptors and broken down by acetylcholinesterase to be recycled in a continuous process.

The Neural transmitter

1. **Acetylcholine**: most common type - used in brain and in transmission to muscles.
2. **Norepinephrine** (noradrenaline):

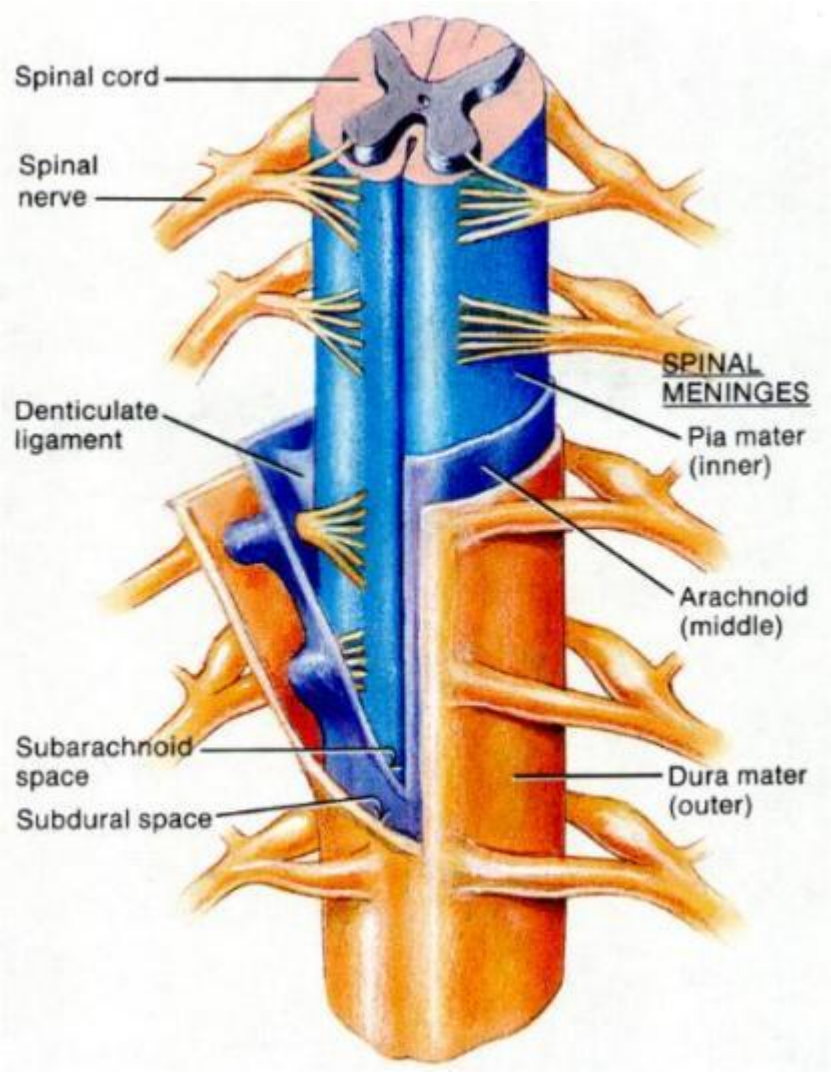
- Used in Sympathetic branch of Autonomic nervous system

Organization of the NERVOUS SYSTEM



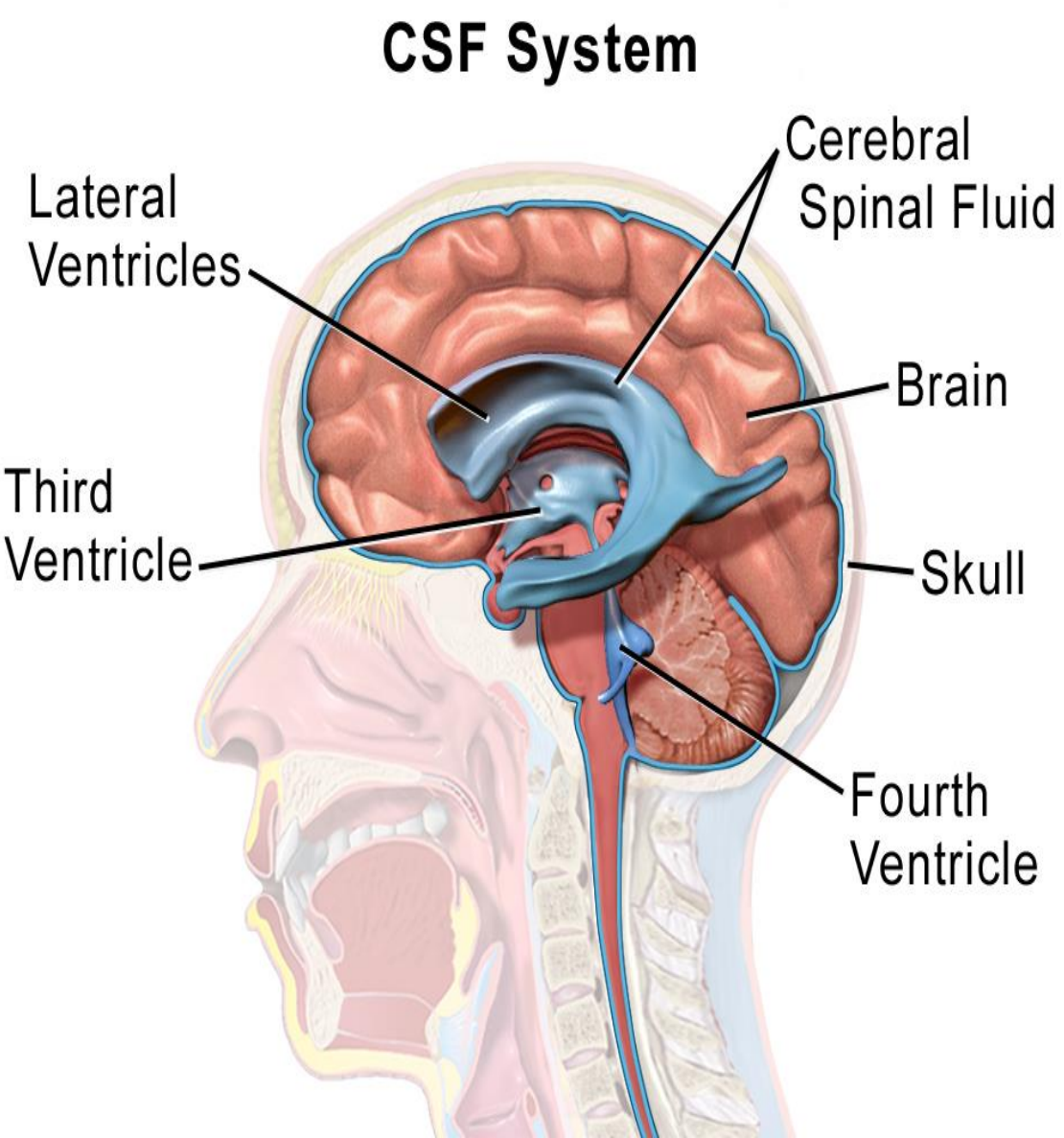
17.2- The Central Nervous System (CNS)

- **Function:** sensory information received and motor control initiated
- Consists of : **spinal cord** & **brain**
  - Both are protected by bone and **meninges** (protective membrane)



17.2- The Central Nervous System (CNS)

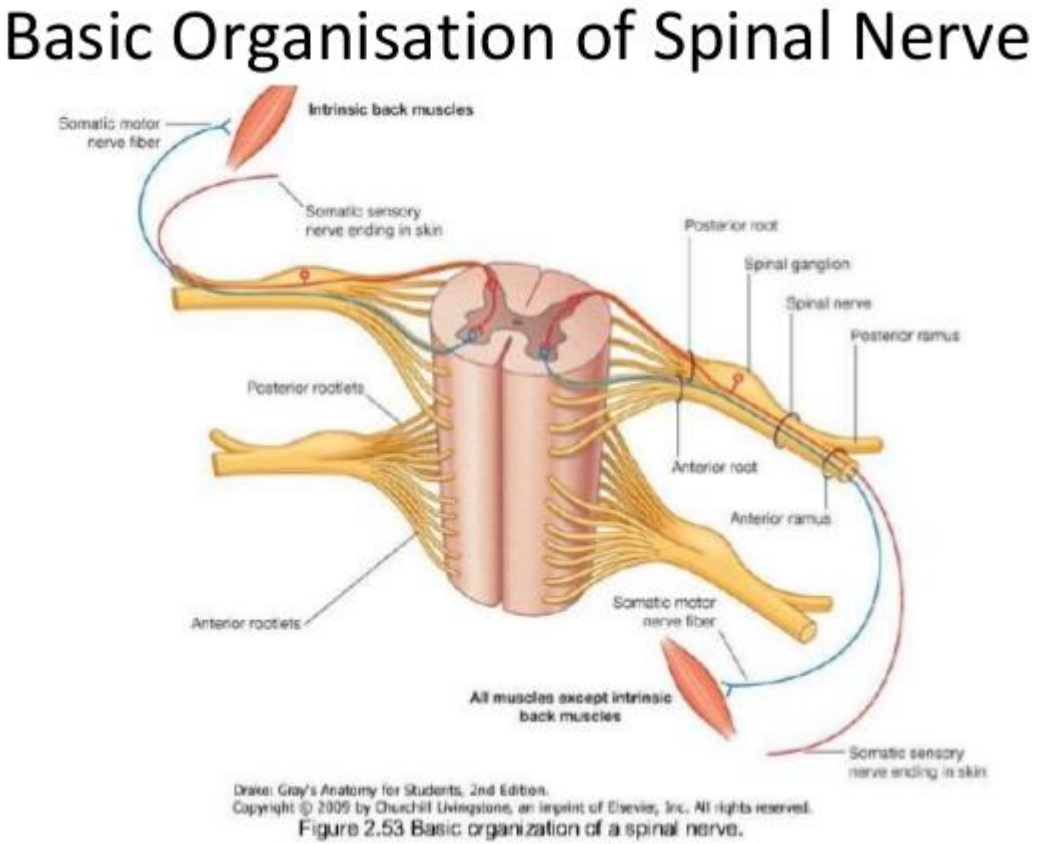
- **Cerebral Spinal Fluid** (CSF) = fills the space between the meninges → functions to cushion and protect



1. Spinal Cord (CNS)

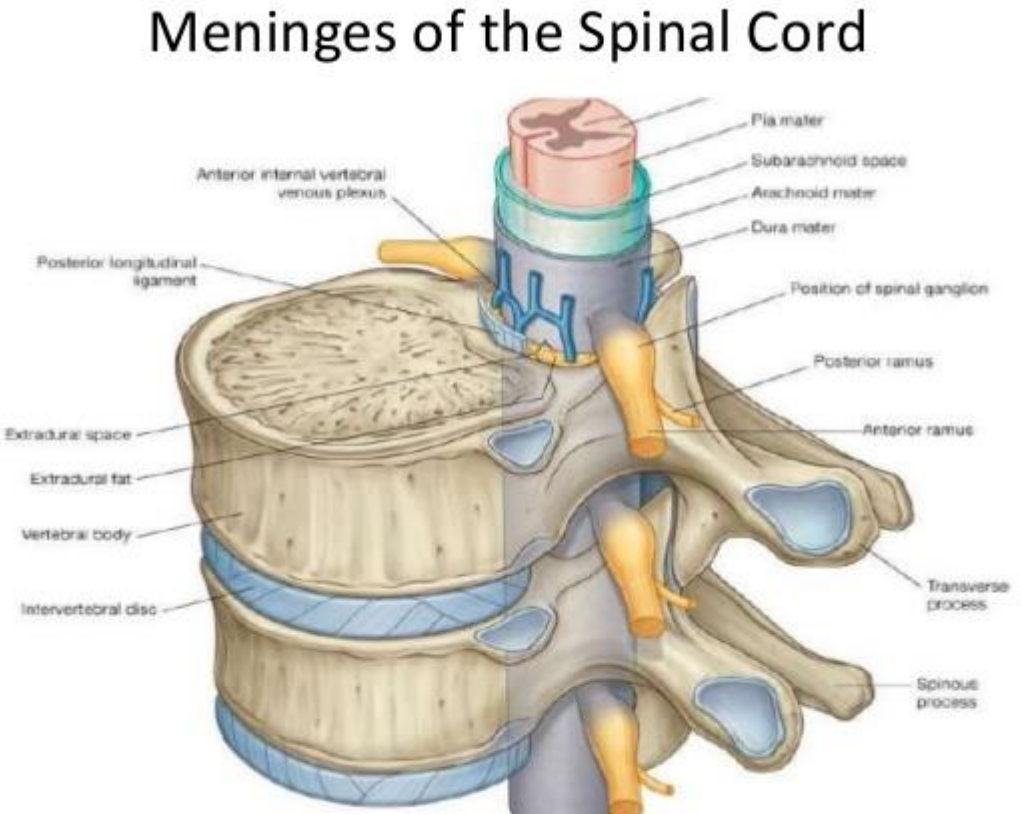
Function:

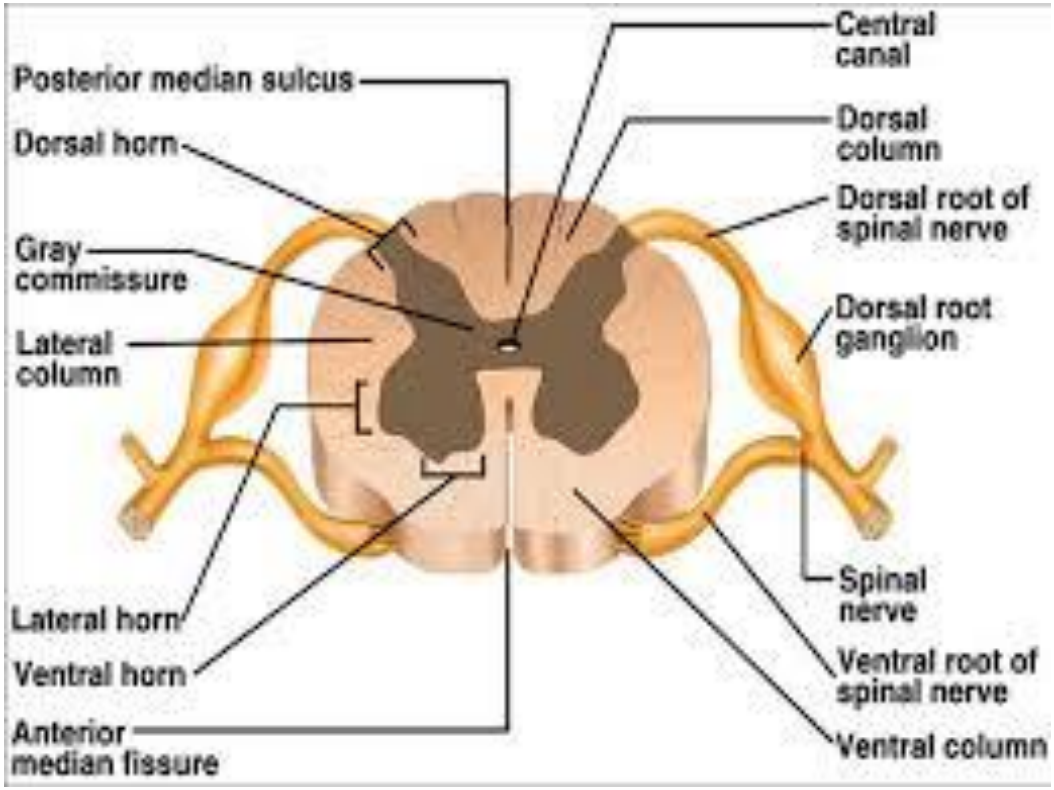
- Provides communication between brain and peripheral nerves
- Center for thousands of reflex arcs



1. Spinal Cord (CNS)

- **Has – between the vertebrates –Intervertebral disks**= fluid filled cushions that separates the vertebrae

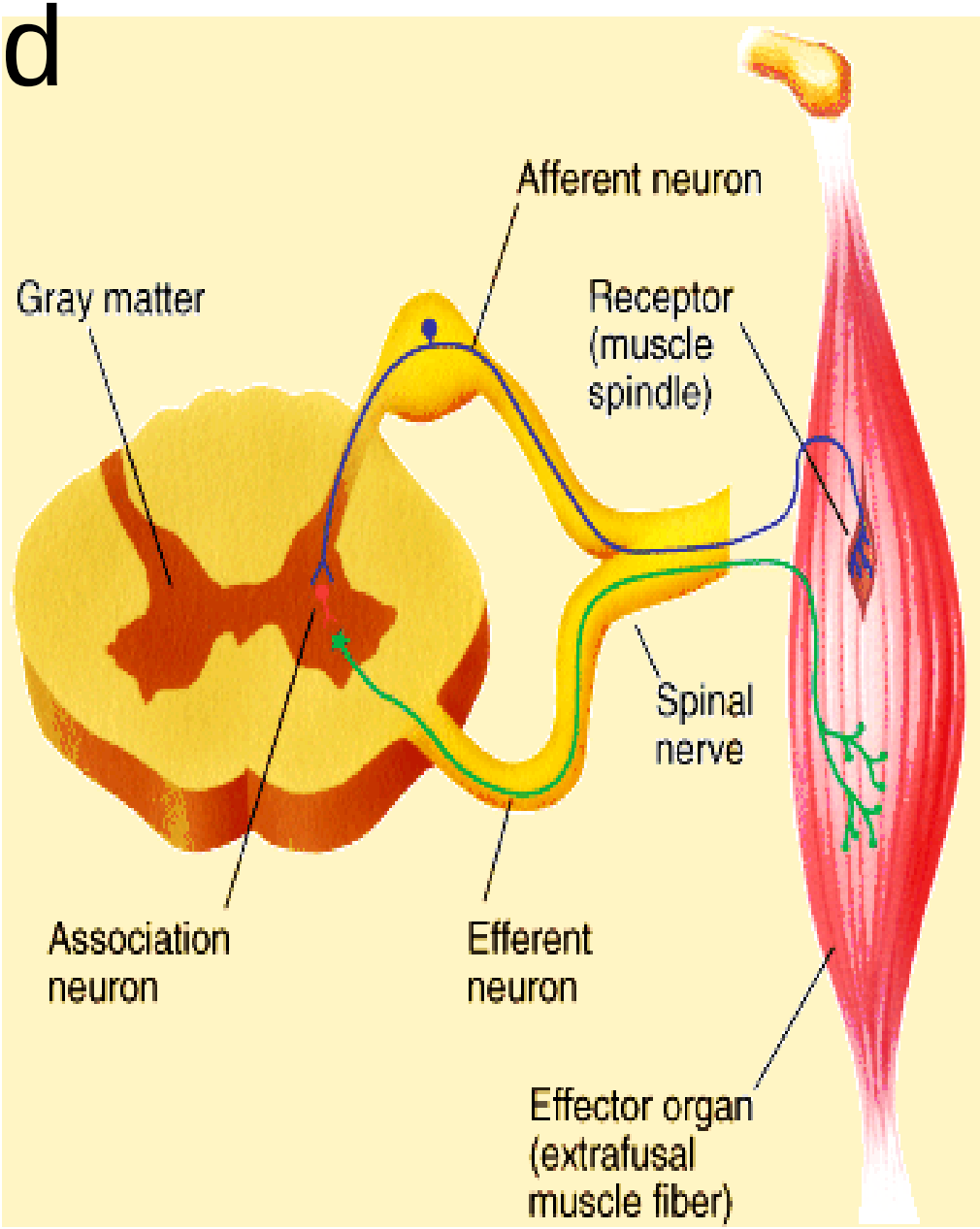



Posterior median sulcus
Dorsal horn
Gray commissure
Lateral column
Lateral horn
Ventral horn
Anterior median fissure
Central canal
Dorsal column
Dorsal root of spinal nerve
Dorsal root ganglion
Spinal nerve
Ventral root of spinal nerve
Ventral column

The Spinal Cord

The Reflex Arc:

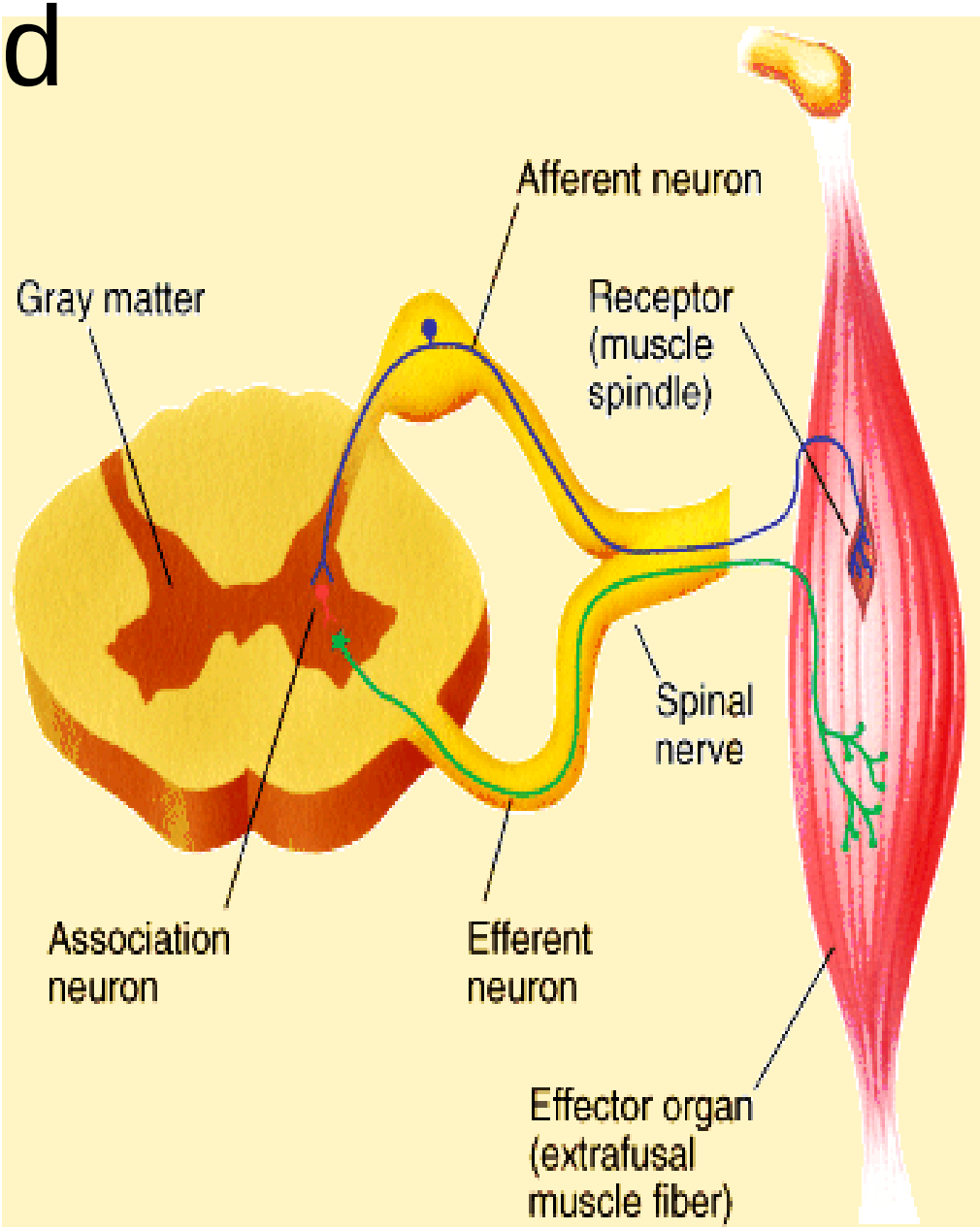
- Used to respond to emergencies.
- Three types of neurons involved:



