

Biology 223

Human Anatomy and Physiology

Week 4; Lecture 2; Wednesday

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INTRODUCTION TO NERVOUS SYSTEM

NEURON PHYSIOLOGY

Nervous System

- Fast acting
- Electrical impulses
- (As opposed to endocrine system)
- Derived from Neural Ectoderm, or Neural Crest

REGIONAL ORGANIZATION OF NERVOUS SYSTEM

- **Central Nervous System (CNS) = brain and spinal cord (dorsal hollow nerve cord)**
- **Peripheral Nervous System = all nerves that exit or enter the CNS (always paired, right and left)**

Somatic vs. Visceral Components

- SOMATIC
- Somatic Sensory (=somatic afferent)
- Somatic Motor (=somatic efferent*)
- VISCERAL
- Visceral Sensory (=visceral afferent)
- Visceral Motor (=visceral efferent)

*efferent means “away”

SOMATIC NERVOUS SYSTEM

- Sensory (afferent) nerves receive input from:
 - Body wall (skin, musculature)
 - Some Special Senses (sight, sound)
- Motor nerves (efferent) send messages to musculature of body wall (somatopleure)

VISCERAL NERVOUS SYSTEM

- Visceral Sensory:
 - Receive signals from organs of splanchnopleure (hunger, discomfort, full bladder, some taste, some smell)
- Visceral Motor – **AUTONOMIC NERVOUS SYSTEM** (next lecture)

NEURON

- Basic component of the nervous system
- (Though there are many supporting elements.)

NEURONS – Properties that makes them special

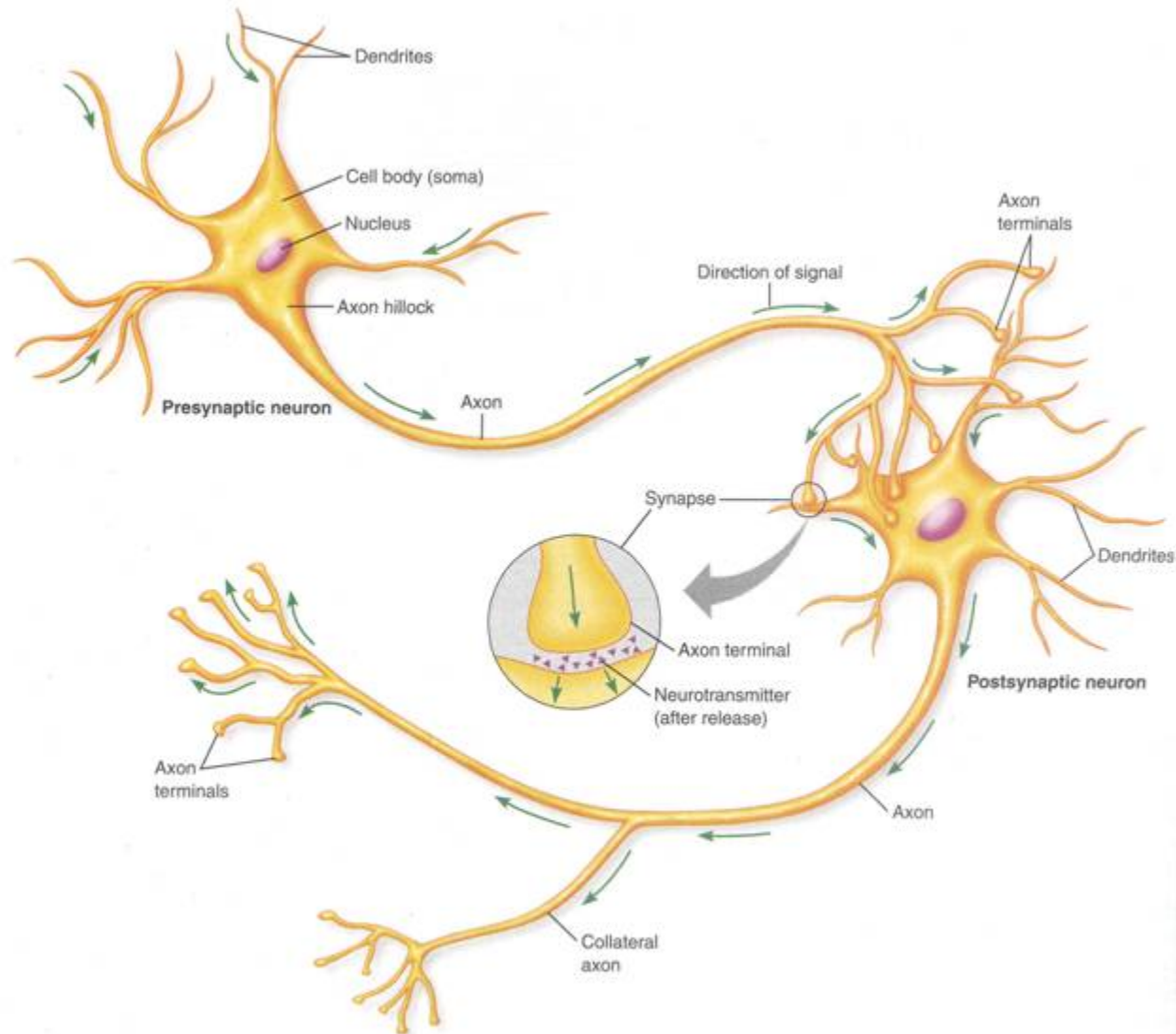
- They have ability to respond to stimuli.
- They have ability to CONDUCT AN ELECTRICAL SIGNAL.