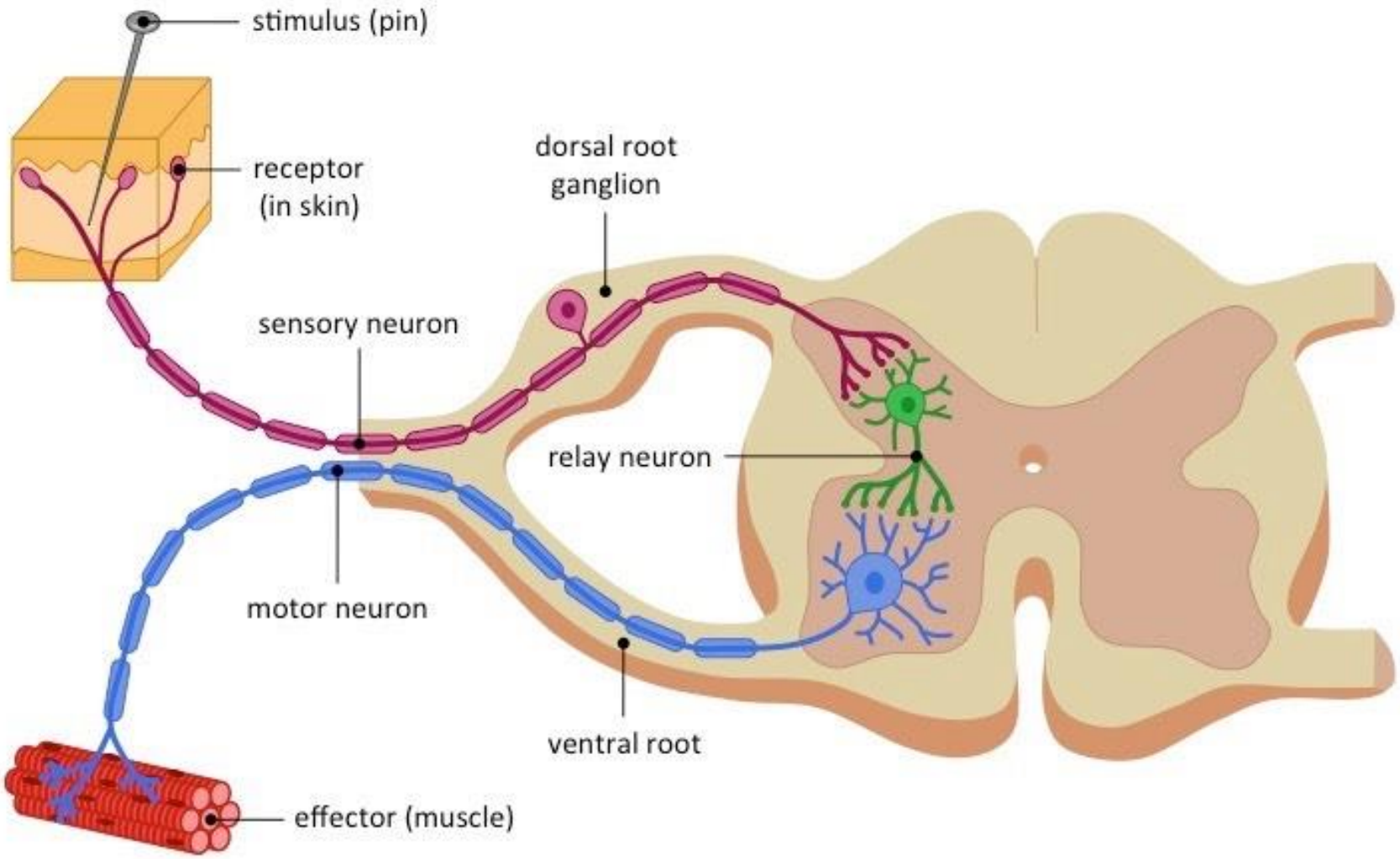
The Spinal Cord

The Reflex Arc:

1. **Sensory neurons**: from sensory receptor to spinal cord.



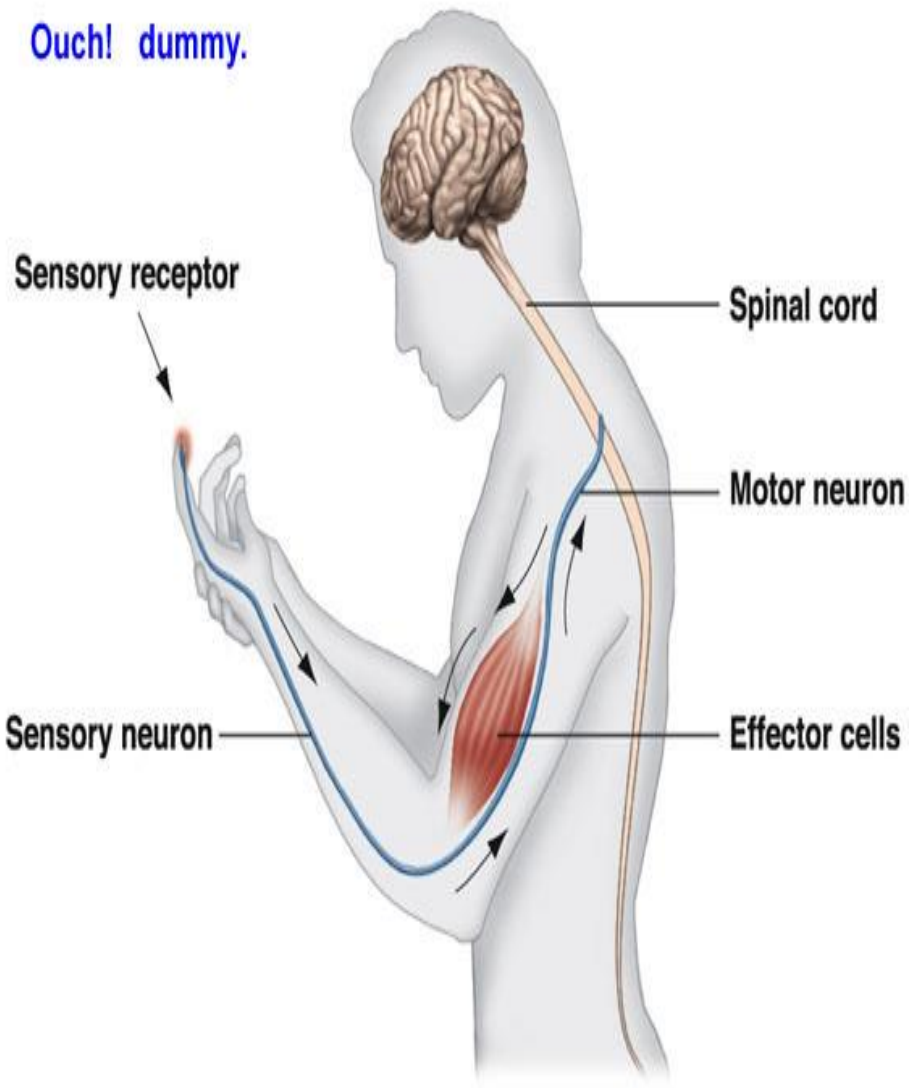
Reflex Arc

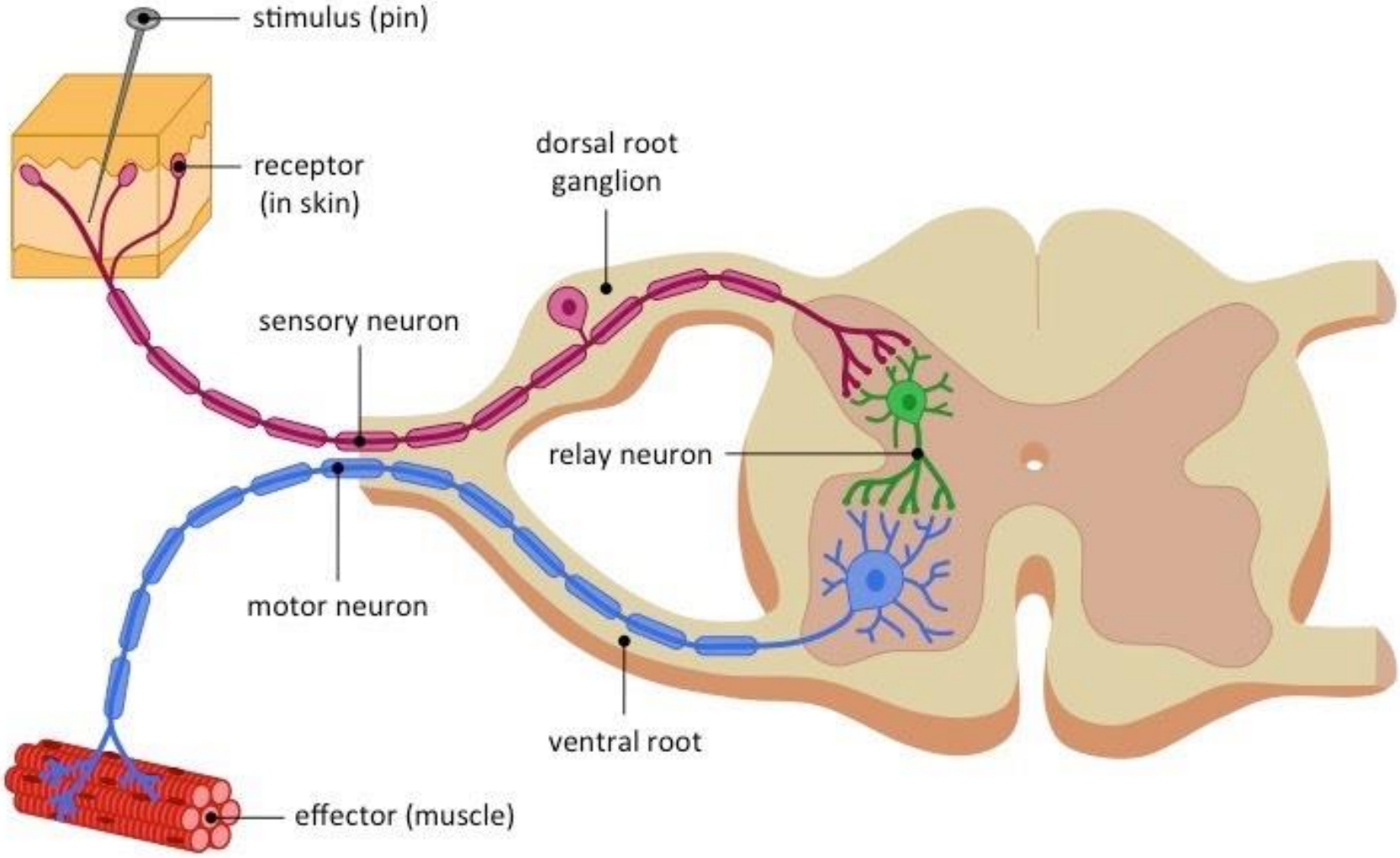

stimulus (pin)
receptor
(in skin)
dorsal root
ganglion
sensory neuron
relay neuron
motor neuron
ventral root
effector (muscle)

2. **Motor neurons**: connect spinal cord to muscles.

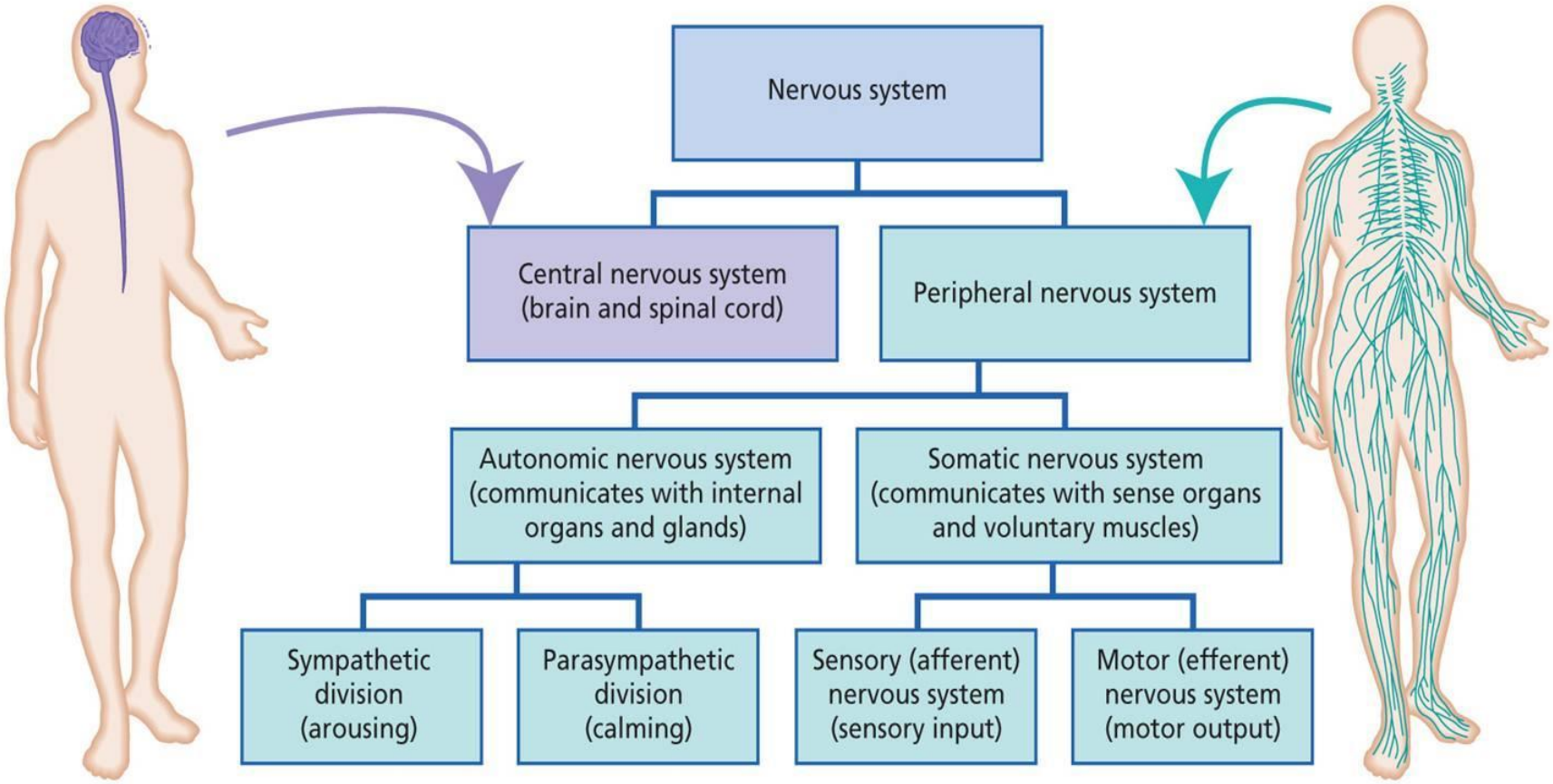
3. **Interneurons**: inside spinal cord, connect sensory neuron to motor neuron.

- Used as brain bypass when response is obvious.

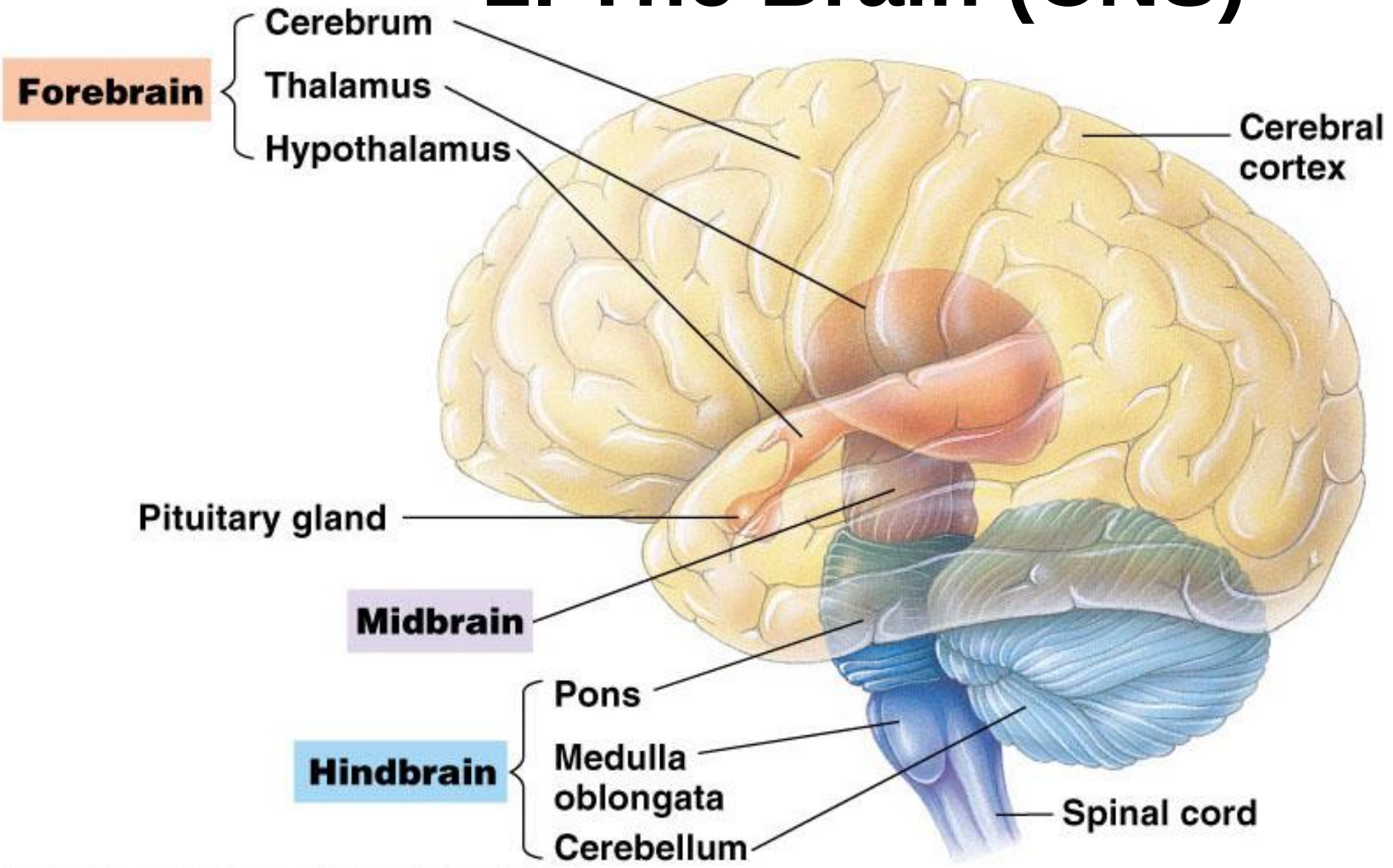



stimulus (pin)
receptor
(in skin)
dorsal root
ganglion
sensory neuron
relay neuron
motor neuron
ventral root
effector (muscle)

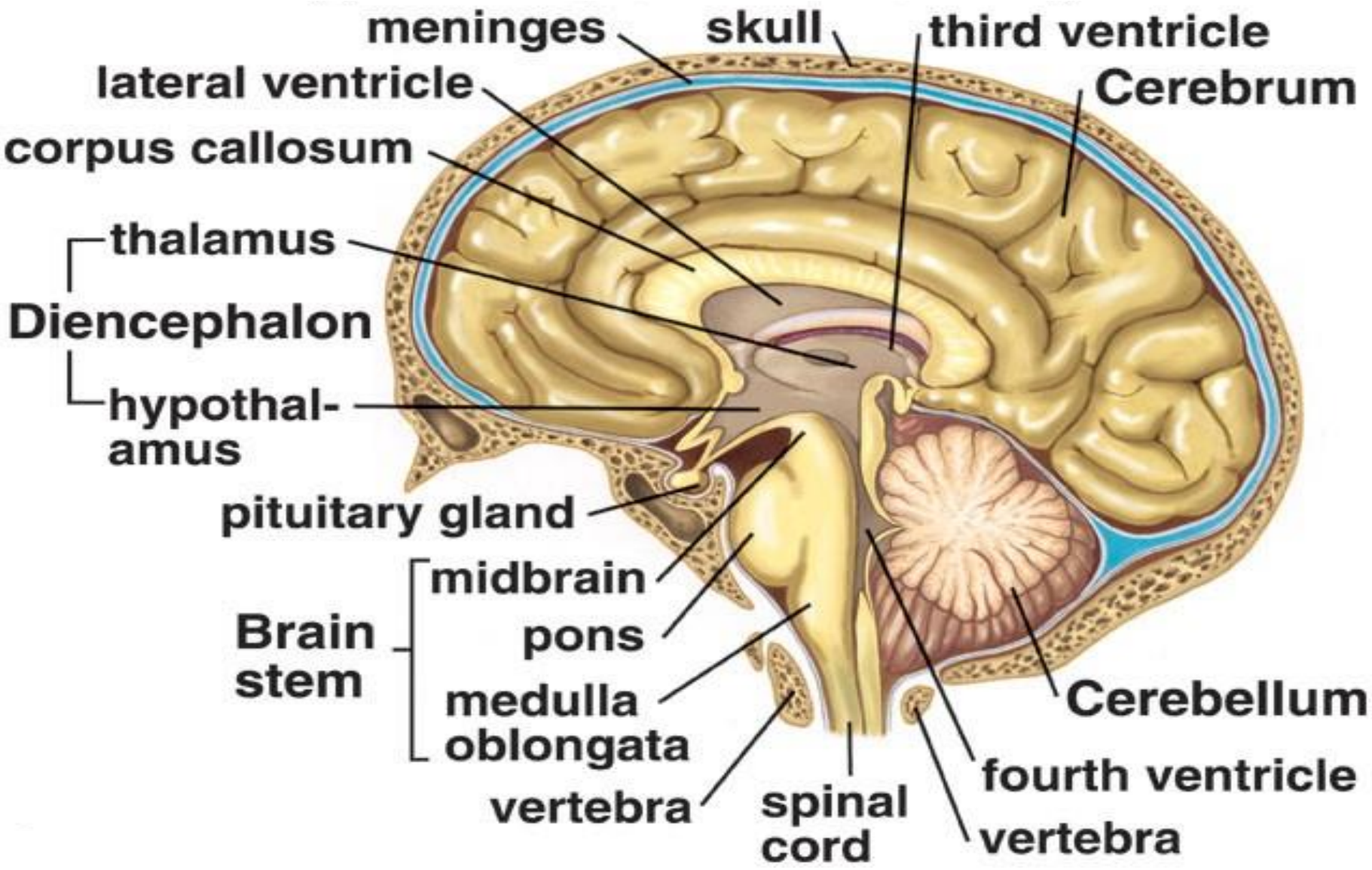
Organization of the NERVOUS SYSTEM



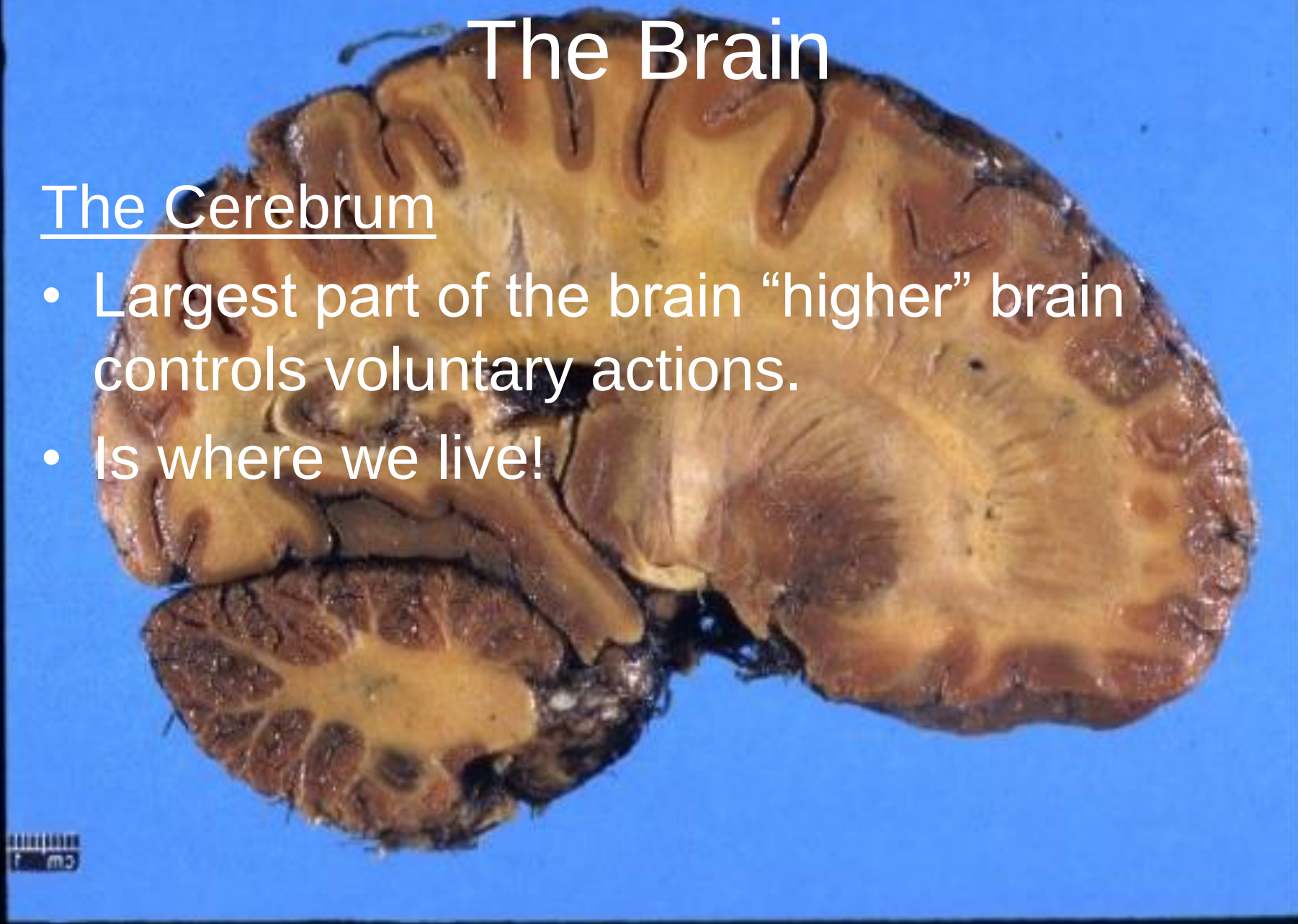
2. The Brain (CNS)



The Brain


meninges
skull
third ventricle
lateral ventricle
Cerebrum
corpus callosum
thalamus
Diencephalon
hypothal-
amus
pituitary gland
midbrain
Brain
stem
pons
medulla
oblongata
Cerebellum
fourth ventricle
vertebra
spinal
cord
vertebra

The Brain

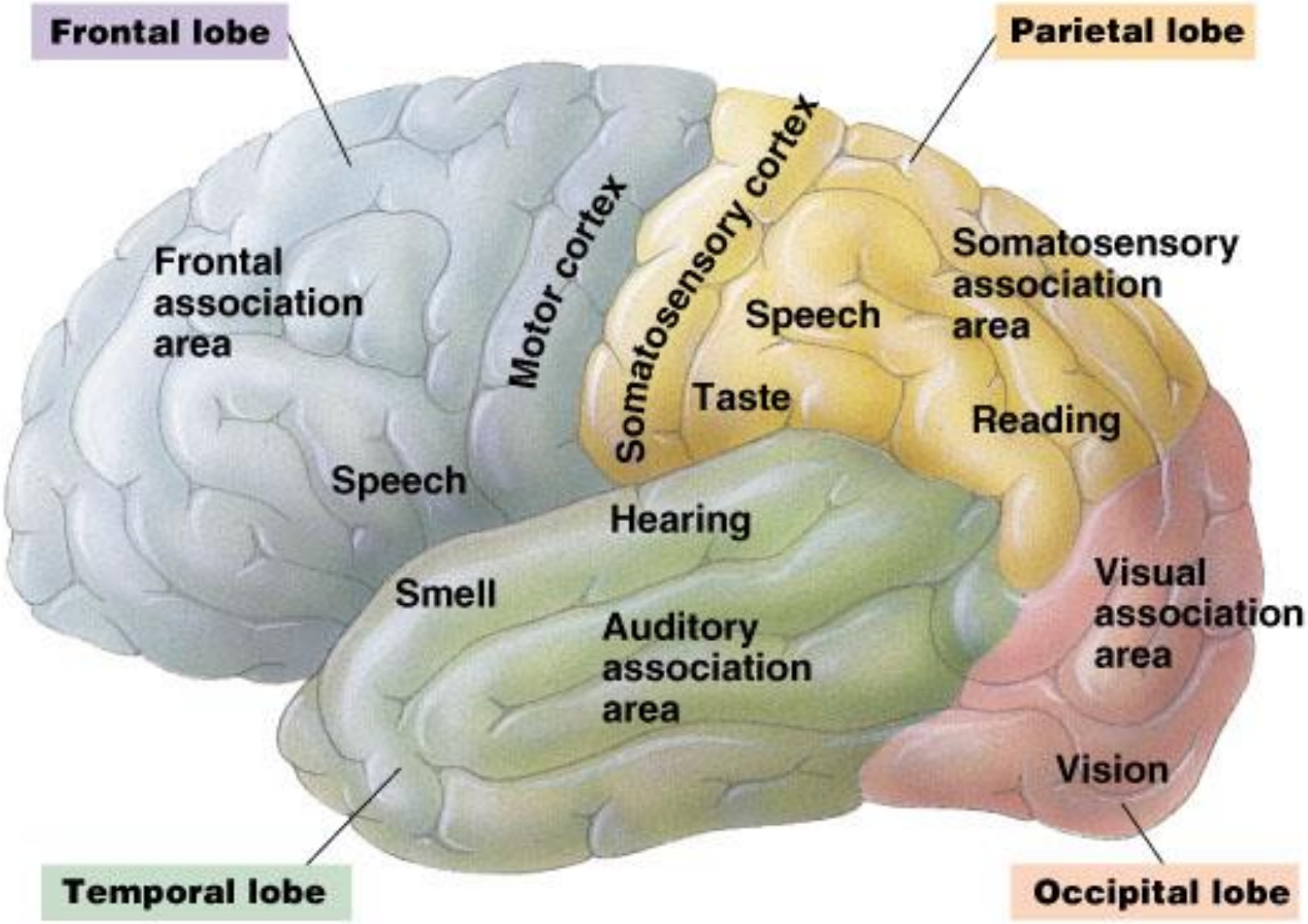


The Cerebrum

- Largest part of the brain “higher” brain controls voluntary actions.
- Is where we live!

Lobes of the Cerebrum (not examinable):

1. **Frontal Lobe:** motor area, concentration, planning, judgment, problem solving.
2. **Parietal Lobe:** Sensory for touch and taste, speech and language centers.
3. **Temporal Lobe:** Sensory for hearing and smell, memory and sensory interpretation.
4. **Occipital Lobe:** Vision and integration of vision with other senses.

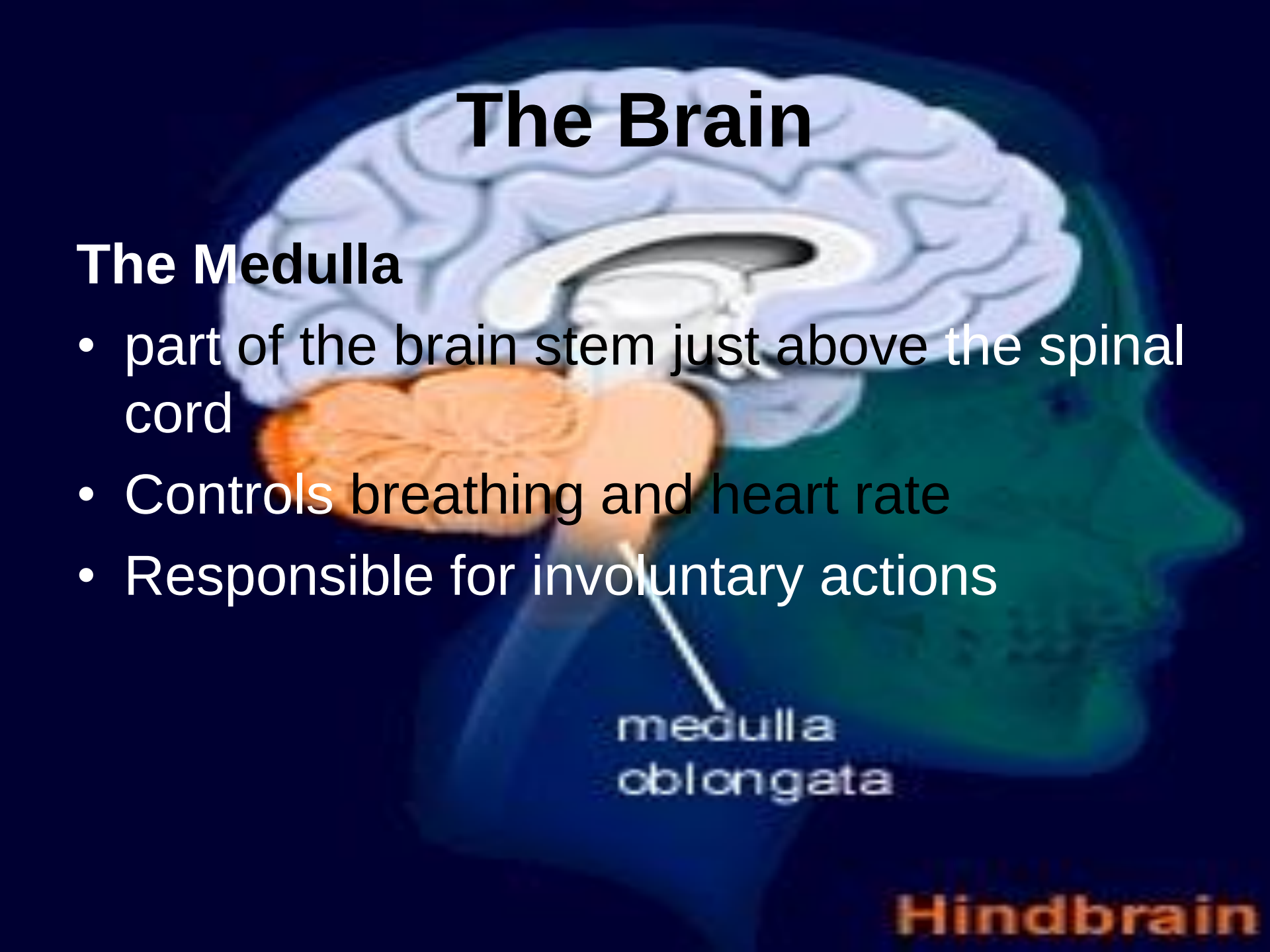


(b) Left side of brain

The Brain

The Medulla

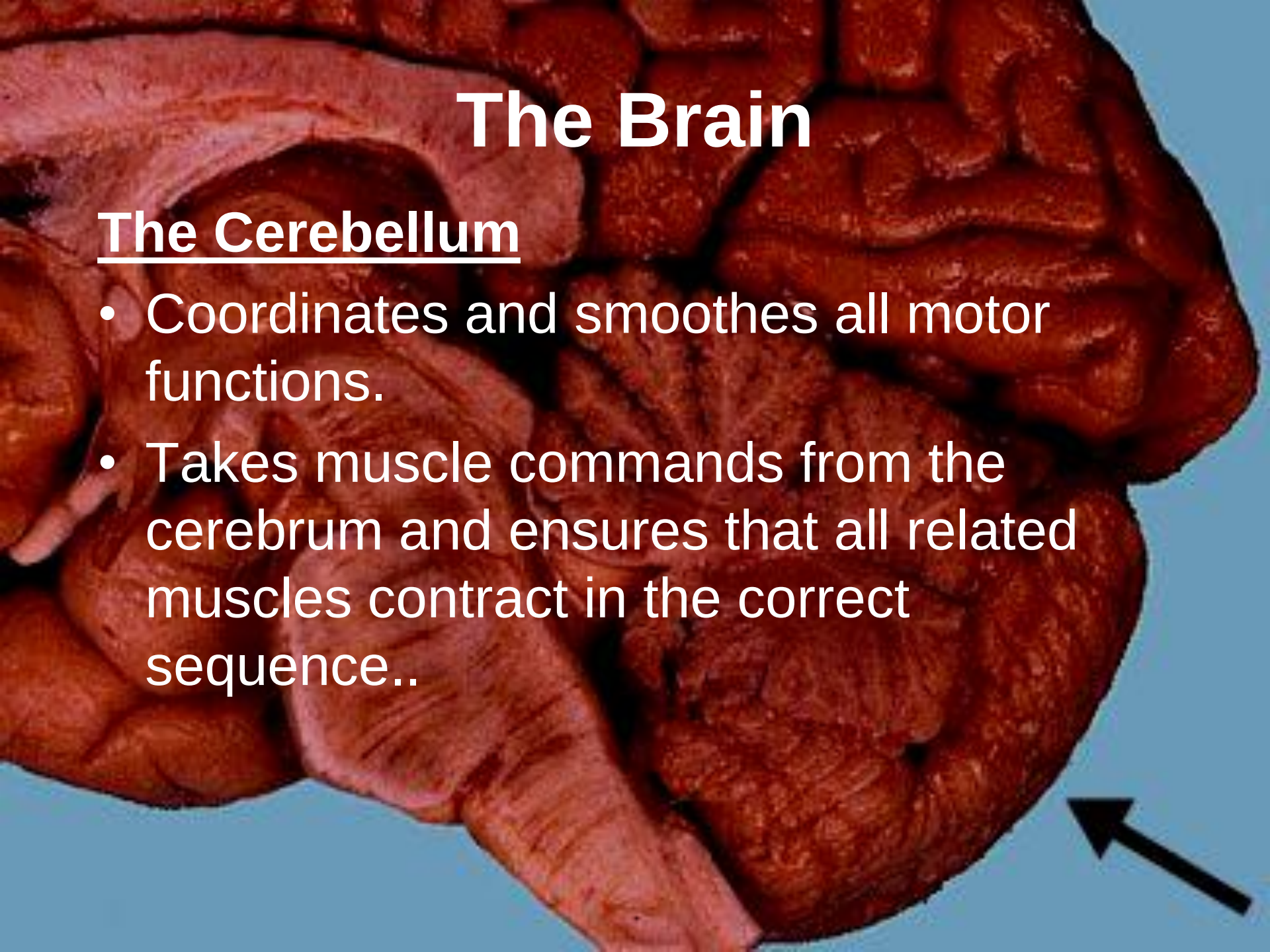
- part of the brain stem just above the spinal cord
- Controls breathing and heart rate
- Responsible for involuntary actions



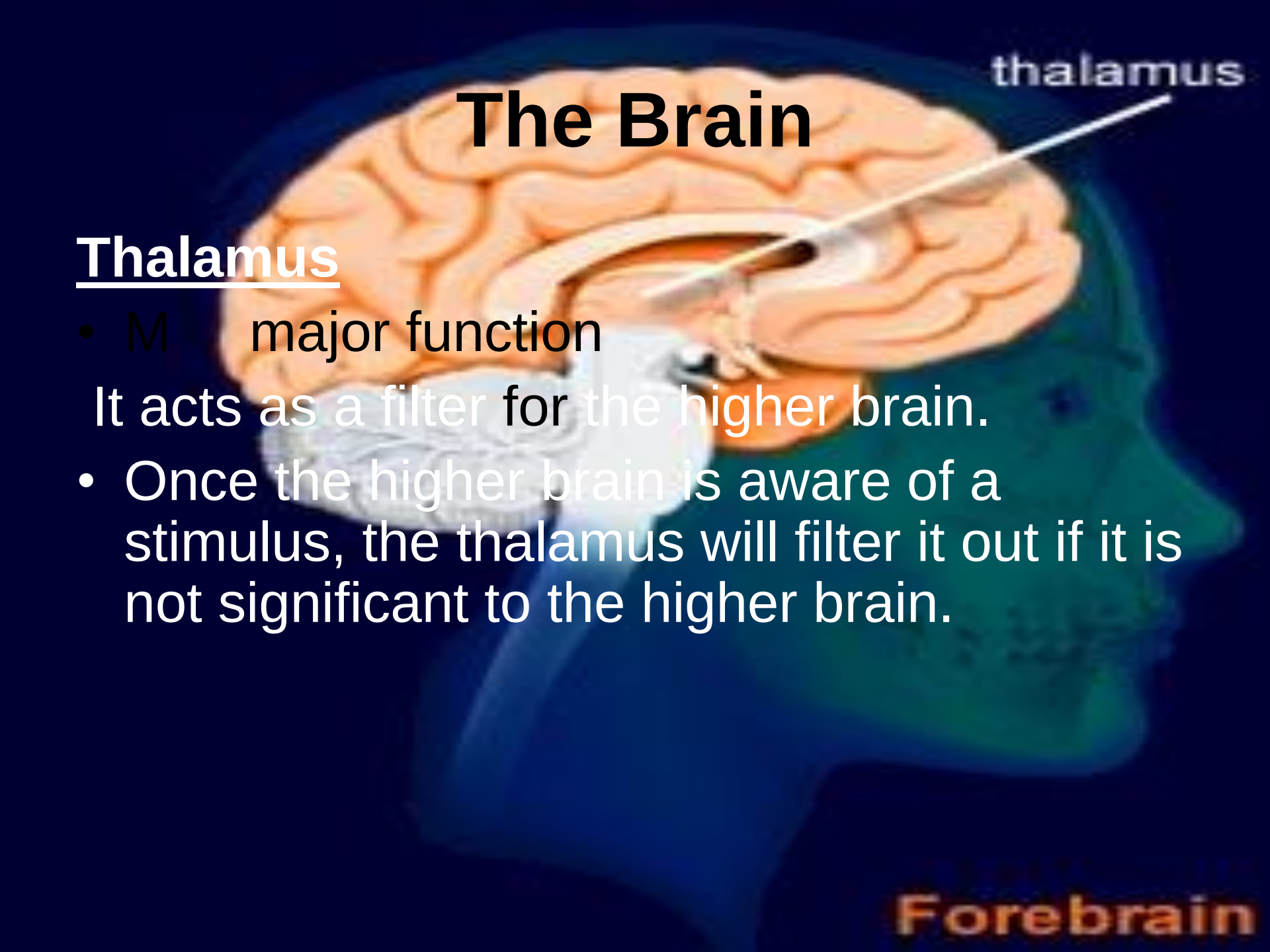
The Brain

The Cerebellum

- Coordinates and smoothes all motor functions.
- Takes muscle commands from the cerebrum and ensures that all related muscles contract in the correct sequence..



The Brain



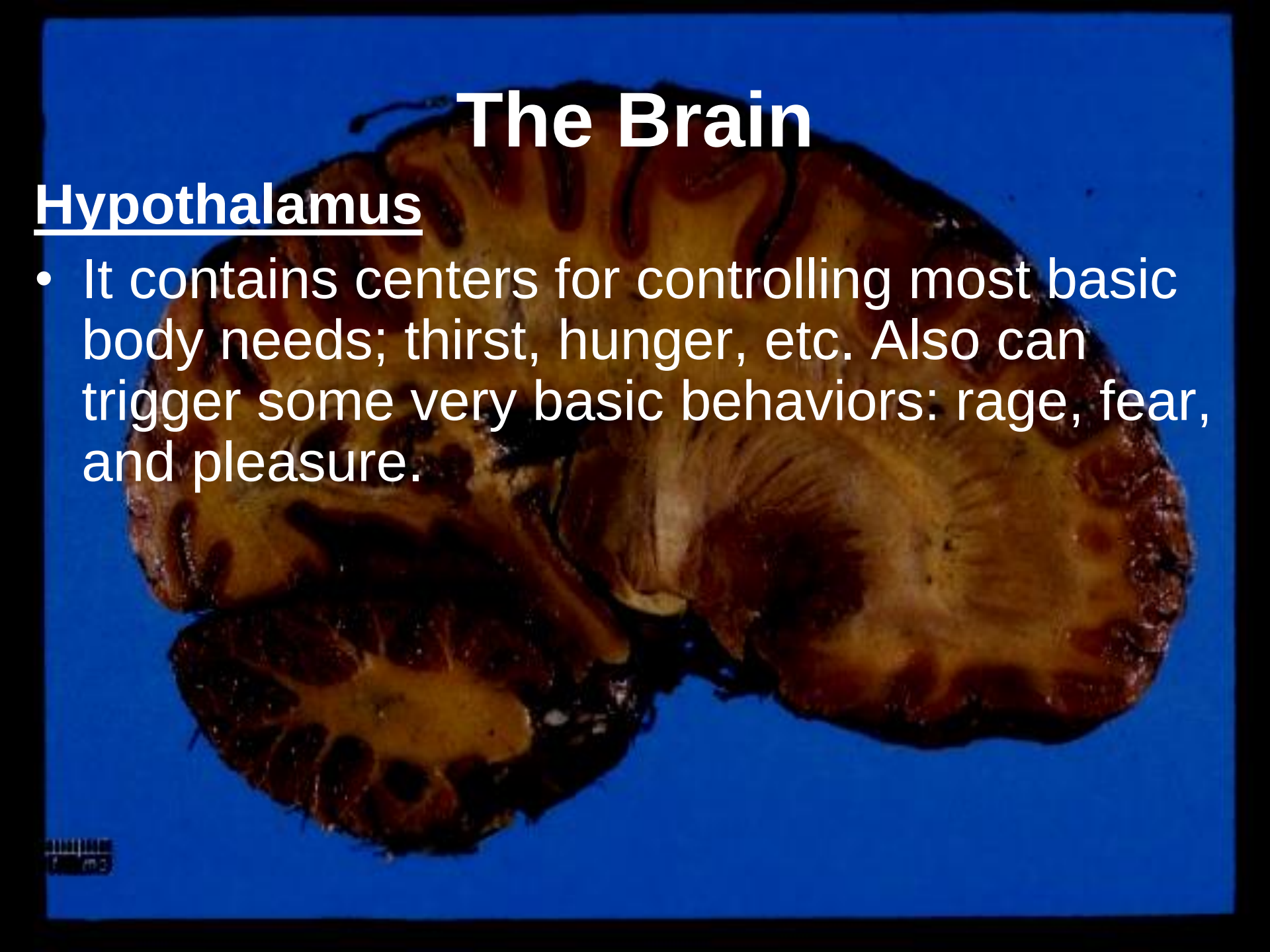
Thalamus

- M major function

It acts as a filter for the higher brain.