Standard Warning:

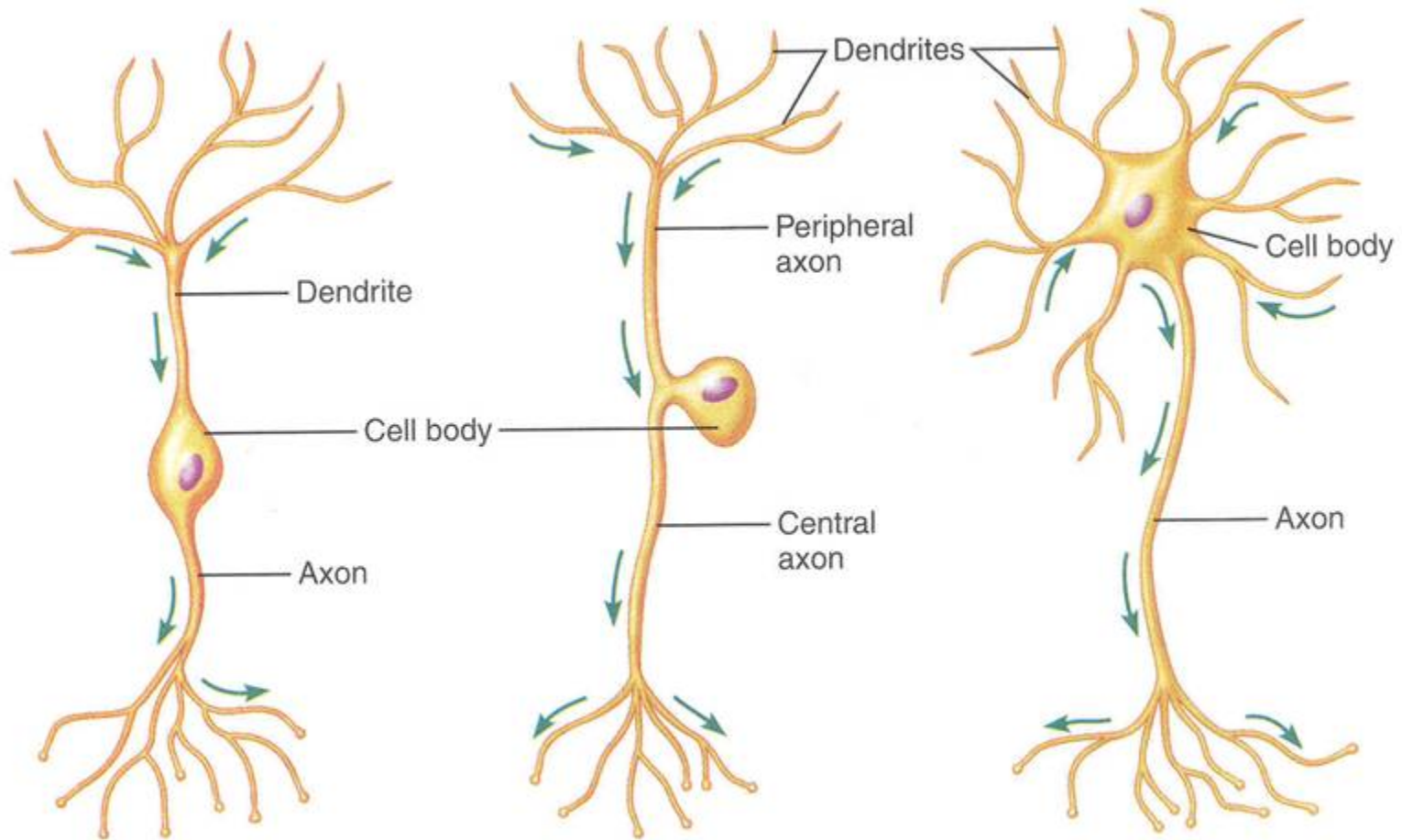
If you do not remember the basic components of a cell, review your Biology 100 (or equivalent) notes, or early chapters of the Physiology text.

(If you're here without having taken a prerequisite biology course, well, uh, actually...you're not supposed to be here...)

ANATOMY OF A NEURON



Different Neuronal Morphologies



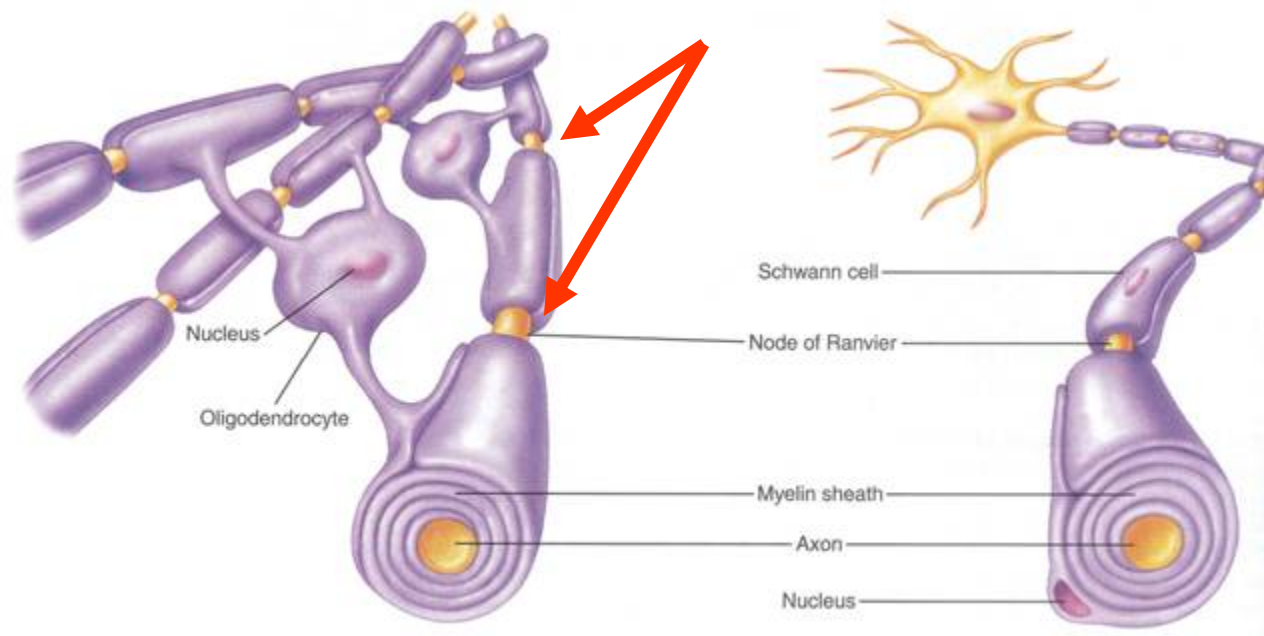
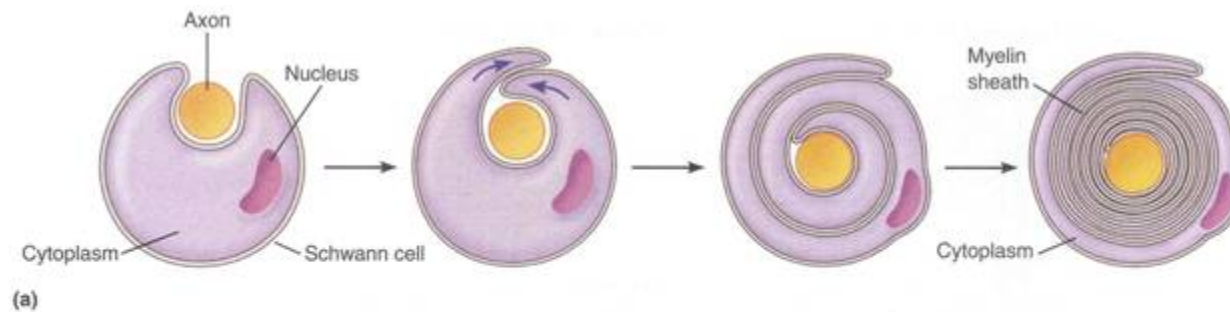
SIGNAL PATHWAYS

- Something causes change in property of neuron cell membrane.
- This causes an electrical signal to enter cell, usually via **dendrite**(s).
- Travel along cell.
- Usually leave via **axon**.
- SIGNAL DEGRADATION IS REPRESSED DUE TO INSULATION BY **MYELIN**.

INSULATION OF NEURONS

- To prevent electrical charge and current from “leaking out”, axons are insulated by a special type of material called MYELIN.
- In peripheral nervous system, myelin is produced by non-neural cells called **SCHWANN CELLS**.
- In central nervous system, myelin is produced by non-neural cells called **OLIGODENDROCYTES**.

Layers of myelin are wrapped around most of axon. Unlike that of an electrical cord, the covering is not continuous. These brief interruptions are called neurofibril **NODES**.



Larger Scale Organization of Nervous Tissue

- Many neurons gathered together = **NERVE**.
- (Frequently) cell bodies are concentrated in a spot along a nerve, forming a swelling called a **GANGLION** (plural = ganglia).

PHYSIOLOGY OF NEURONAL IMPULSES

- Neurons “maintain a resting electrical charge”.
- The plasma membrane (cell membrane) is said to be **POLARIZED**.
- This means – at rest, the cell membrane has an electrical charge. In the case of human neurons, it is negative 70 millivolts, or -70 mV.

-70 mV RESTING ELECTRICAL CHARGE

- This is the difference in charge between the outside of the cell and the inside of the cell.
- The **charge difference** is due to the differential distribution of charged ions on either side of the membrane.
- The primary ions involved are potassium (K^+) and sodium (Na^+)

CHARGE DIFFERENCE

- Energy is required to maintain the neuron's charge difference.
- Sodium ions are actively pumped out of the cell (active transport).
- Thus, more sodium ions outside of cell membrane than inside.
- This is maintained by the **sodium-potassium pump** (which is powered by ATP).
- The **sodium potassium pump** functions CONTINUOUSLY to maintain the charged membrane.