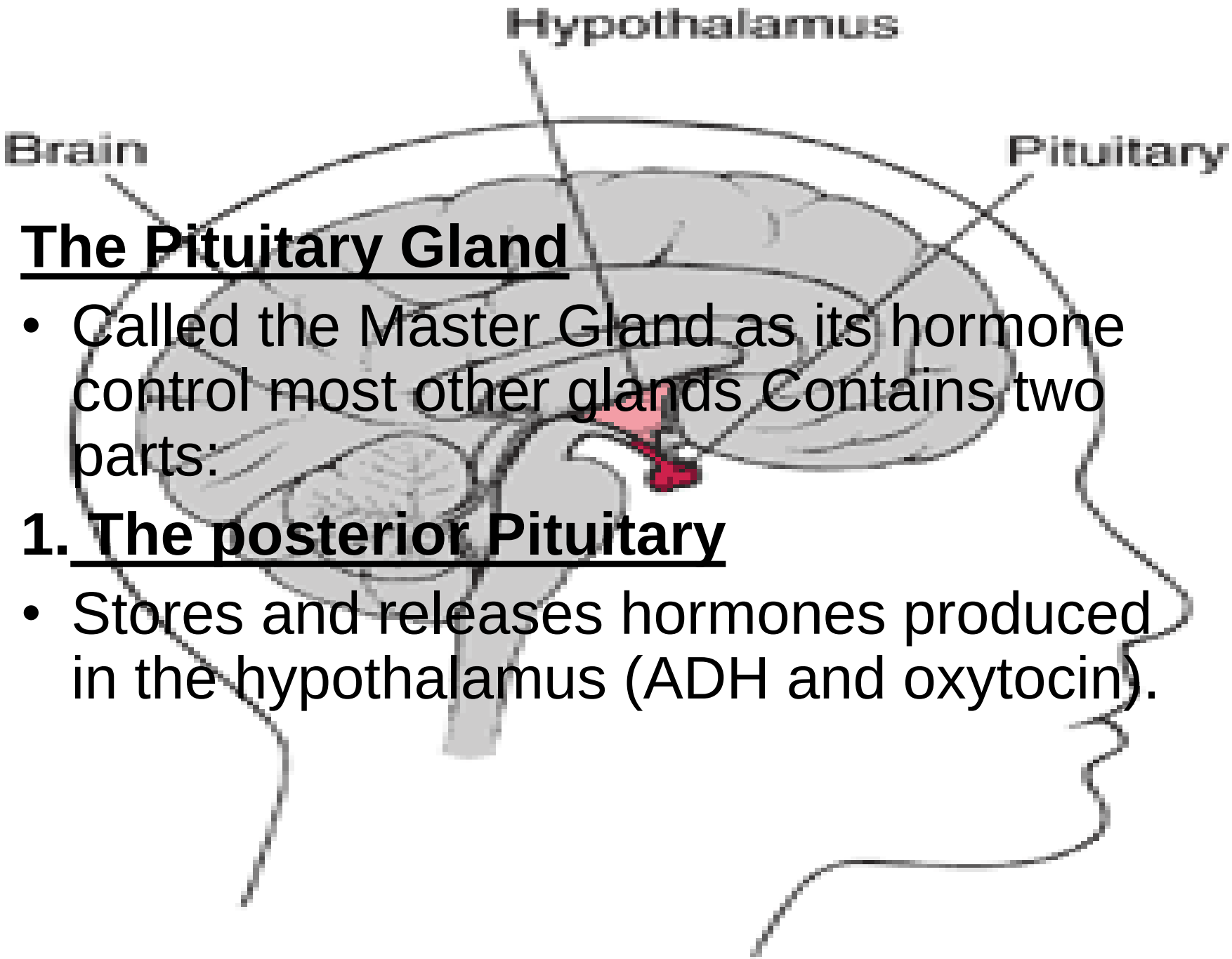
- Once the higher brain is aware of a stimulus, the thalamus will filter it out if it is not significant to the higher brain.

The Brain



Hypothalamus

- It contains centers for controlling most basic body needs; thirst, hunger, etc. Also can trigger some very basic behaviors: rage, fear, and pleasure.



The Pituitary Gland

- Called the Master Gland as its hormone control most other glands Contains two parts:

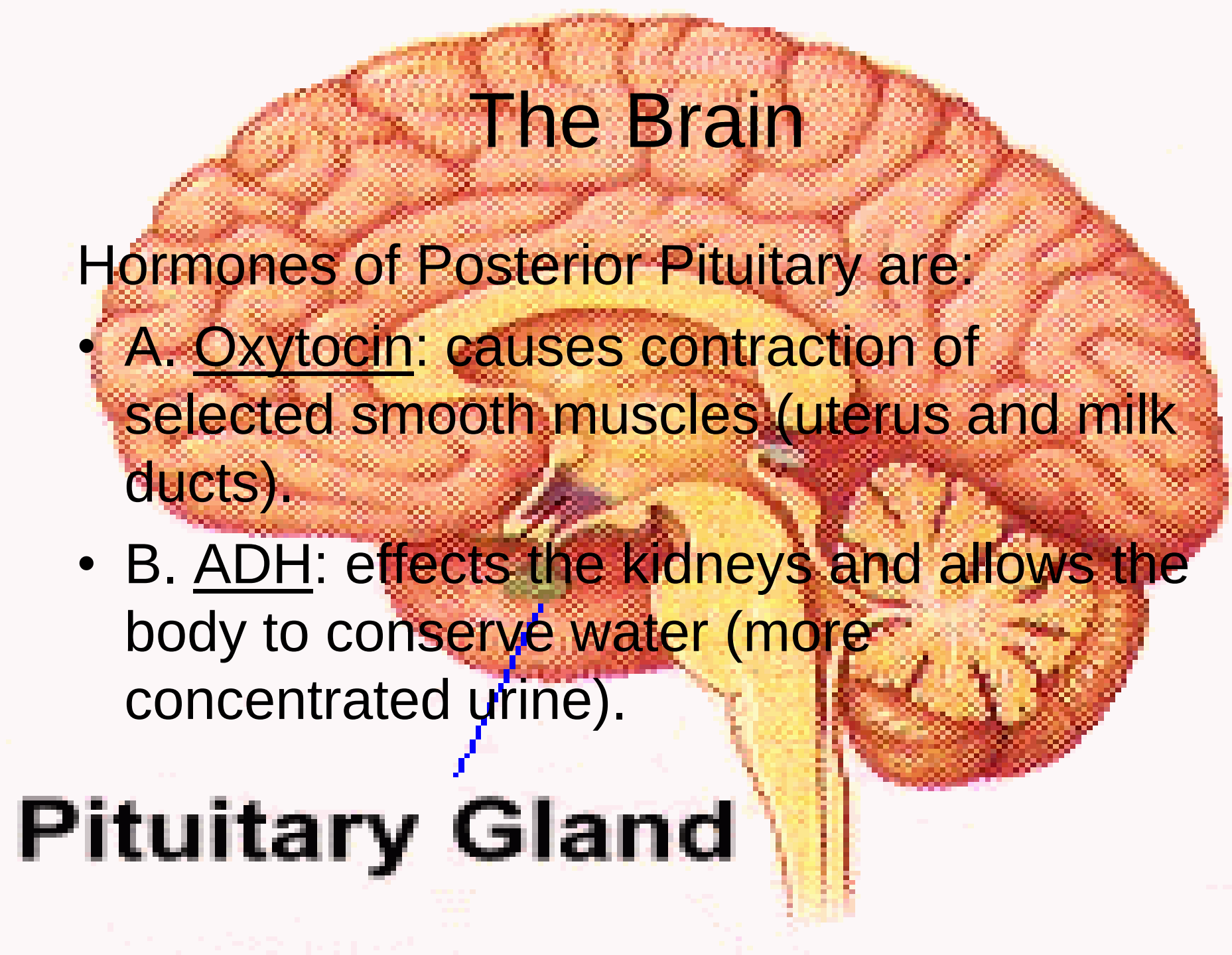
1. The posterior Pituitary

- Stores and releases hormones produced in the hypothalamus (ADH and oxytocin).

The Brain

Hormones of Posterior Pituitary are:

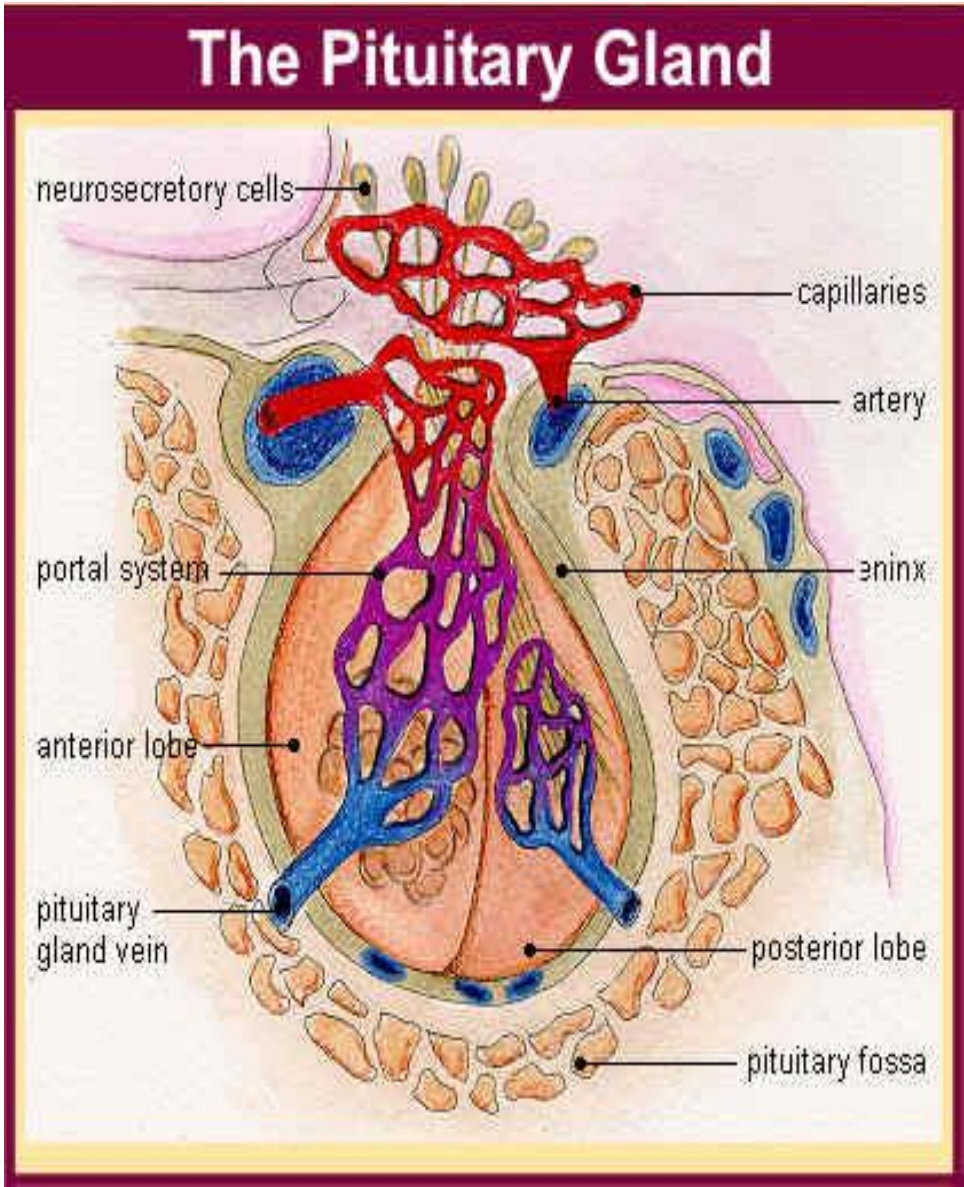
- A. Oxytocin: causes contraction of selected smooth muscles (uterus and milk ducts).
- B. ADH: effects the kidneys and allows the body to conserve water (more concentrated urine).



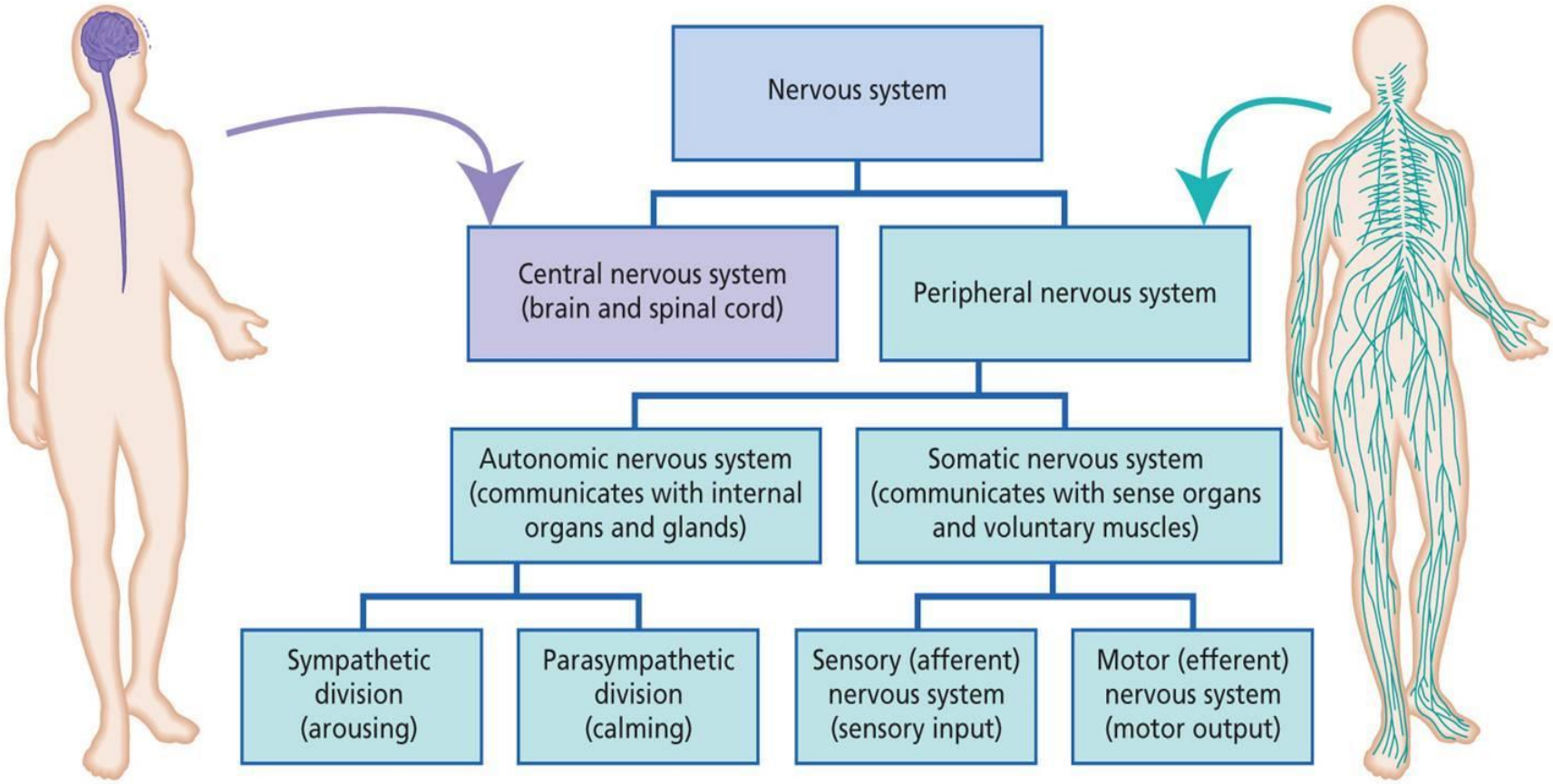
The Brain

2. The Anterior Pituitary

- Makes and releases its own hormones.
- Releases them upon stimulation from hypothalamus
- Hormones include: Growth hormones, TSH (thyroid stimulating hormone), FSH and LH (reproductive), and ACTH (stimulates release of cortisol – the stress hormone).



Organization of the NERVOUS SYSTEM



A) Peripheral Nerves- Somatic Nervous System

- Serves the skin, skeletal muscles, and tendons
- Includes nerves that:
  - Take **sensory info** from external sensory receptors **to** CNS
  - Take **motor commands away** from CNS to skeletal muscles
- Some actions due to **reflexes** (automatic response to stimulus)
- Other actions are **voluntary** (originate in cerebral cortex)

B) Peripheral - Autonomic Nervous System

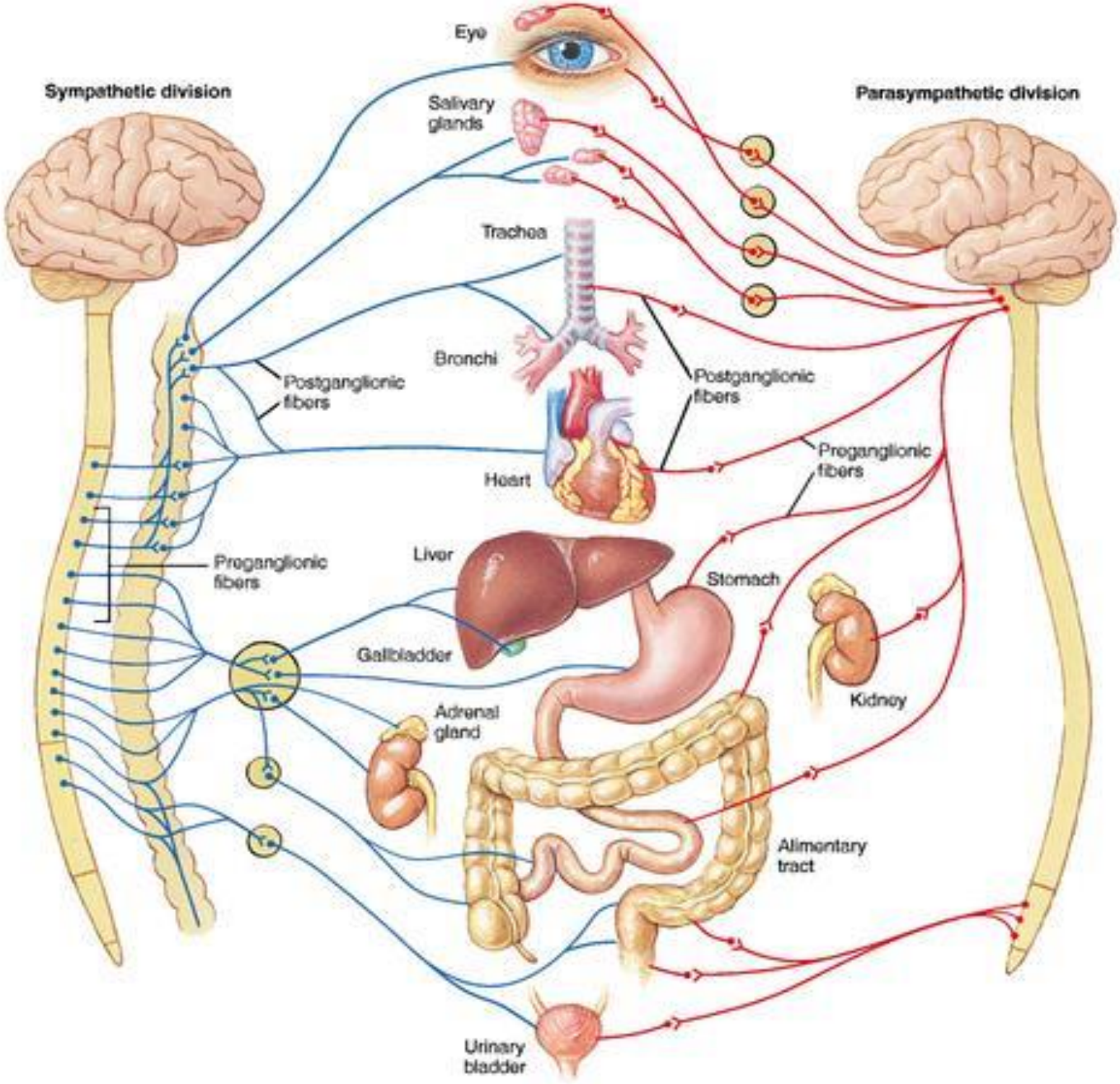
- **Involuntary:** Regulates the activity of cardiac and smooth muscle and glands
- Made of two opposing divisions:

1.Sympathetic Division

2.Parasympathetic Division

Both

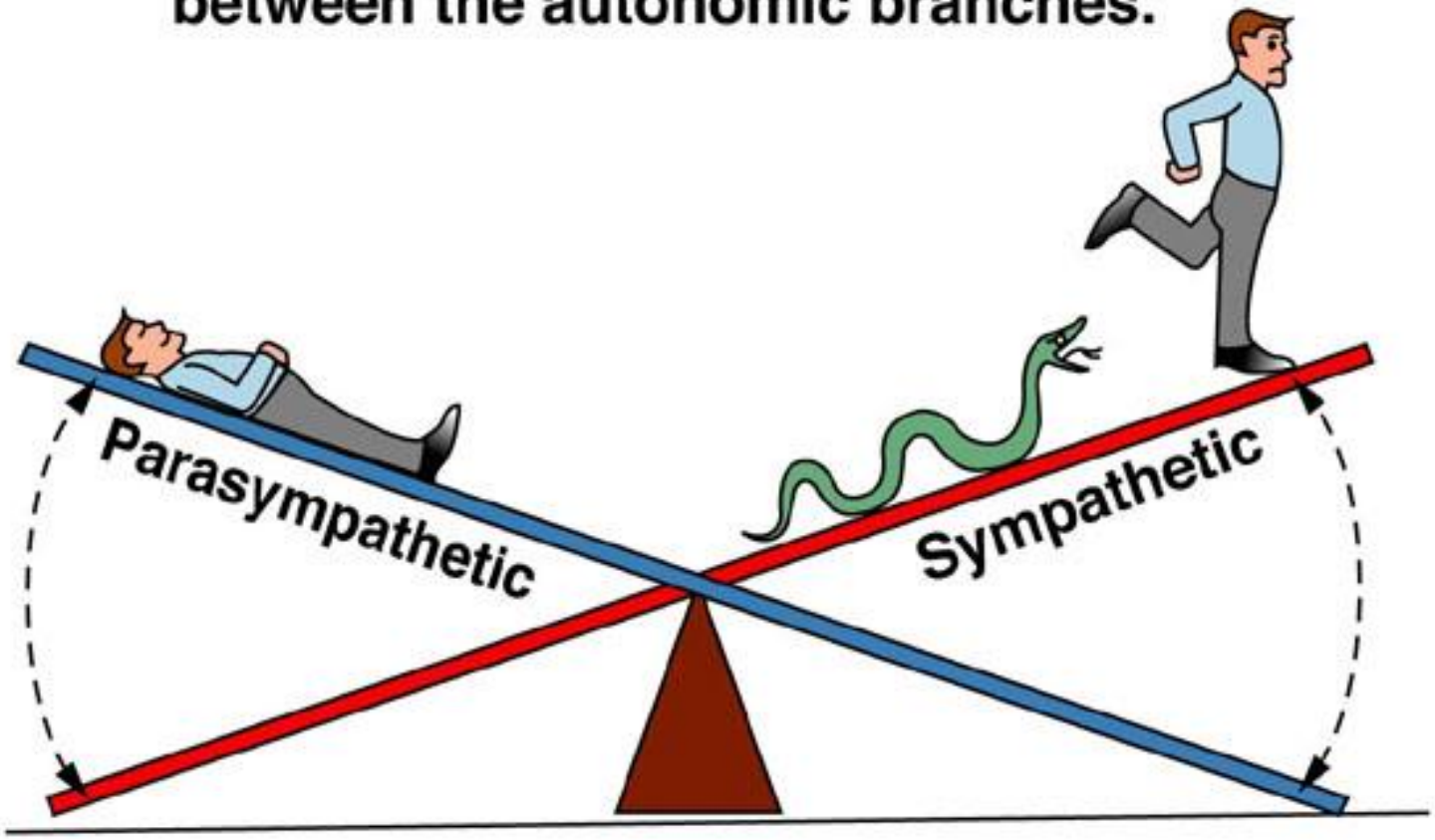
i. Function automatically and usually involuntary
ii. Controls all internal organs