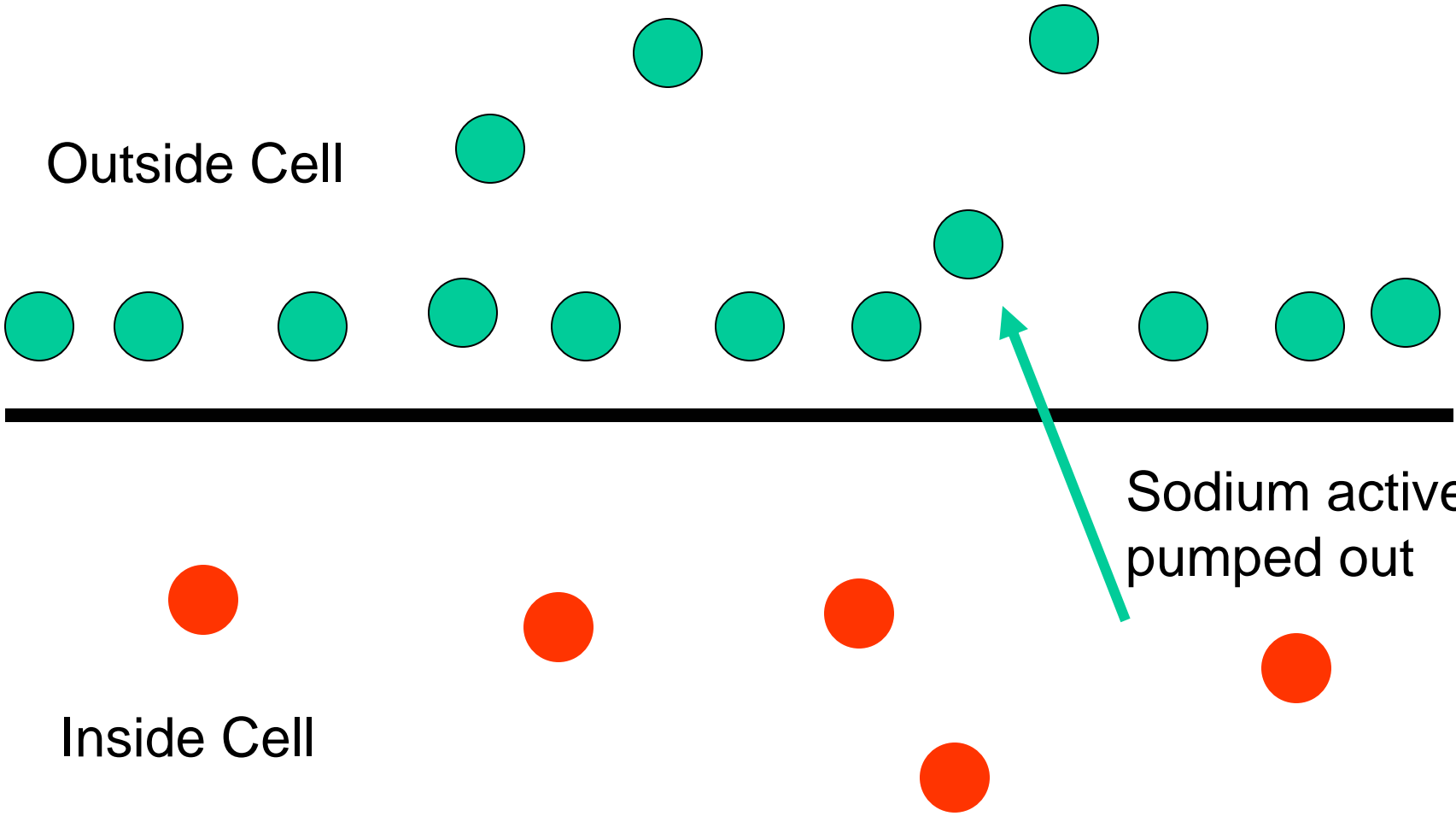
● Na+

● K+

Outside Cell

Inside Cell

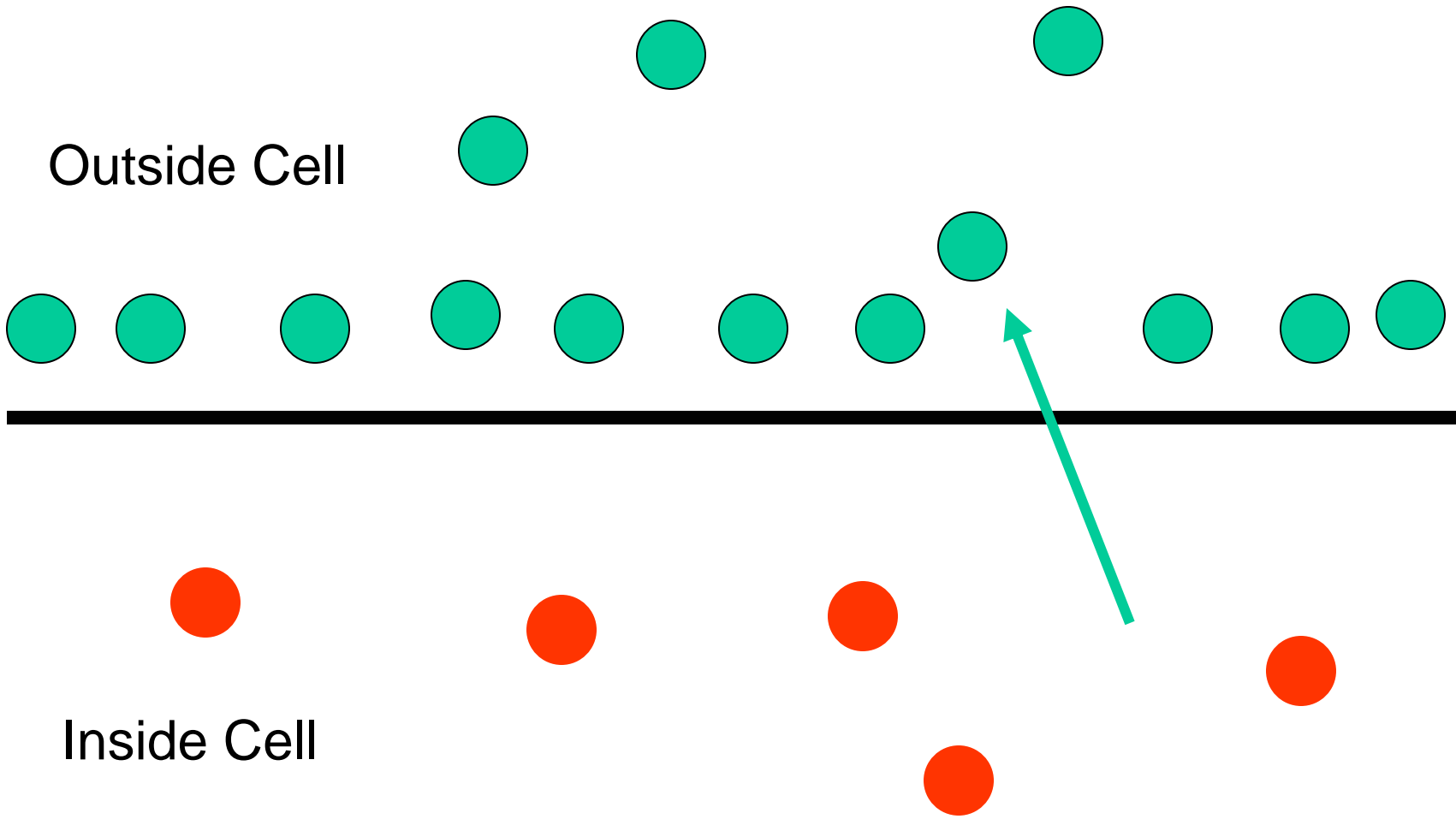
Sodium actively
pumped out



● Na⁺

Outside relatively more positive, thus
inside relatively more negative...

● K⁺



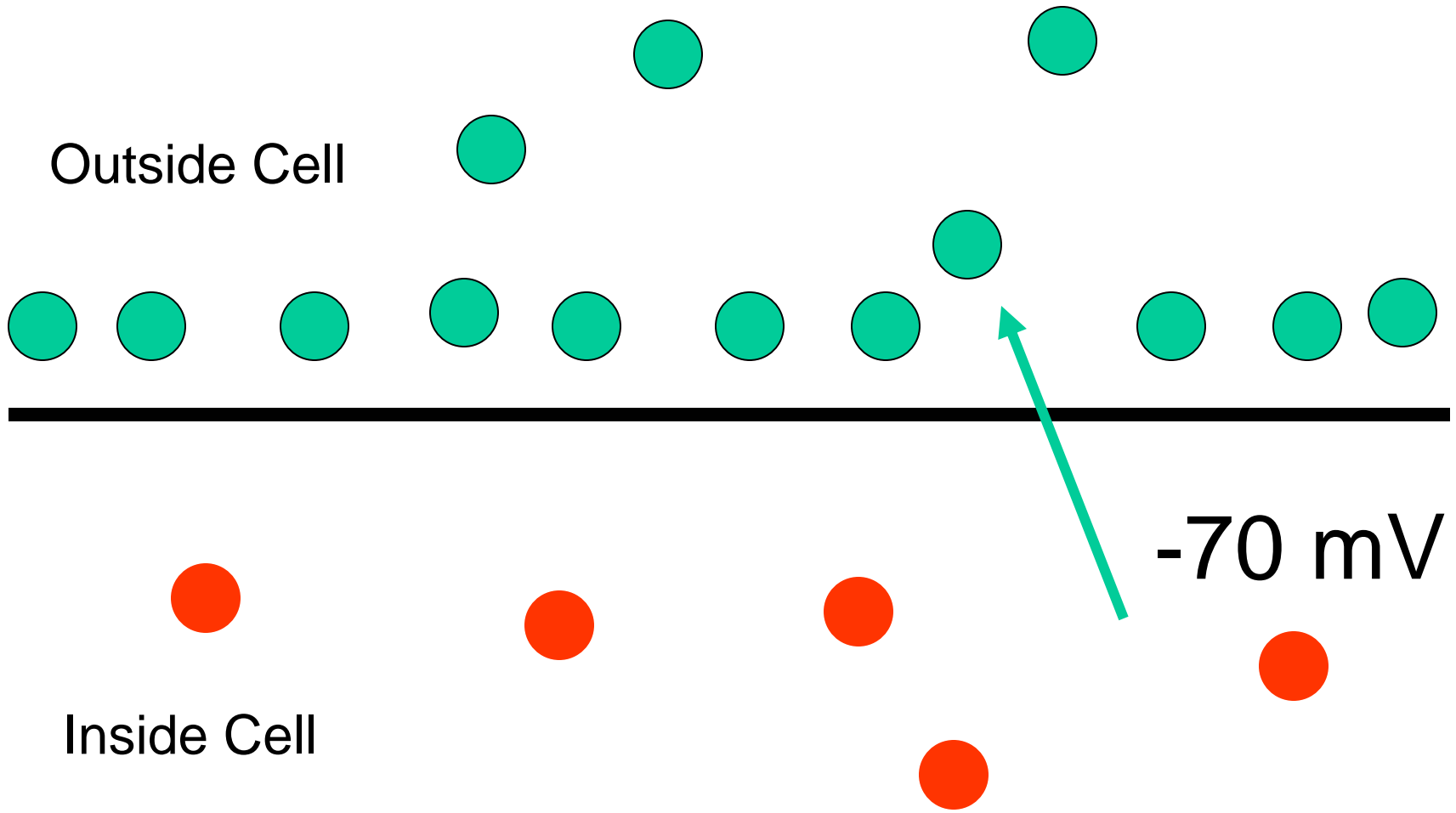
Outside Cell

Inside Cell

● Na+

Outside relatively more positive, thus
inside relatively more negative...

● K+



Outside Cell

-70 mV

Inside Cell

TRANSMISSION of Nervous Impulses

- A **CHANGE IN THE ELECTRICAL POTENTIAL** (the -70 mV charge) across the cell membrane is usually what triggers an impulse.
- This **CHANGE IN THE ELECTRICAL POTENTIAL** is usually caused by a change in the **PERMIABILITY OF THE CELL MEMBRANE**.

PERMIABILITY CHANGE OF PLASMA MEMBRANE

- This can be caused by **STIMULUS**:
 - Signal from neighboring neuron
 - Deformation of receptor cell of a special sense.
-
- PERMIABILITY CHANGE allows ions to move across membrane.

THRESHOLD STIMULUS

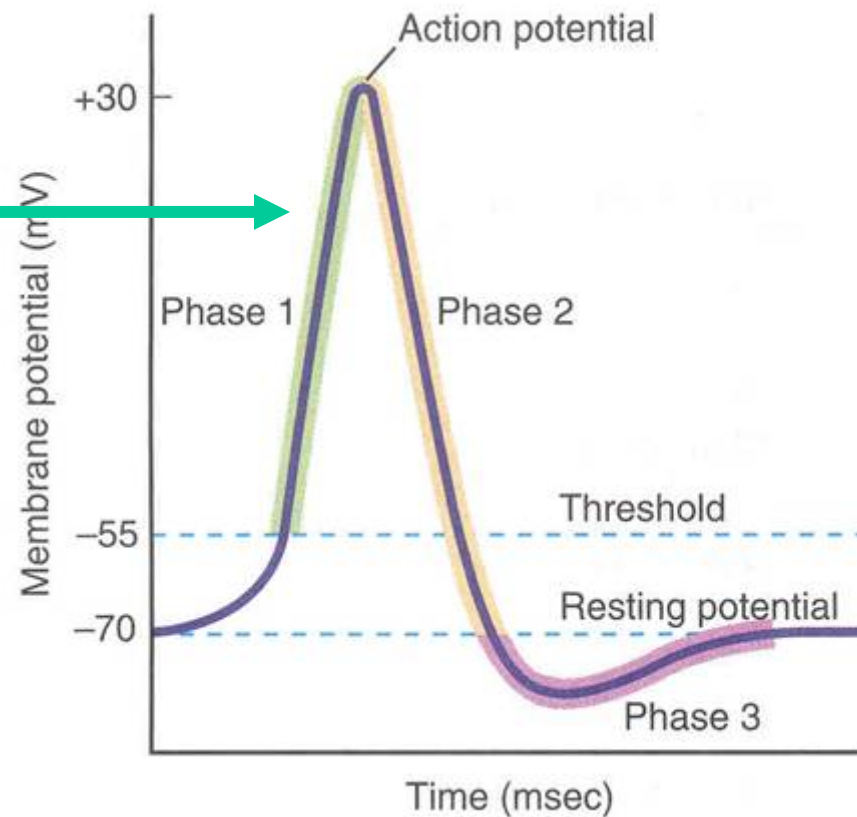
- If a stimulus is strong enough (or if enough stimuli combine) to trigger an impulse, it is referred to as a **THRESHOLD STIMULUS**.
- When this threshold stimulus is reached, permeability of the membrane changes enough to allow Na^+ ions to flood in.