Sympathetic division
Parasympathetic division
Eye
Salivary glands
Trachea
Bronchi
Postganglionic fibers
Postganglionic fibers
Preganglionic fibers
Heart
Preganglionic fibers
Liver
Stomach
Gallbladder
Kidney
Adrenal gland
Alimentary tract
Urinary bladder

1. The Sympathetic Division

- Prepares body for action **“fight or flight”**
- **Increases activity in survival areas (increases heart rate, breathing, more blood flow to muscles, more sensitive sense organs)**
- **Adrenalin is released from Adrenal medulla**
- **Decreases activity in non-survival areas** (decreases digestion and excretion)

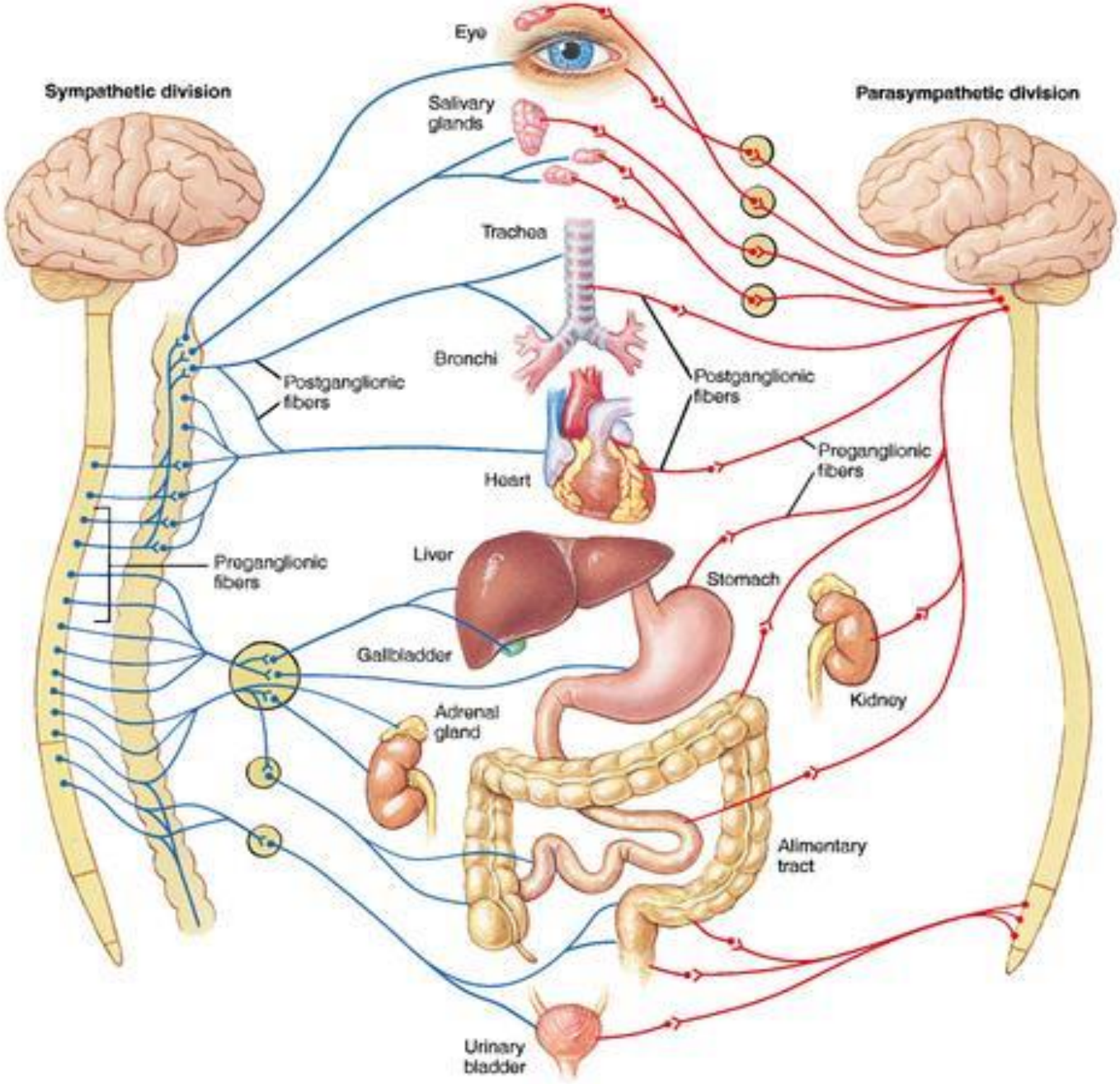
between the autonomic branches.



Rest-and-digest: Parasympathetic activity dominates.

Fight-or-flight: Sympathetic activity dominates.

Figure 11-1


Sympathetic division
Parasympathetic division
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Salivary glands
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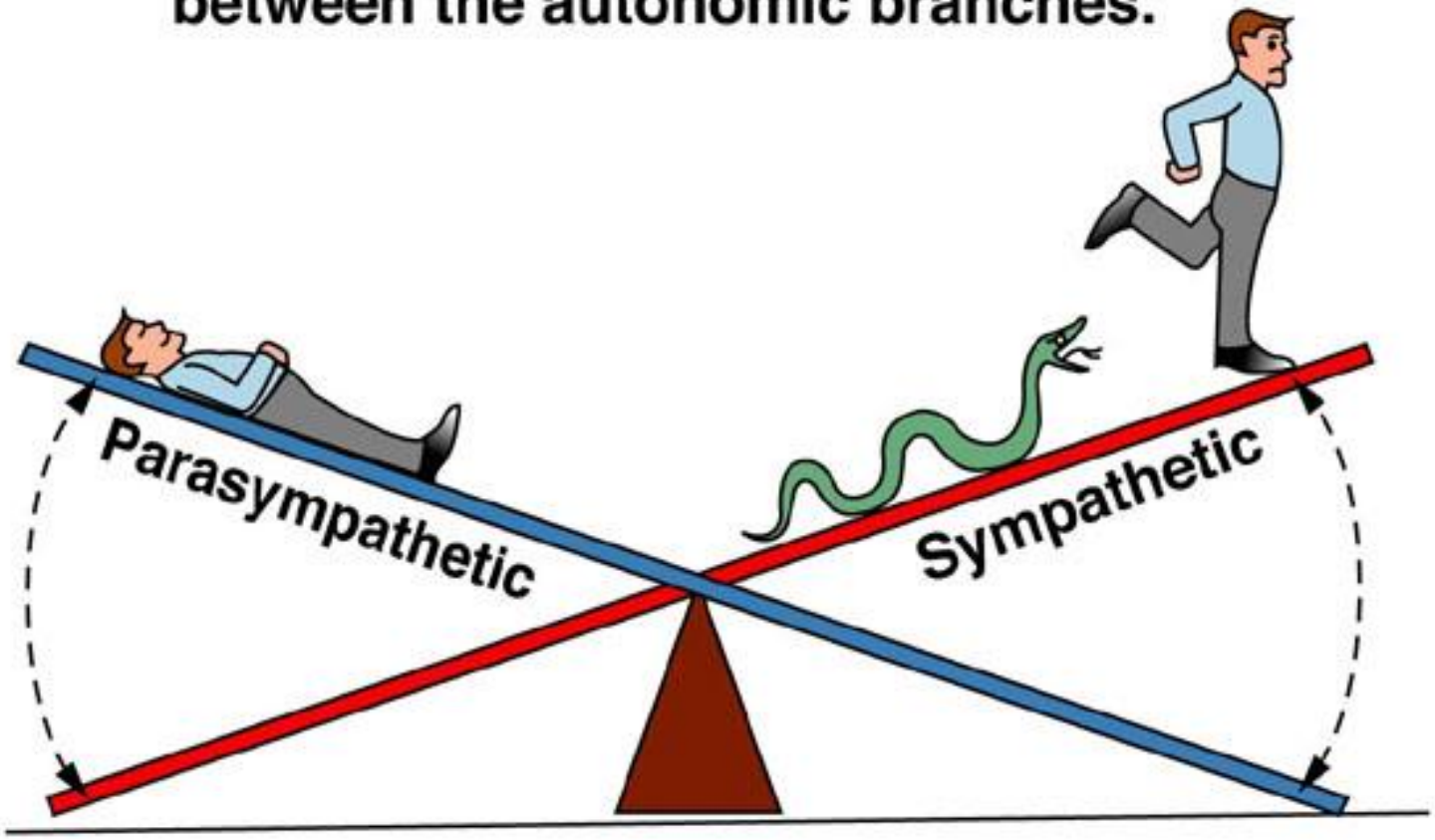
Postganglionic fibers
Preganglionic fibers
Heart
Preganglionic fibers
Liver
Stomach
Gallbladder
Kidney
Adrenal gland
Alimentary tract
Urinary bladder

2. The Parasympathetic Division:

- Used during rest-- returns systems to **“normalcy”**
- **Causes:** all systems to return to normal.
- Digestion increases, excretion increases, heart beat decreases, respiration decreases, senses because less sensitive, blood flow returns to normal.

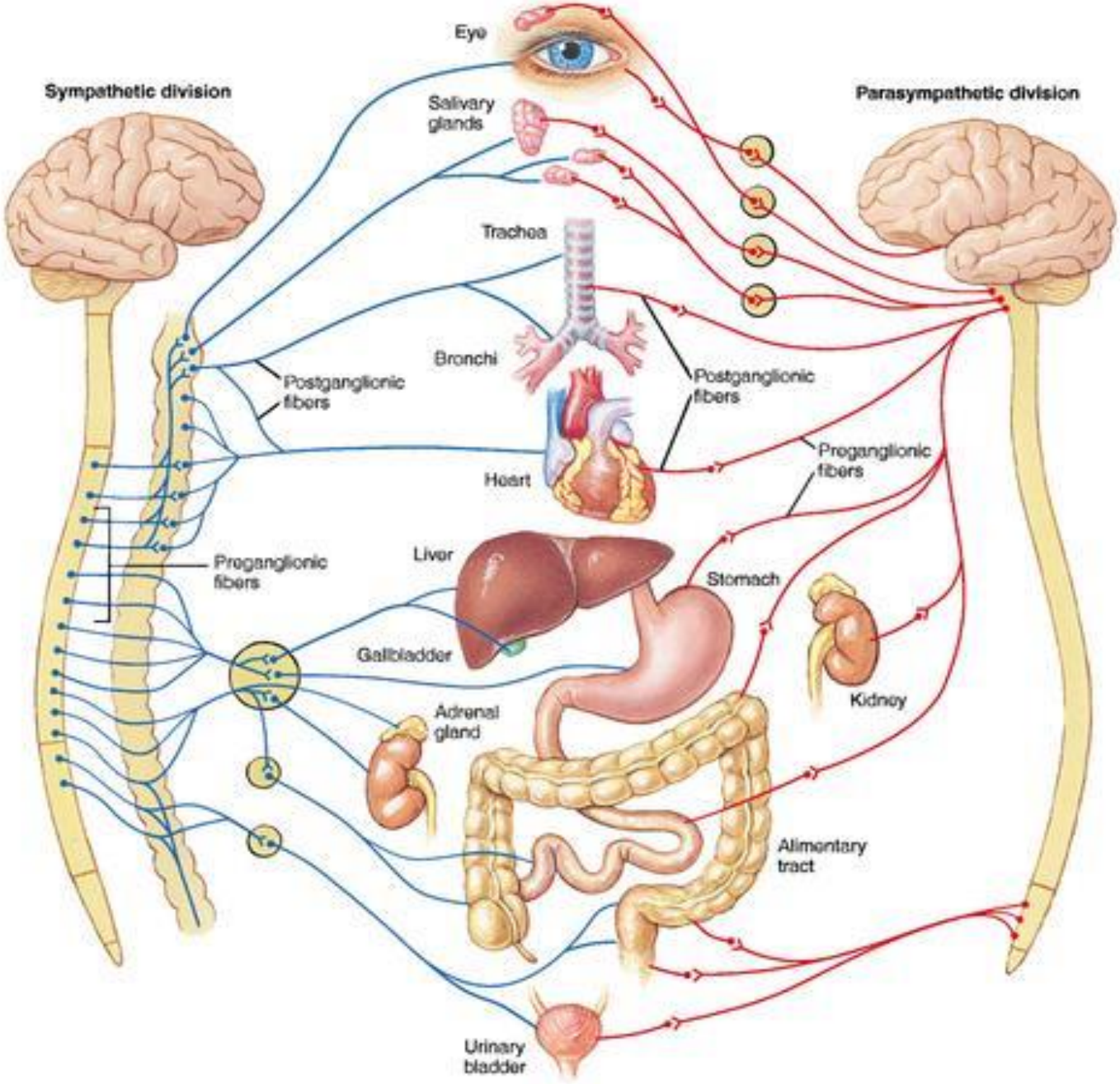
between the autonomic branches.



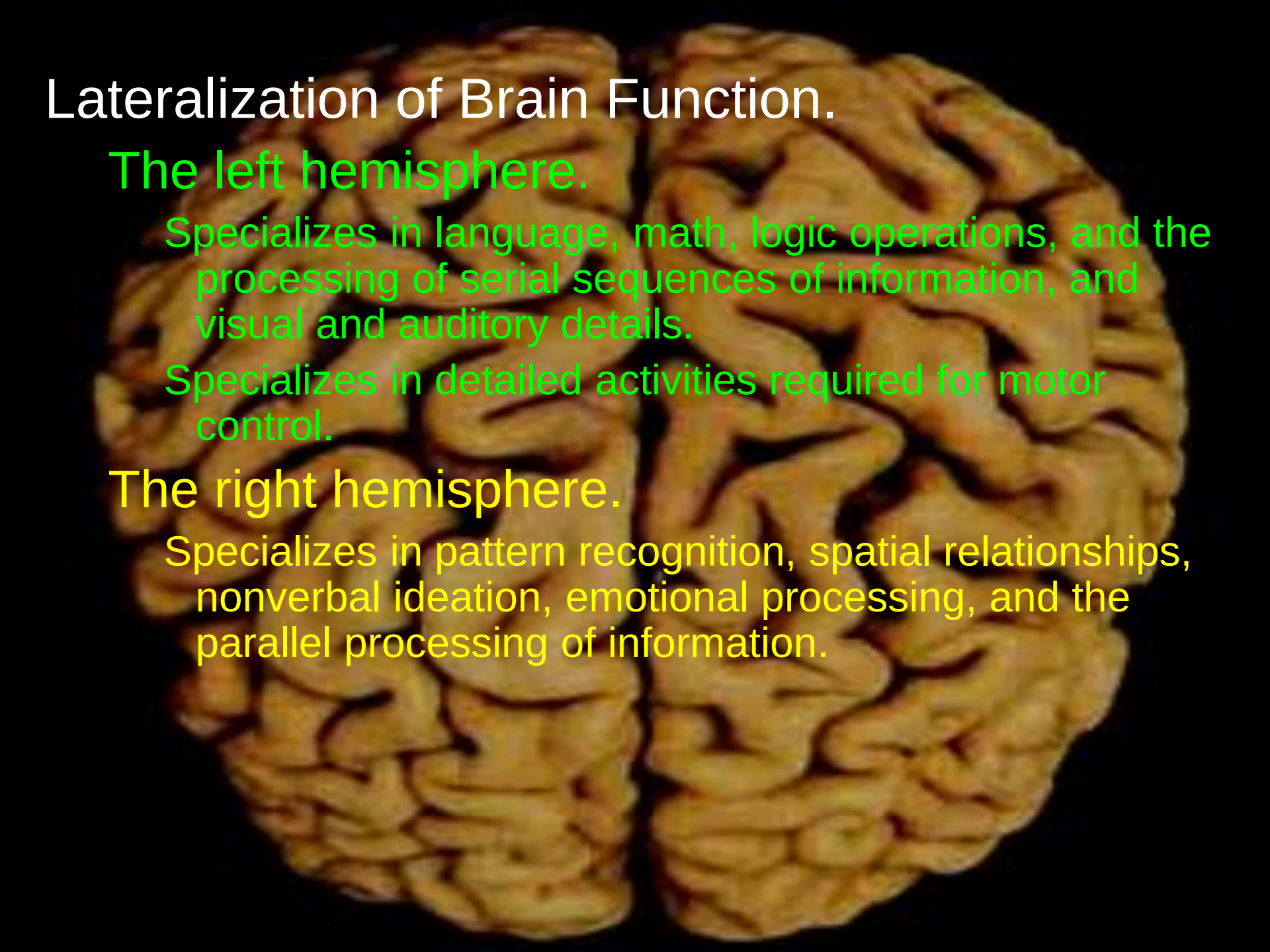
Rest-and-digest: Parasympathetic activity dominates.

Fight-or-flight: Sympathetic activity dominates.

Figure 11-1


Sympathetic division
Parasympathetic division
Eye
Salivary glands
Trachea
Bronchi
Postganglionic fibers
Postganglionic fibers
Preganglionic fibers
Heart
Preganglionic fibers
Liver
Stomach
Gallbladder
Kidney
Adrenal gland
Alimentary tract
Urinary bladder

Optional – extra



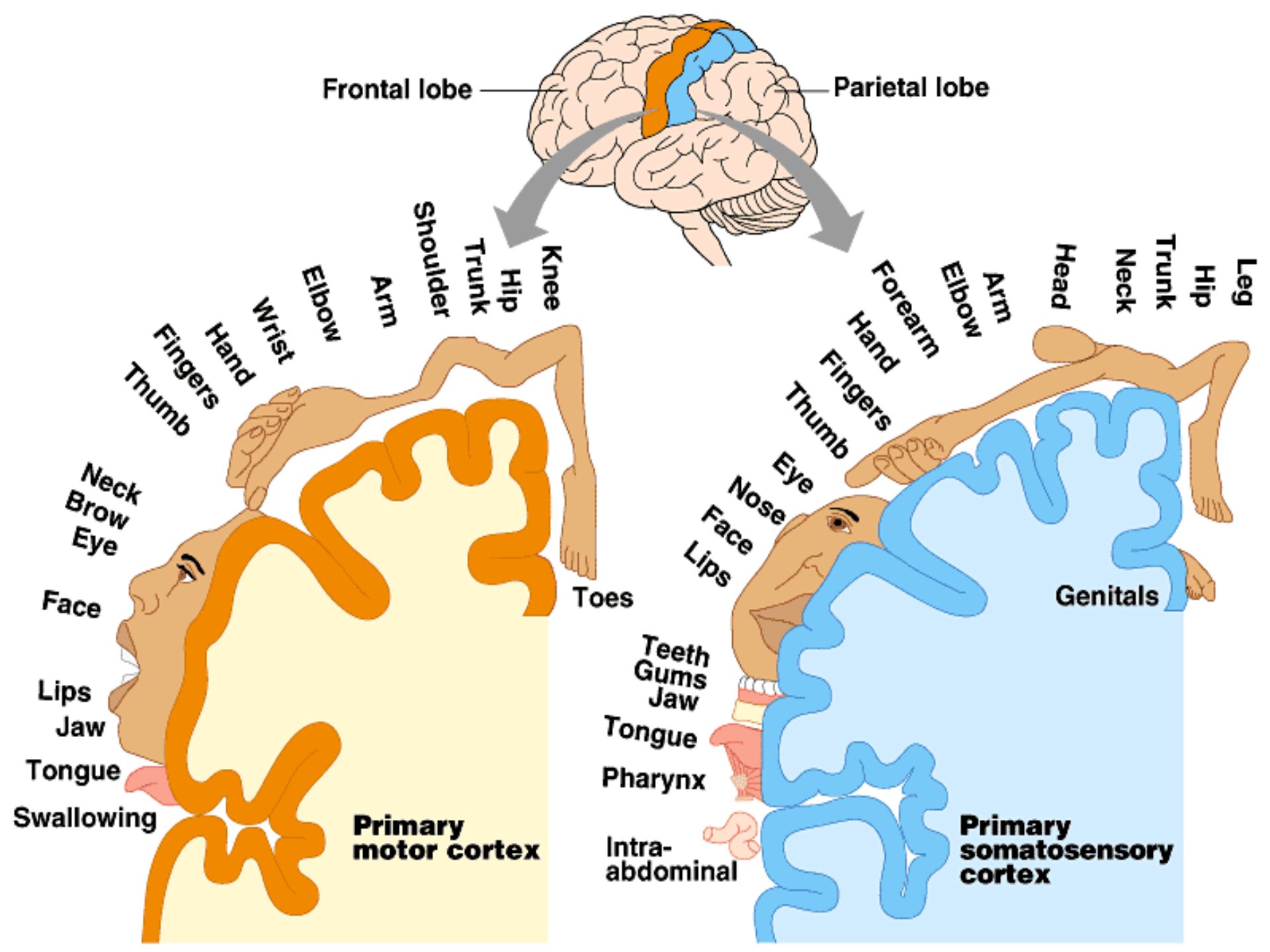
Lateralization of Brain Function.