PERMIABILITY CHANGE allows ions to move across membrane.

- If inside is more negative,
- And, if there is more positive Na^+ outside, they will tend to flood in.
- This changes the distribution of ions relative to the cell membrane.
- Changing the “polarized” condition of the membrane is called **DEPOLARIZATION.**

DEPOLARIZATION initiates what is called an **ACTION POTENTIAL**

DEPOLARIZATION initiates what is called an **ACTION POTENTIAL**



Once a small region of an axon is depolarized, it can stimulate an adjacent area...

...which in turn stimulates, the next...

...and the next...

...and so on...

...and so on.

This, directional, continued depolarization along an axon is what is known as the **ACTION POTENTIAL.**

REFRACTORY PHASE

- Shortly after a region is depolarized, the sodium pump works very hard to re-establish the resting potential.
- During this period, that particular region of the axon can't respond to stimuli.
- This period when it can't respond is called the **REFRACTORY PHASE**.

REFRACTORY PHASE

- A period when an axon can't respond (the **REFRACTORY PHASE**) has important implications:
 1. A spot just stimulated can't be immediately restimulated, so only the next spot can be. In otherwords, a signal can't double back on itself.
 2. Neuronal Transmission is thus **UNIDIRECTIONAL**.

SPEED OF CONDUCTION

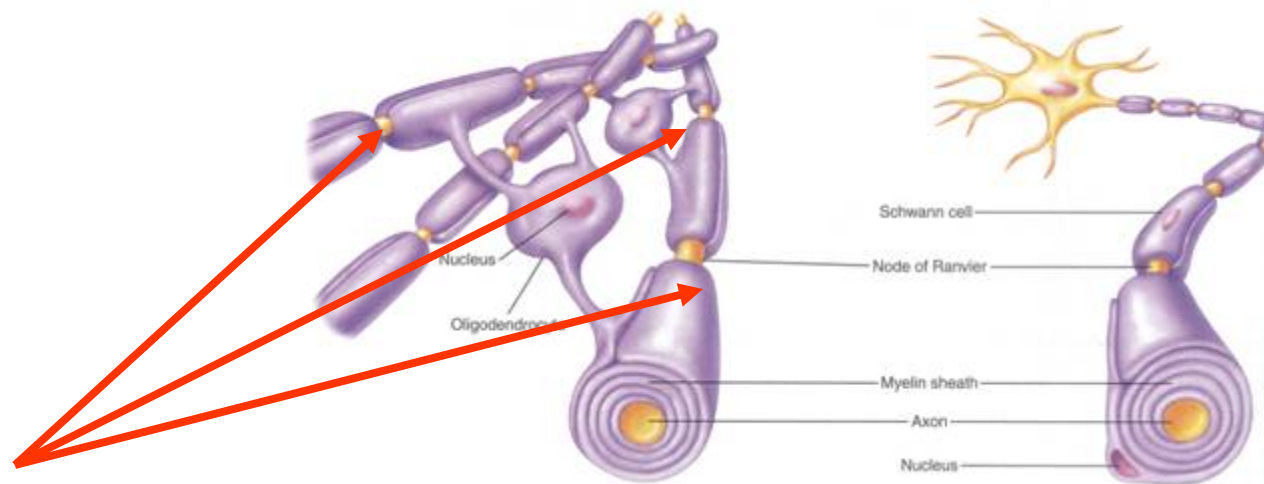
- Fast (electrical)
- (But not the speed of light...)
- In human neurons that are insulated, about **100 meters/second**.

SPEEDING UP CONDUCTION - I

- Insulating material (myelin) helps a lot.
- BUT, if there is insulation in the way, how can ions move due to depolarization?
- Remember, the NODES. There are intermittent spots without insulation.

SPEEDING UP CONDUCTION - II

- Sodium channels are concentrated near the **NODES**, and the depolarization literally skips from node to node, increasing speed of transmission significantly.



Important functions of MYELIN

- 1. **Insulates** axon so that it is easier to maintain differential resting potential.
- 2. **Speeds** up conduction of action potentials.
- 3. **Prevents “cross-talk”** between different neurons grouped in a single nerve.
(remember sensory and motor signals are traveling in different directions).

NEUROTRANSMITTERS

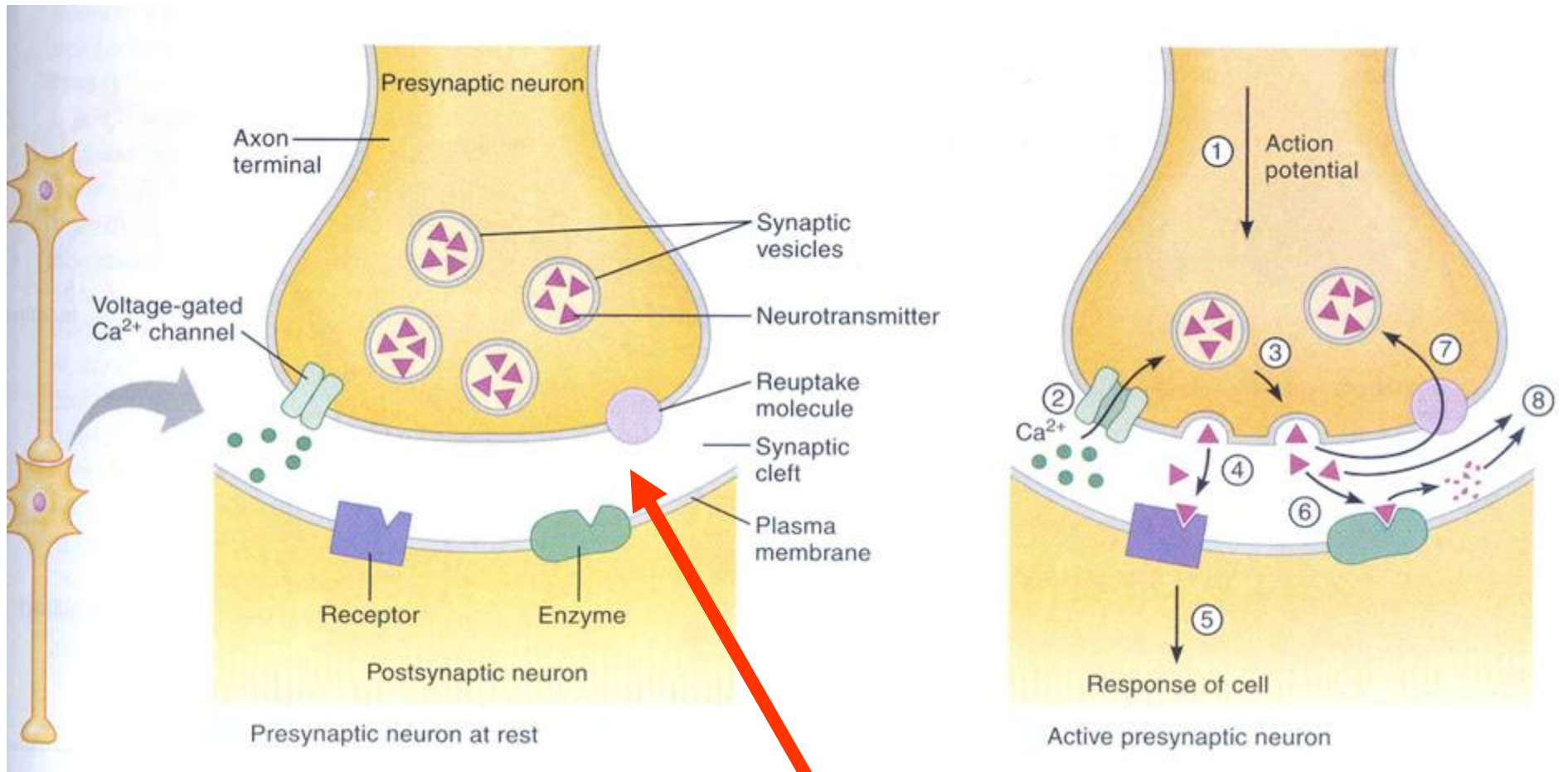
- The nervous system is an ELECTRICAL SYSTEM.
- However, it is important to note that COMMUNICATION BETWEEN NEURONS is via chemicals.
- These chemicals are called NEUROTRANSMITTERS.

NEUROTRANSMITTER RELEASE - I

- When depolarization of an action potential gets to end of a neuron, it still allows the influx of positively charged ions.
- But in this case, the positively charged ion is **CALCIUM—Ca²⁺**
- **Ca²⁺** causes storage vesicles at end of axon to fuse with plasma membrane.

NEUROTRANSMITTER RELEASE - II

- Ca^{2+} causes storage vesicles at end of axon to fuse with plasma membrane.
- The vesicles contain neurotransmitters.
- They are released into the space between neurons, the **SYNAPTIC CLEFT**.
- The distance across the SYNAPTIC CLEFT is very small, so diffusion is nearly instantaneous (less than a millisecond).
- They bind with receptors on the next neuron.