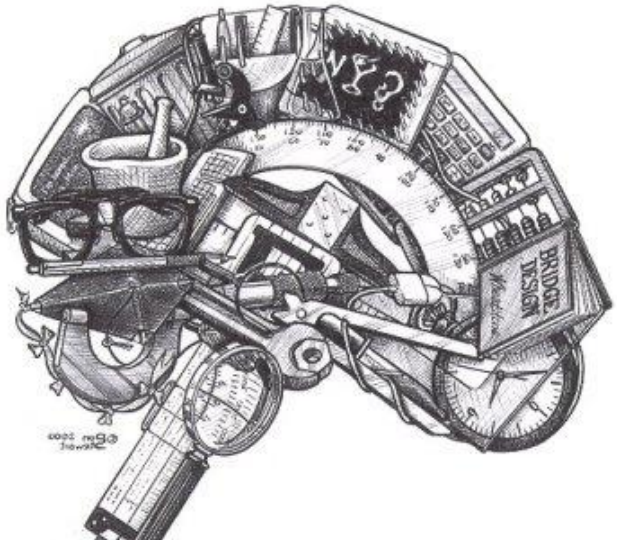
The left hemisphere.

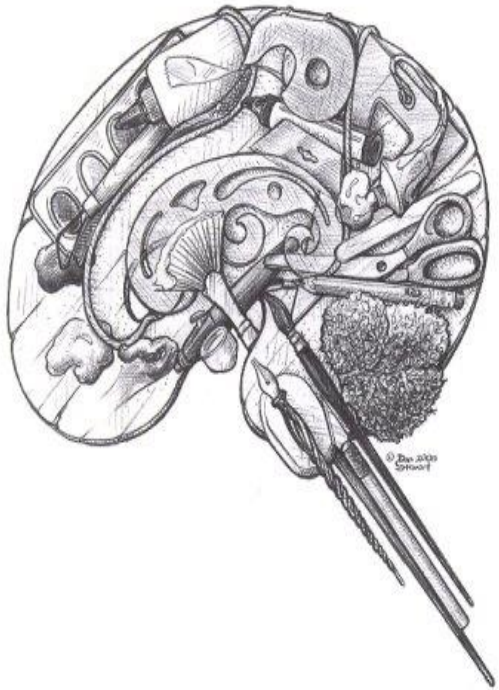
- Specializes in language, math, logic operations, and the processing of serial sequences of information, and visual and auditory details.
- Specializes in detailed activities required for motor control.

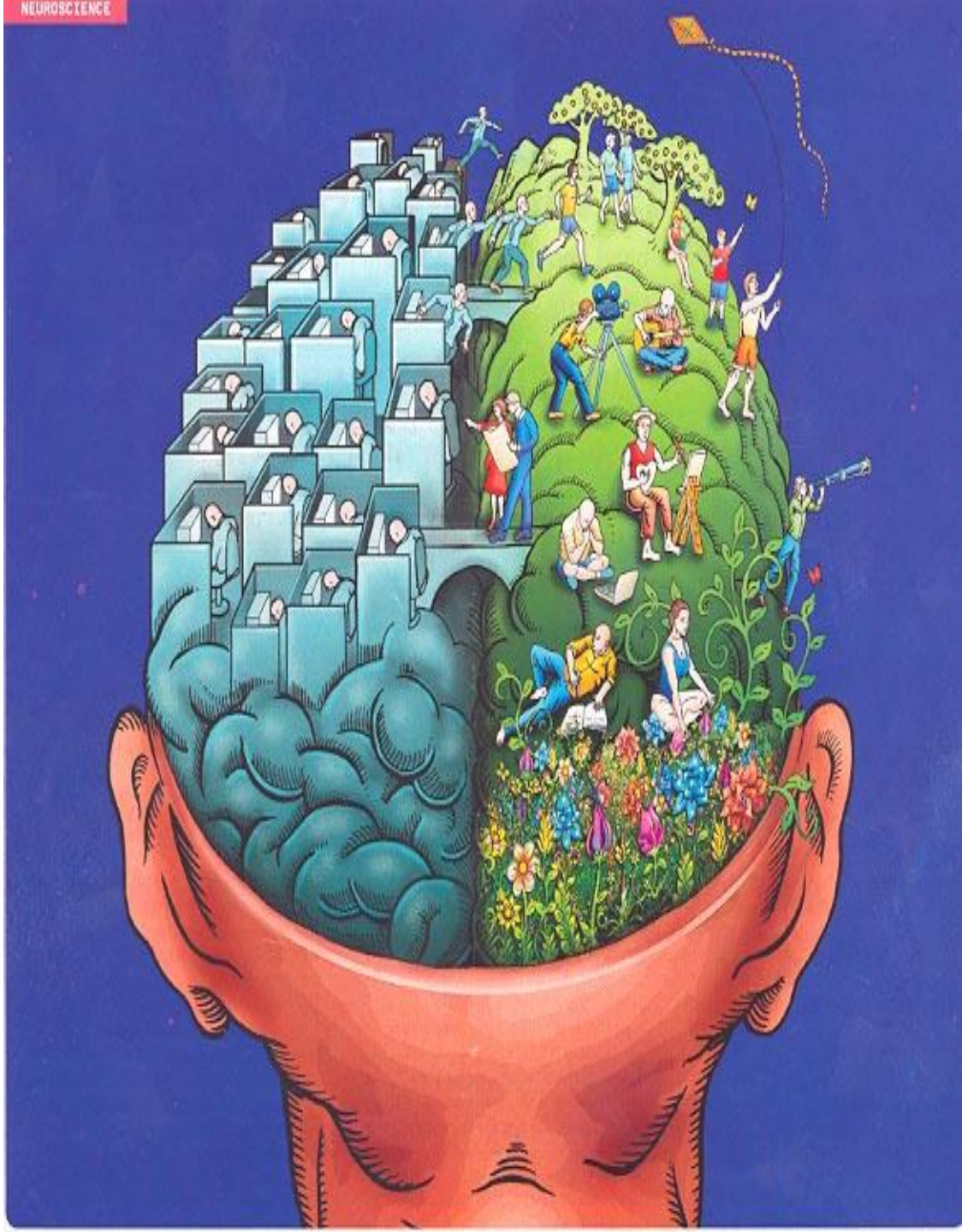
The right hemisphere.

- Specializes in pattern recognition, spatial relationships, nonverbal ideation, emotional processing, and the parallel processing of information.


Frontal lobe
Parietal lobe
Shoulder
Trunk
Hip
Knee
Arm
Elbow
Wrist
Hand
Fingers
Thumb
Neck
Brow
Eye
Face
Lips
Jaw
Tongue
Swallowing
Toes
Primary motor cortex
Head
Neck
Trunk
Hip
Leg
Arm
Elbow
Forearm
Hand
Fingers
Thumb
Eye
Nose
Face
Lips
Genitals
Teeth
Gums
Jaw
Tongue
Pharynx
Intra-abdominal
Primary somatosensory cortex


BRIDGE
DESIGN

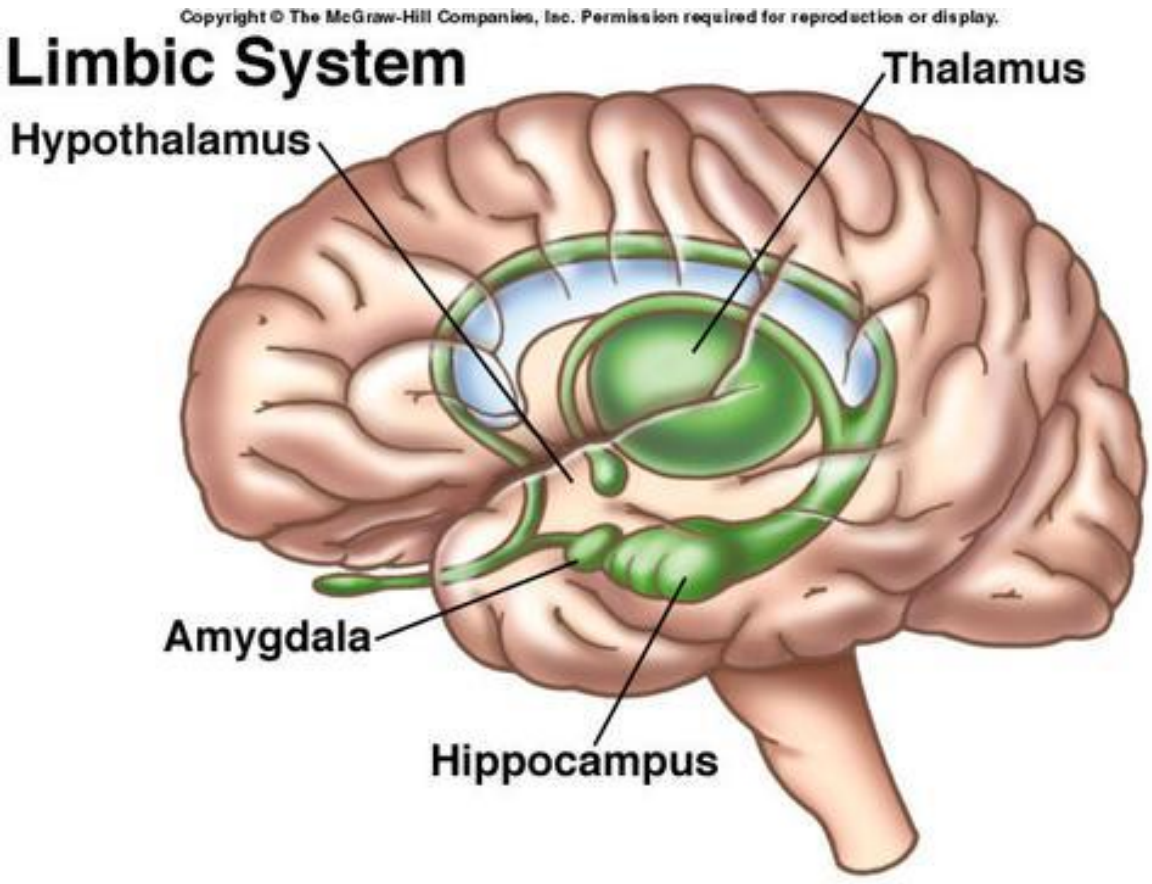



NEUROSCIENCE

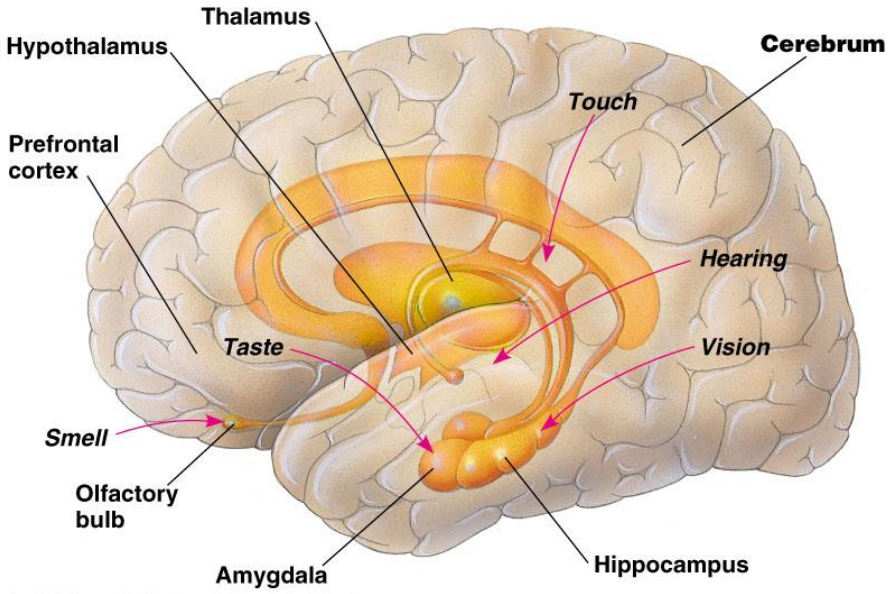
17.3 Limbic System and Higher Mental Functions

Limbic System

- Intimately involved in our emotions and higher mental functions



- Emotions.
  - In mammals, the **limbic system** is composed of the hippocampus, olfactory cortex, inner portions of the cortex's lobes, and parts of the thalamus and hypothalamus.
    - Mediates basic emotions (fear, anger), involved in emotional bonding, establishes emotional memory
      - For example, the amygdala is involved in recognizing the emotional content of facial expression.



Higher Mental Functions

Memory and Learning

- **Short-term memory** stored in the frontal lobes.
- The establishment of **long-term memory** involves the hippocampus.
  - The transfer of information from short-term to long-term memory.
    - Is enhanced by **repetition** (remember that when you are preparing for an exam).
    - Influenced by **emotional states** mediated by the amygdala.
    - Influenced by **association** with previously stored information.

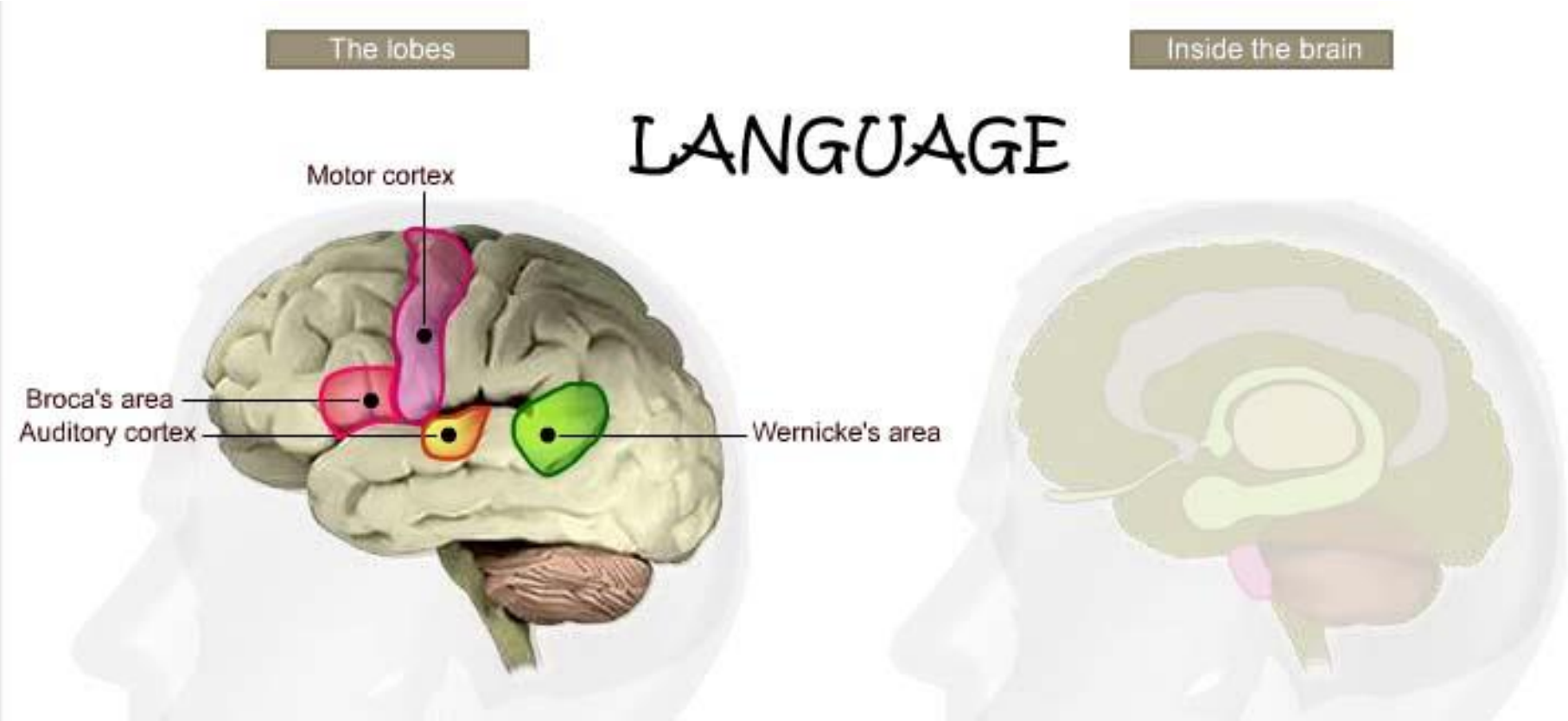
Memory and Learning Cont'

- Different types of long-term memories are stored in different regions of the brain.
- **Memorization-type** memory can be rapid.

  - Primarily involves changes in the strength of existing nerve connections.
- **Learning of skills and procedures** is slower.
  - Appears to involves cellular mechanisms similar to those involved in brain growth and development.

Language and Speech

- **Broca's area**= speaking (motor speech)
- **Wernicke's area**= understanding language (sensory speech)

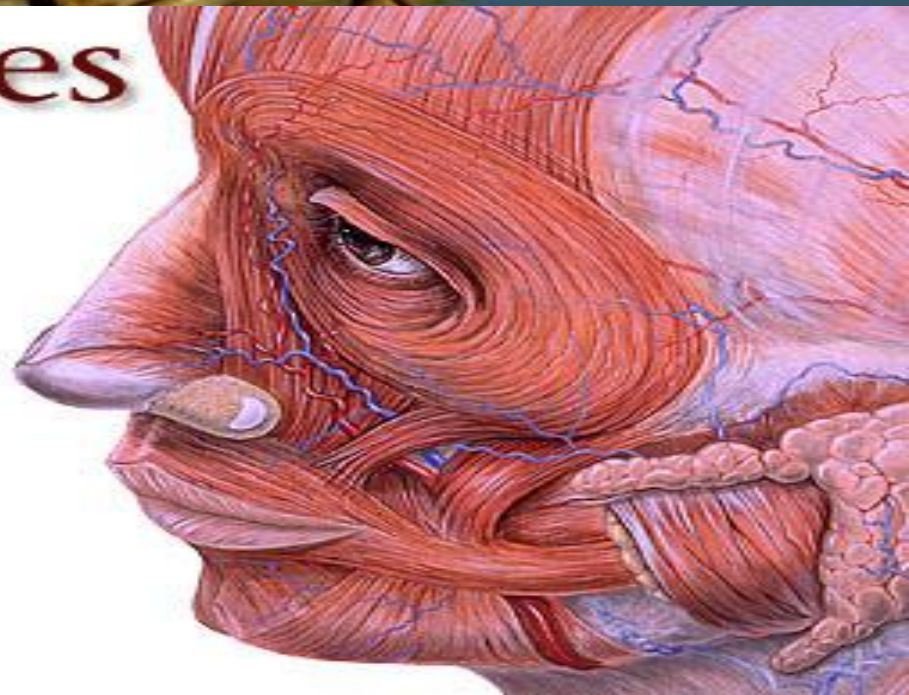


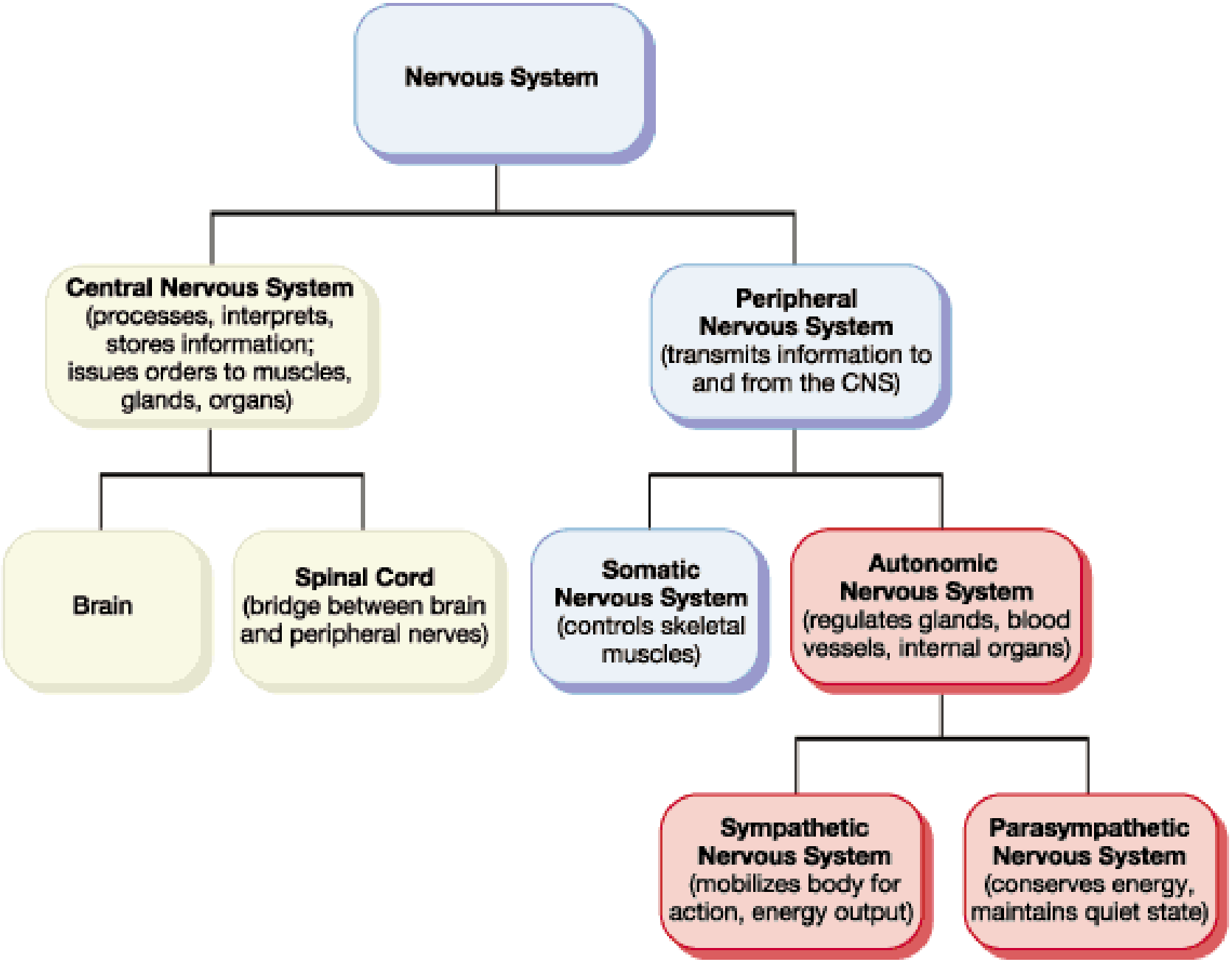
Cranial Nerves: 12 pairs come directly off the brain.

- Some are sensory only (optic, auditory) rest are mixed.
- Control head and upper neck.
- Includes #10, the Vagus nerve, that forms part of the autonomic nervous system.

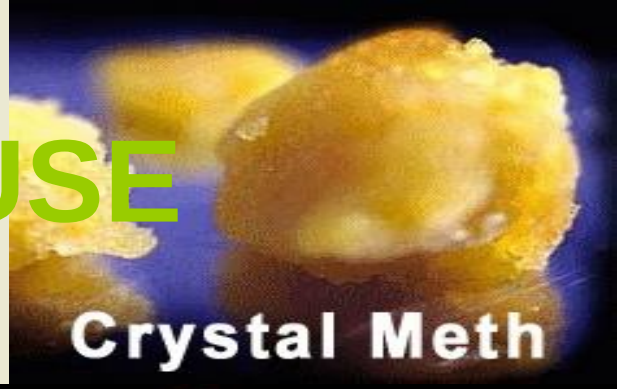
Cranial Nerves

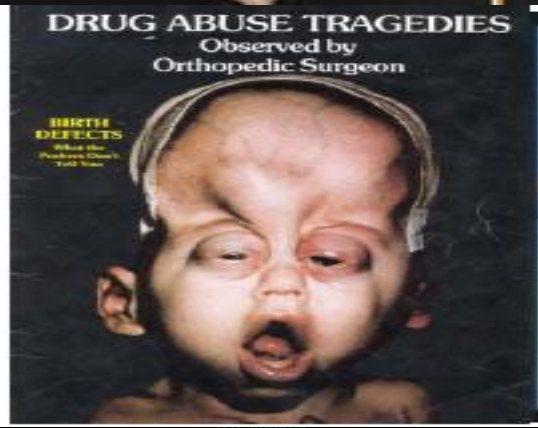
I	Olfactory
II	Optic
III	Oculomotor
IV	Trochlear
V	Trigeminal
VI	Abducens
VII	Facial
VIII	Vestibulocochlear
IX	Glossopharyngeal
X	Vagus
XI	Accessory
XII	Hypoglossal

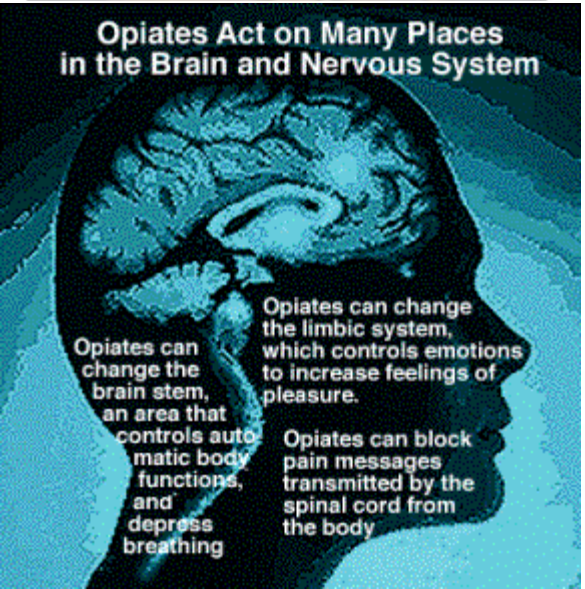


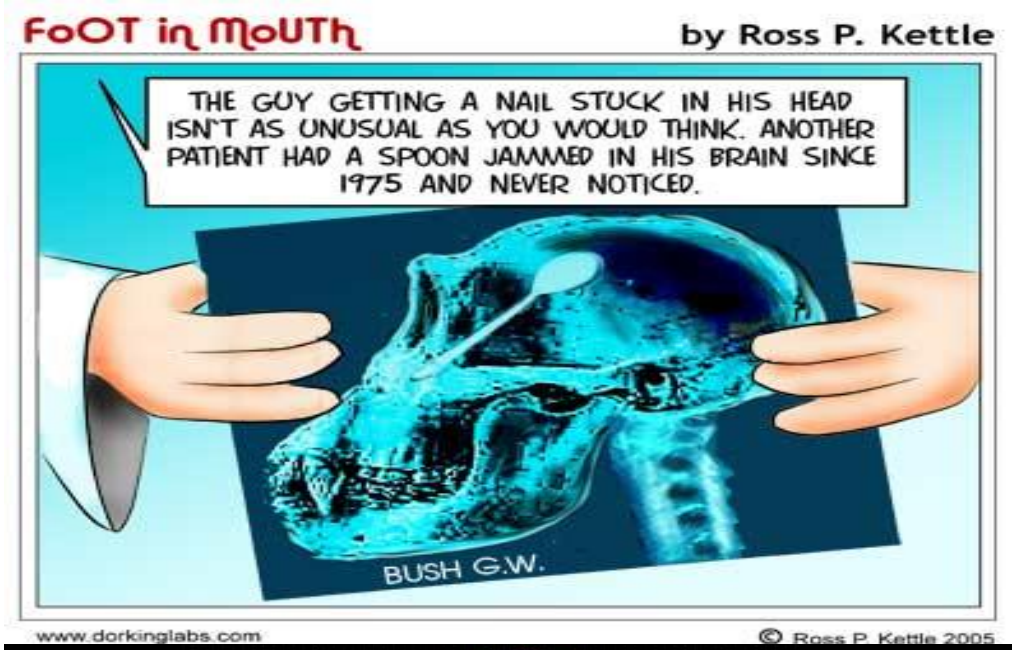

Nervous System
Central Nervous System (processes, interprets, stores information; issues orders to muscles, glands, organs)
Peripheral Nervous System (transmits information to and from the CNS)
Brain
Spinal Cord (bridge between brain and peripheral nerves)
Somatic Nervous System (controls skeletal muscles)
Autonomic Nervous System (regulates glands, blood vessels, internal organs)
Sympathetic Nervous System (mobilizes body for action, energy output)
Parasympathetic Nervous System (conserves energy, maintains quiet state)

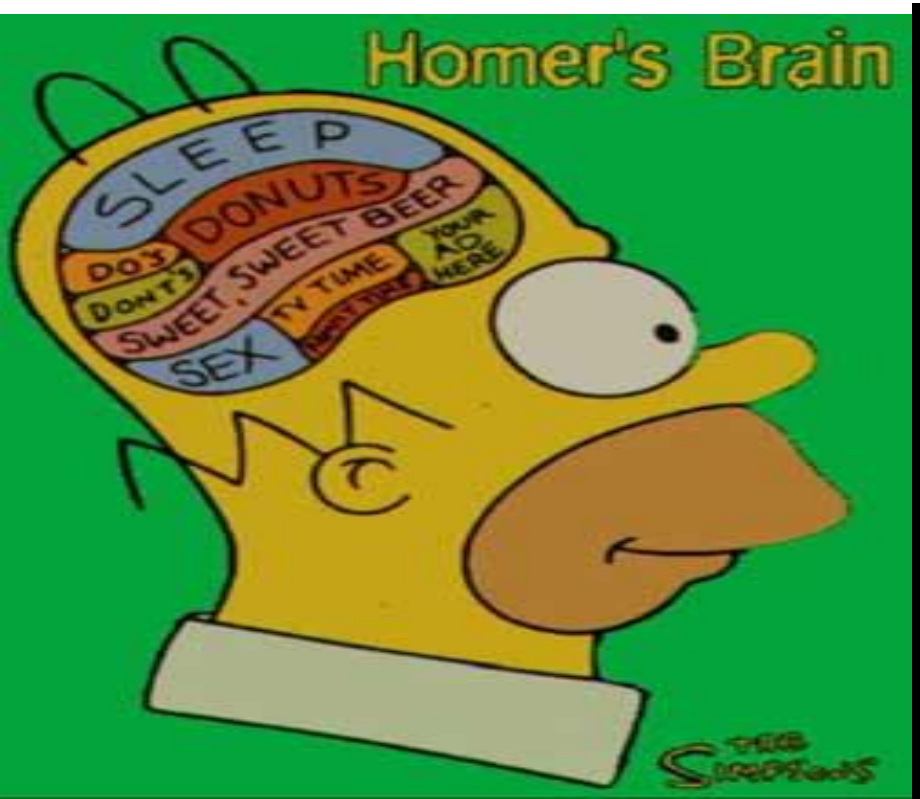
17.5 DRUG ABUSE

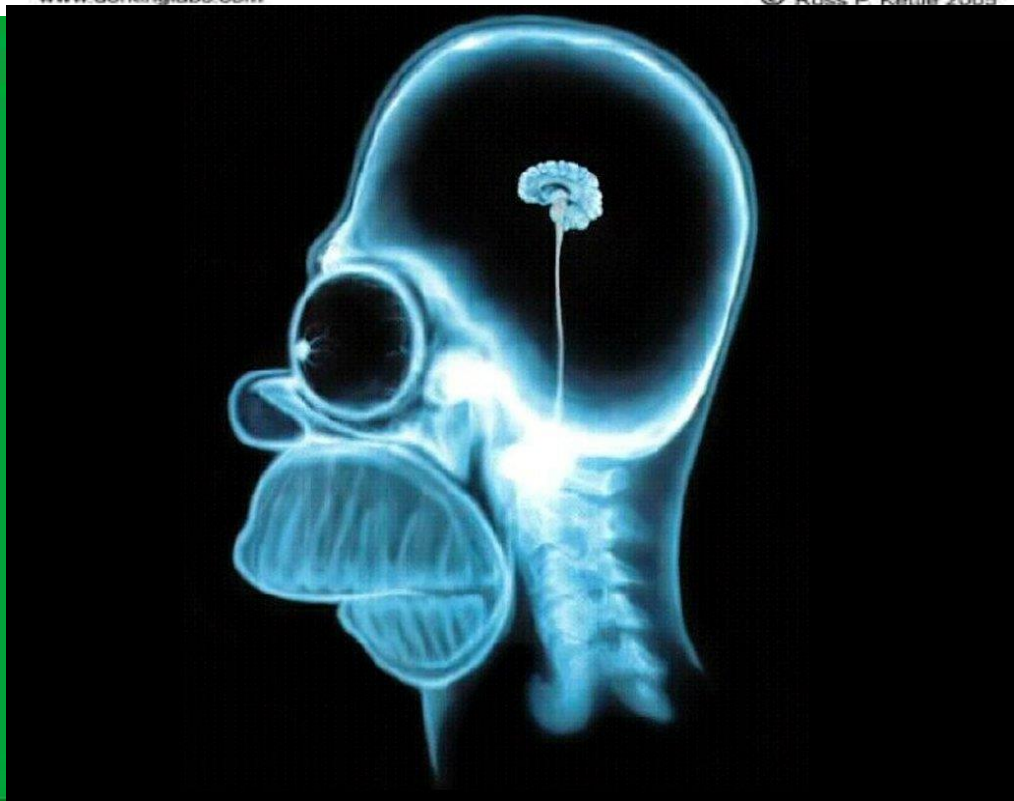







FoOT in MoUTh
by Ross P. Kettle
THE GUY GETTING A NAIL STUCK IN HIS HEAD ISN'T AS UNUSUAL AS YOU WOULD THINK. ANOTHER PATIENT HAD A SPOON JAMMED IN HIS BRAIN SINCE 1975 AND NEVER NOTICED.
BUSH G.W.
www.dorkinglabs.com
© Ross P. Kettle 2005


Homer's Brain
SLEEP
DONUTS
BEER
DO'S
DON'T'S
SWEET
SWEET
TV TIME
SEX
YOUR AD HERE
THE SIMPSONS



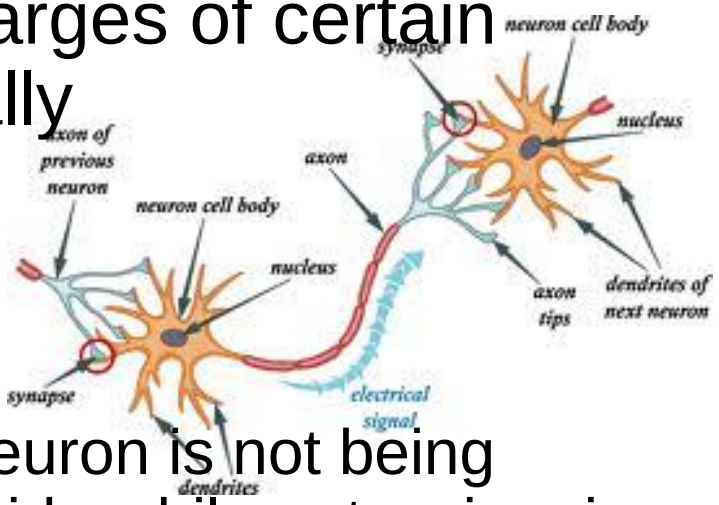
Action potential (optional)

Nerve Impulses

Conduction of the Nerve Impulse

Nerve impulses rely on electrical charges which come about from the ionic charges of certain minerals in the body specifically

Na^+ K+ and Ca^{++}

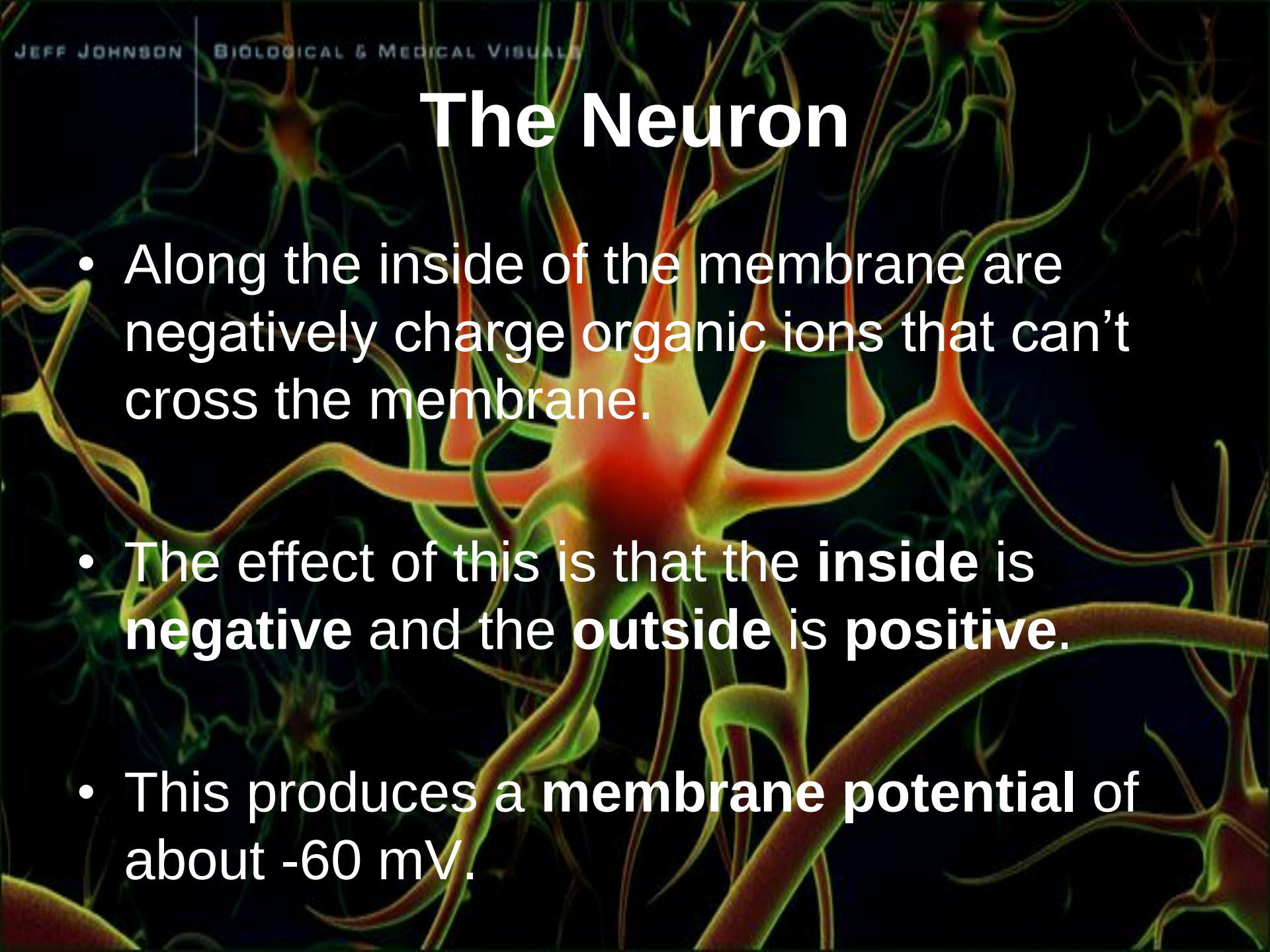


Terminology

- **Resting potential=** while the neuron is not being stimulated sodium remains outside while potassium is inside the neuron (neuron is **POLARIZED +** outside the neuron and **–** inside due to large organic ions)
- **Gated ion channels=** are found along the neuron membrane (axomembrane) and allow ions to move in and out of the cell

Nerve Impulses

- **Threshold** amount of stimulus required to cause the neuron to fire
- **Depolarization** when the threshold is met sodium gates open and **Na^+** rushes into cell causing a swing in polarity
- **Repolarization** immediately following the rush of sodium into the cell potassium gate open and **K^+** rushes out to repolarize neuron
- **Action potential** refers to the movement of ions in and out of cell causing a nerve impulse
- **Refractory period** all neurons must go through a short rest period and redistribute ions in order to carry out another impulse



The Neuron

- Along the inside of the membrane are negatively charge organic ions that can't cross the membrane.
- The effect of this is that the **inside** is **negative** and the **outside** is **positive**.
- This produces a **membrane potential** of about -60 mV.

ACTION POTENTIAL

1. When the impulse reaches any point along the axon, it causes **“sodium gates”** to open and **Na^+** floods in.

2. This is due to both a **concentration gradient** and **electrical attraction.**

3. This influx of positive ions repels **K^+** which leave as the **“potassium gates”** open.

ACTION POTENTIAL Cont'

4. This **depolarizes** the axon = nerve impulse.

5. **depolarization** cause the sodium gates immediately adjacent and downstream to open, **depolarization** now occurs there.

6. This continues as a wave of depolarization along the entire length of the axon.

Conduction of an Action Potential

Refractory Period (Recovery phase)

- As the wave of **depolarization** moves past, the sodium - potassium pump kicks in again pumping the **Na^+ out** and allowing the **K^+** to **passively re-enter.**

- This restores the resting potential and the axon can now fire again.

- Step 1: Resting State.

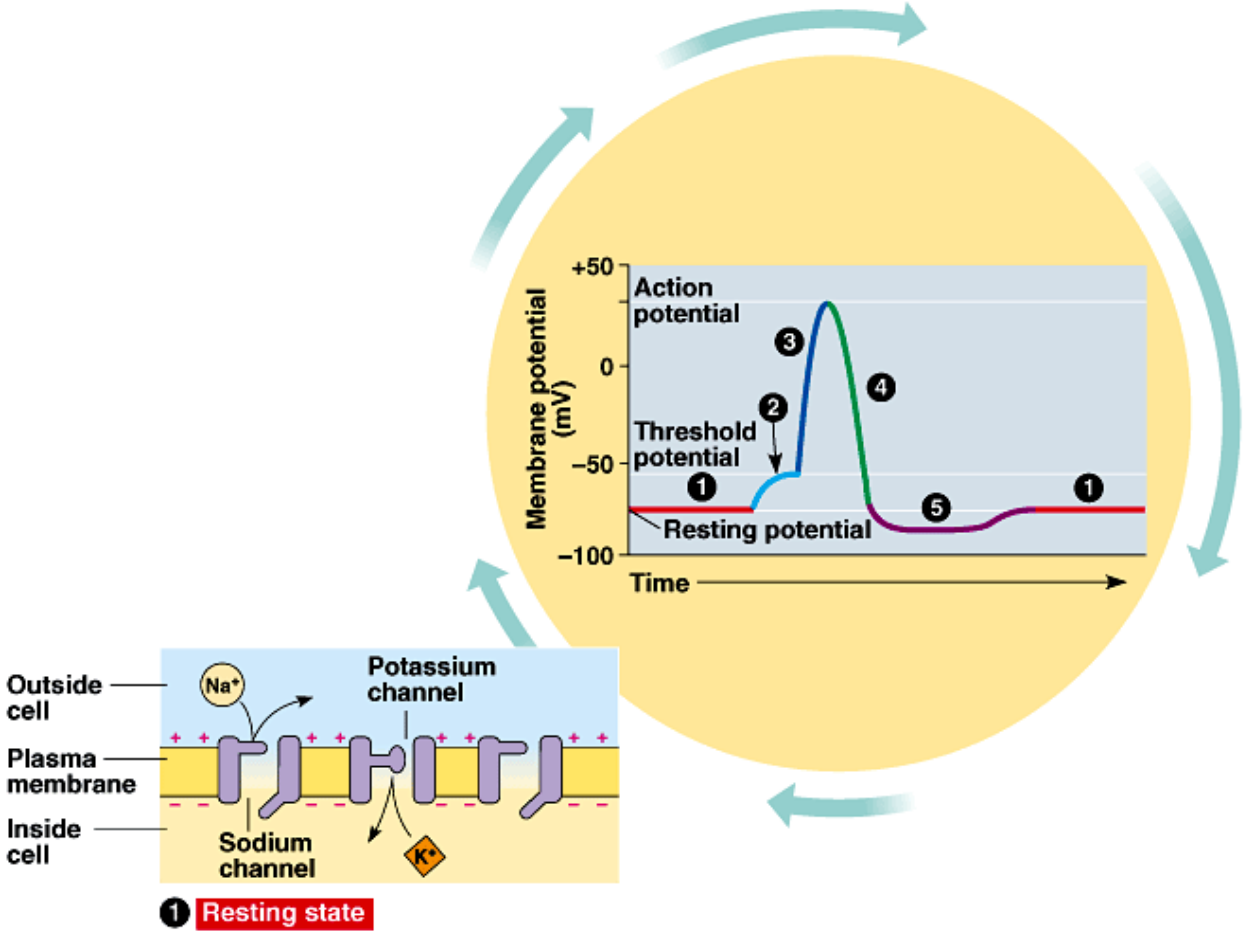


Fig. 48.9

- Step 2: Threshold.

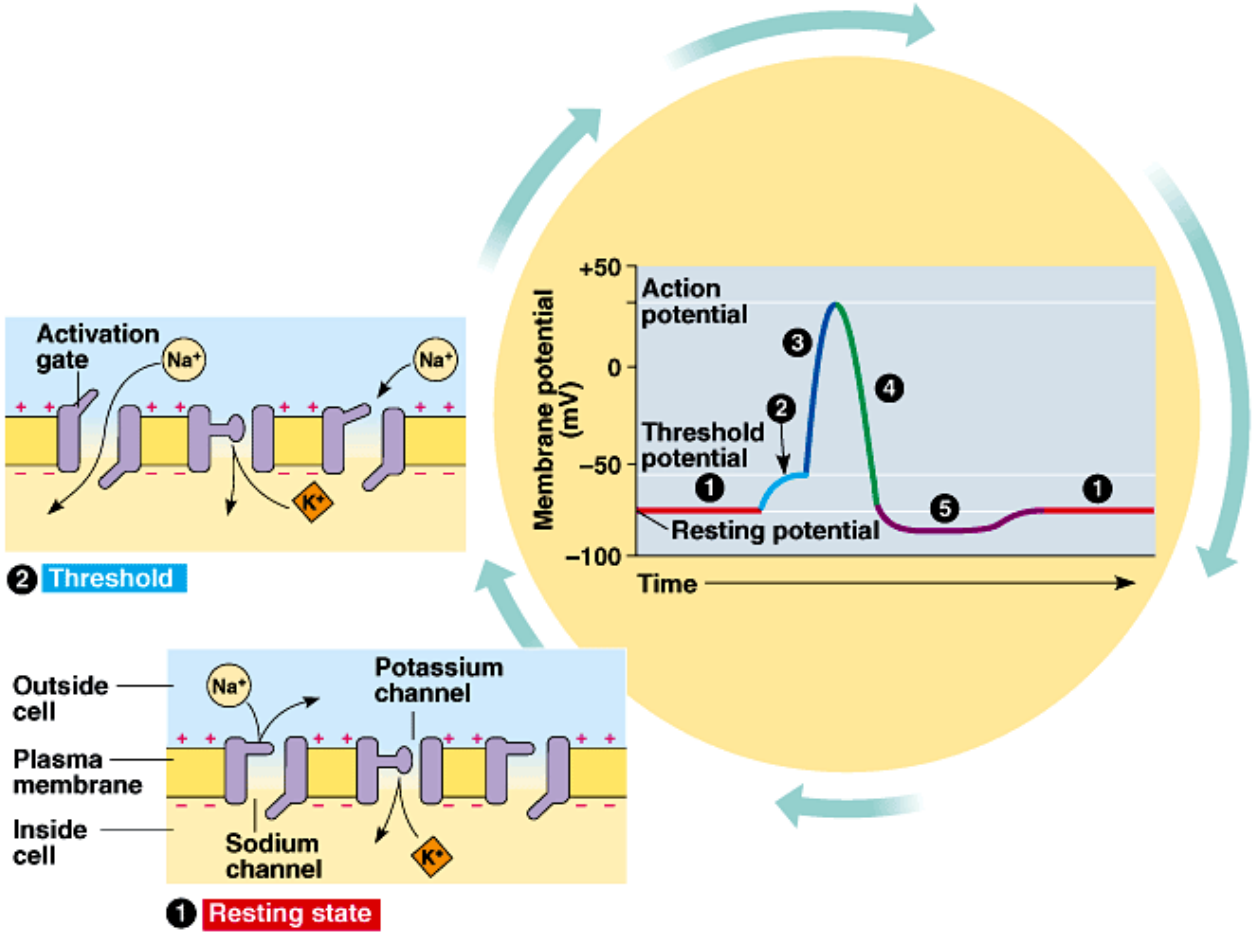


Fig. 48.9

- Step 3: **Depolarization** phase of the action potential.

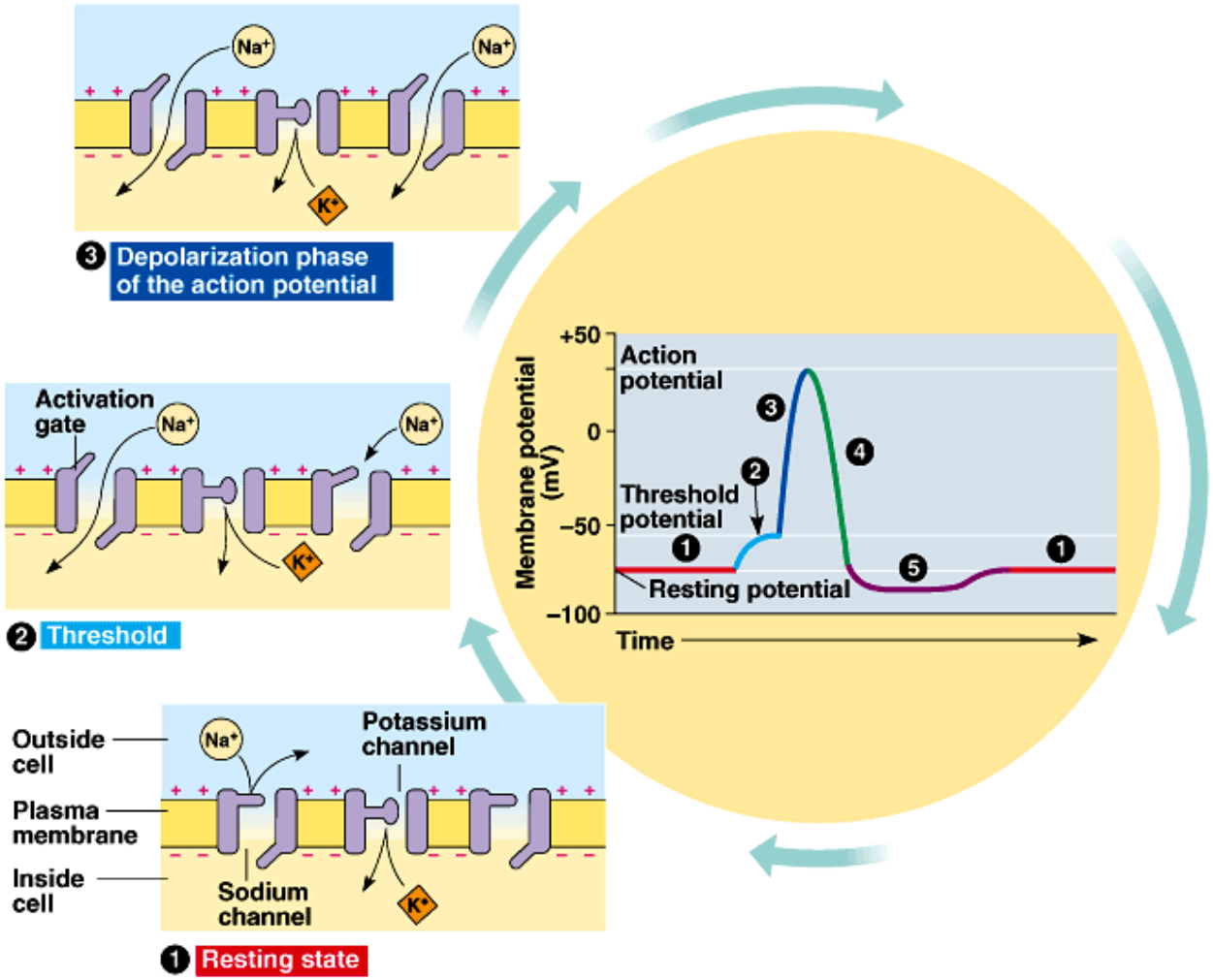


Fig. 48.9

- Step 4: Repolarizing phase of the action potential.

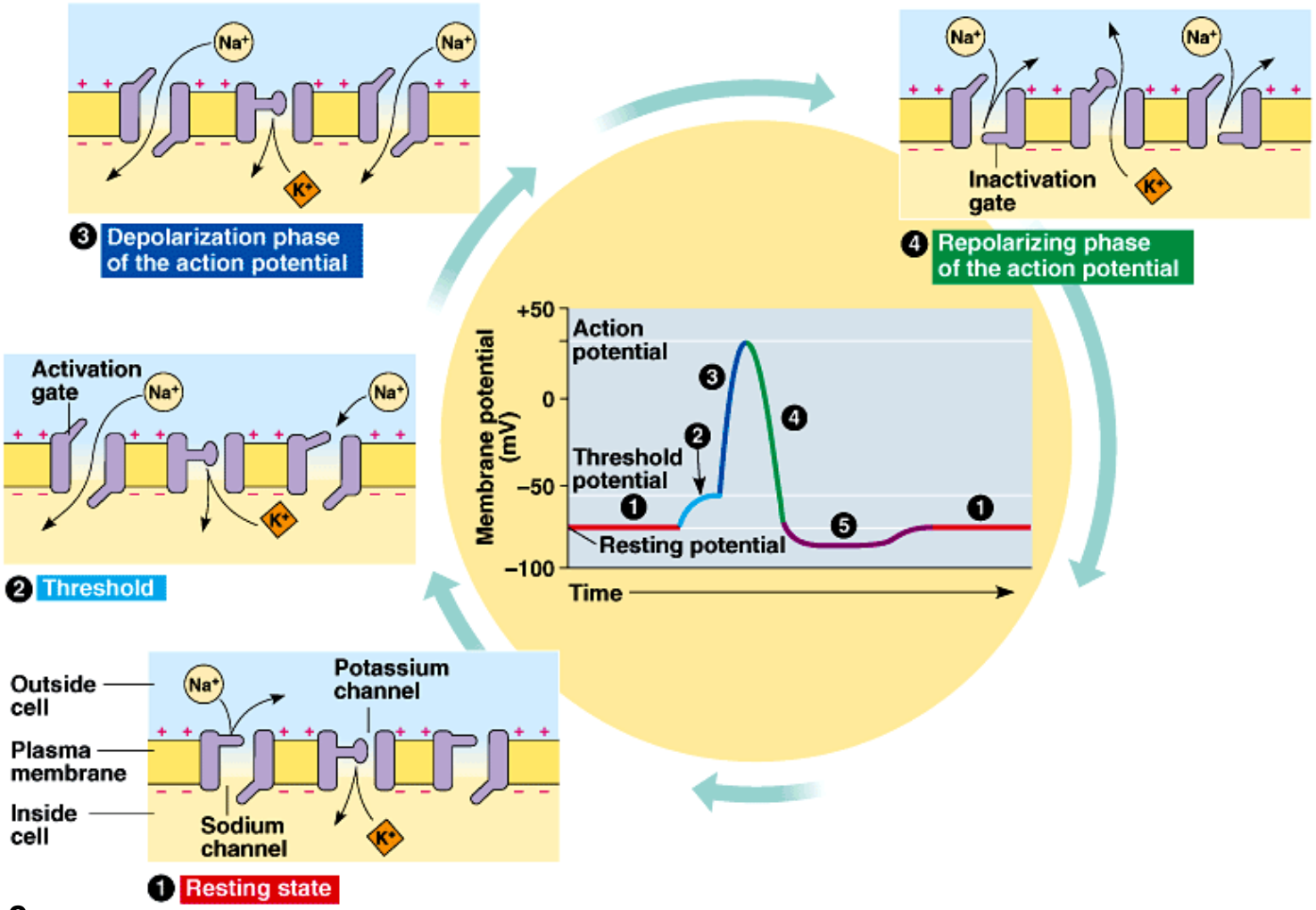


Fig. 48.9

- Step 5: Undershoot.

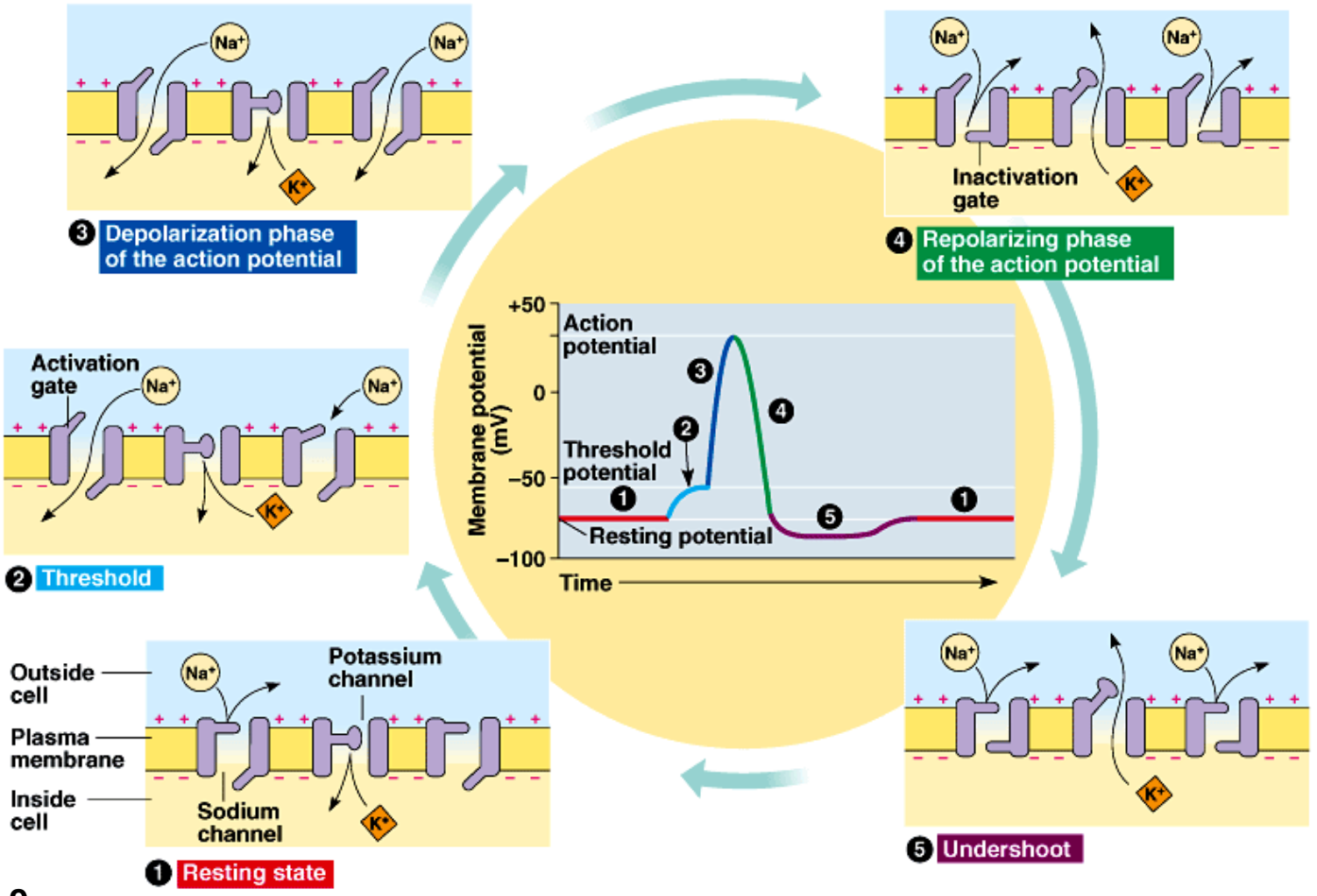
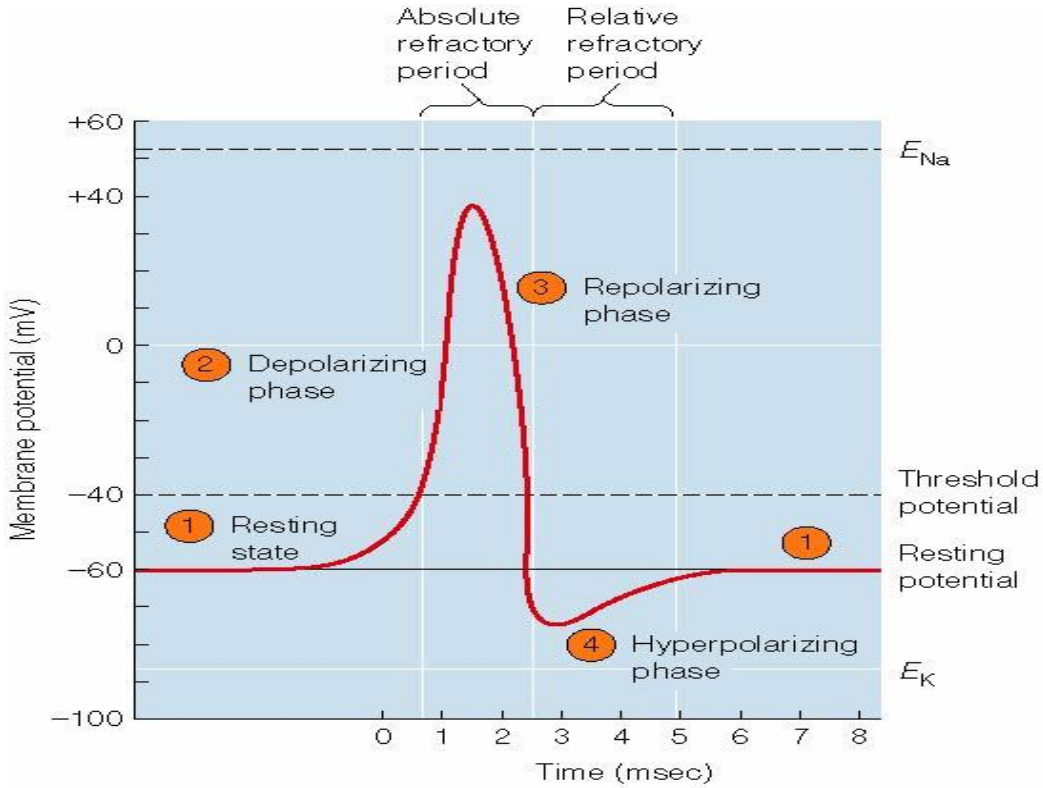
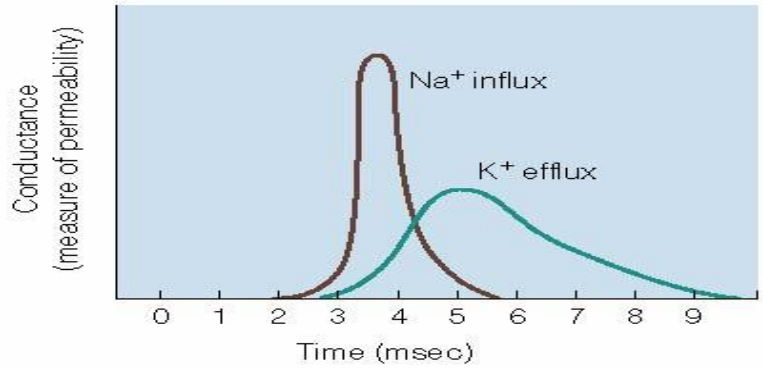


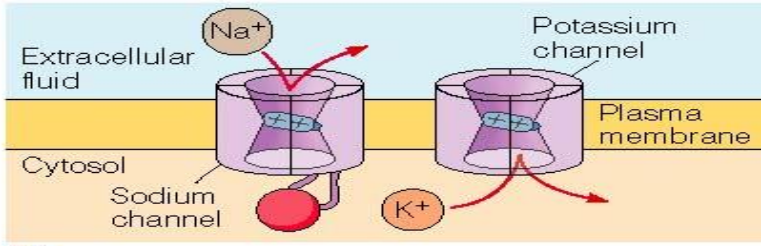
Fig. 48.9



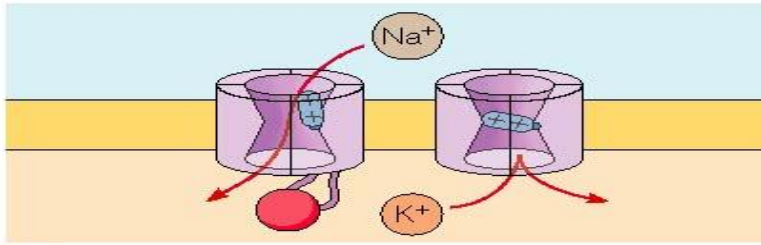
(a) Changes in ion channels and membrane potential



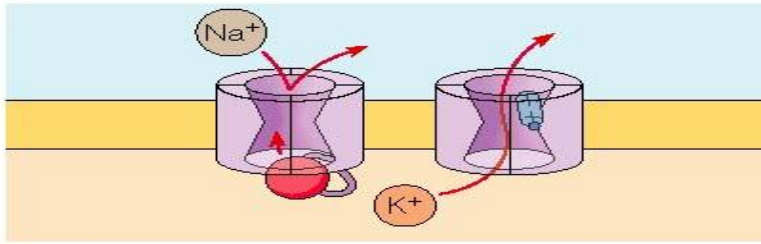
(b) Change in membrane conductance



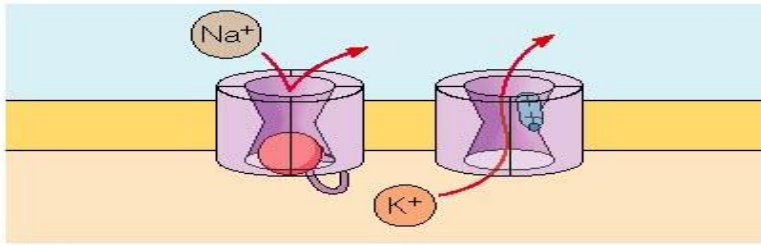
1 Resting state: All gated Na^+ and K^+ channels closed



2 Depolarizing phase: Na^+ channels open

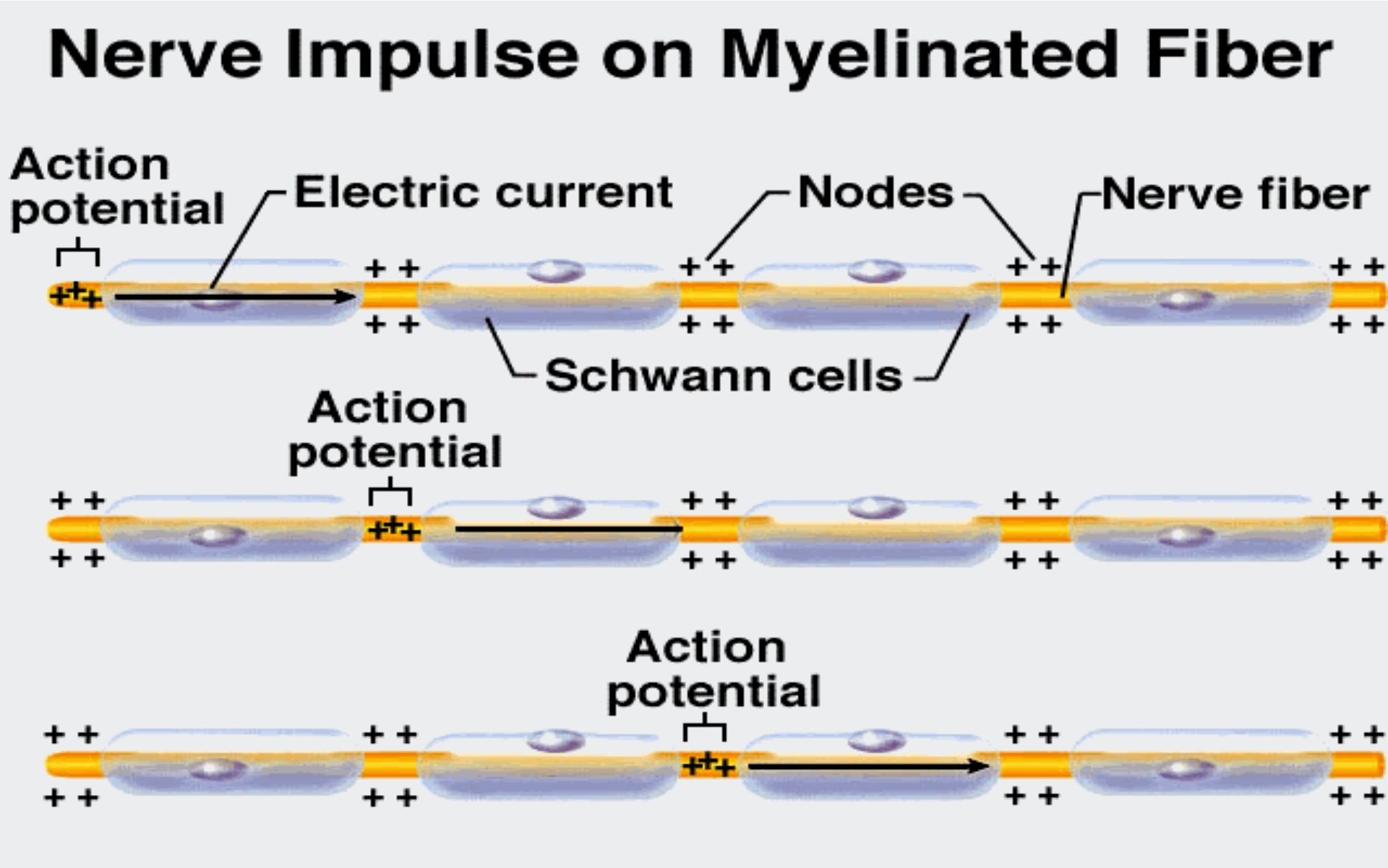


3 Repolarizing phase: Na^+ channels inactivated and K^+ channels open



4 Hyperpolarizing phase (undershoot): K^+ channels remain open and Na^+ channels inactivated

Nodes of Ranvier



End of action potential