Synaptic Cleft

NEUROTRANSMITTER RELEASE - III

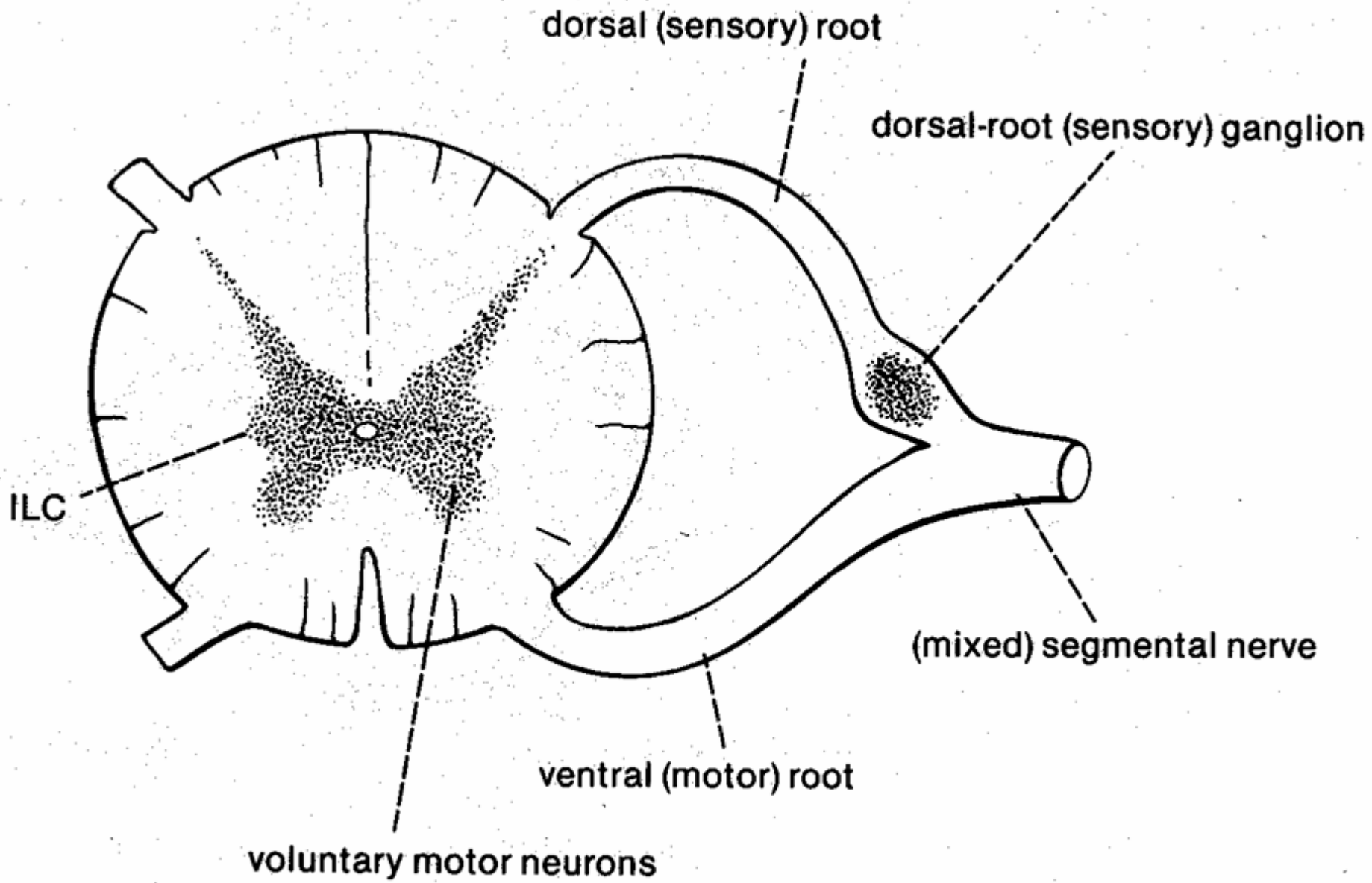
- When they bind with receptors on the next neuron...
- ...they change the configuration of the cell membrane of the next membrane.
- This changes permeability, and it all starts over again.

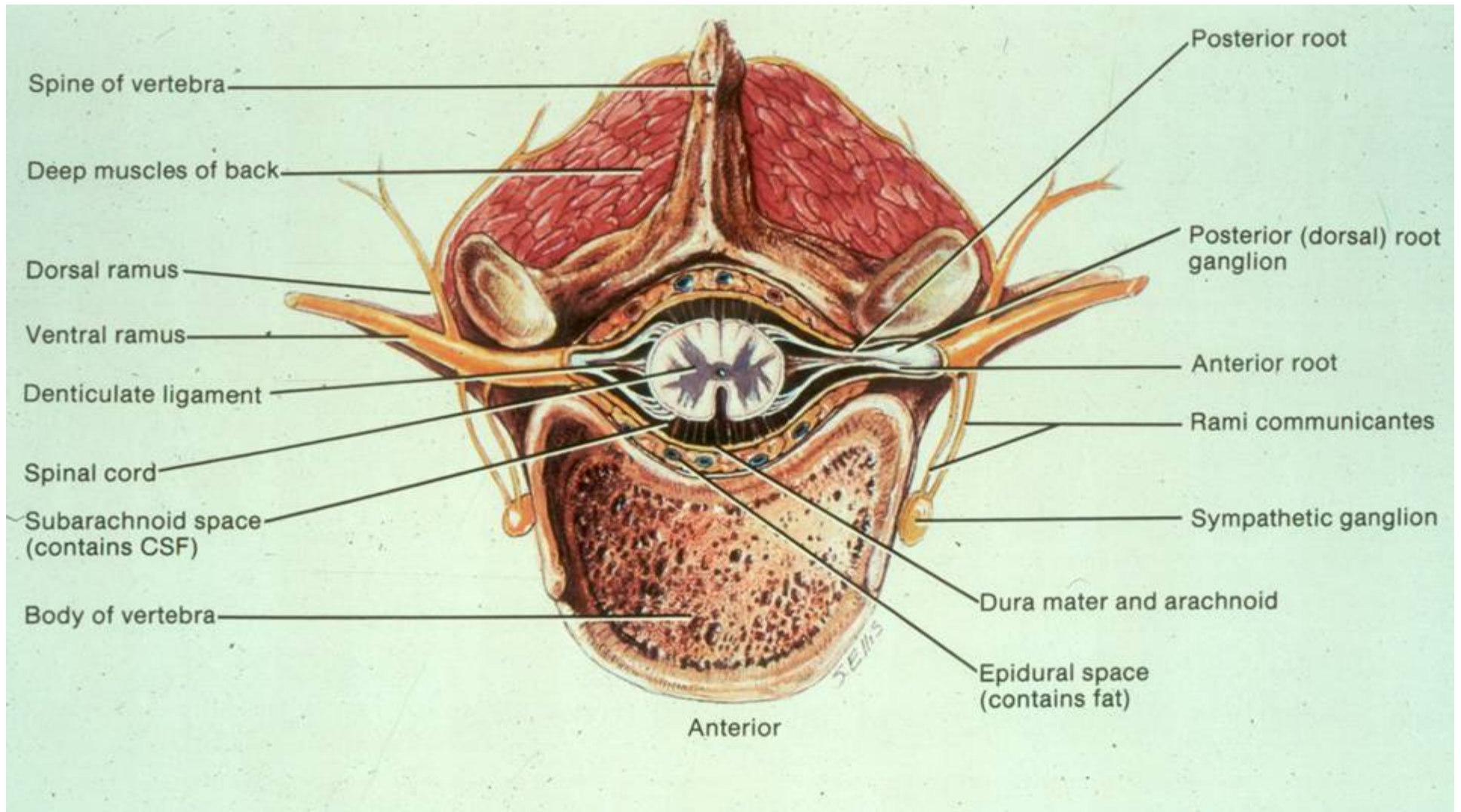
NEUROTRANSMITTERS IV

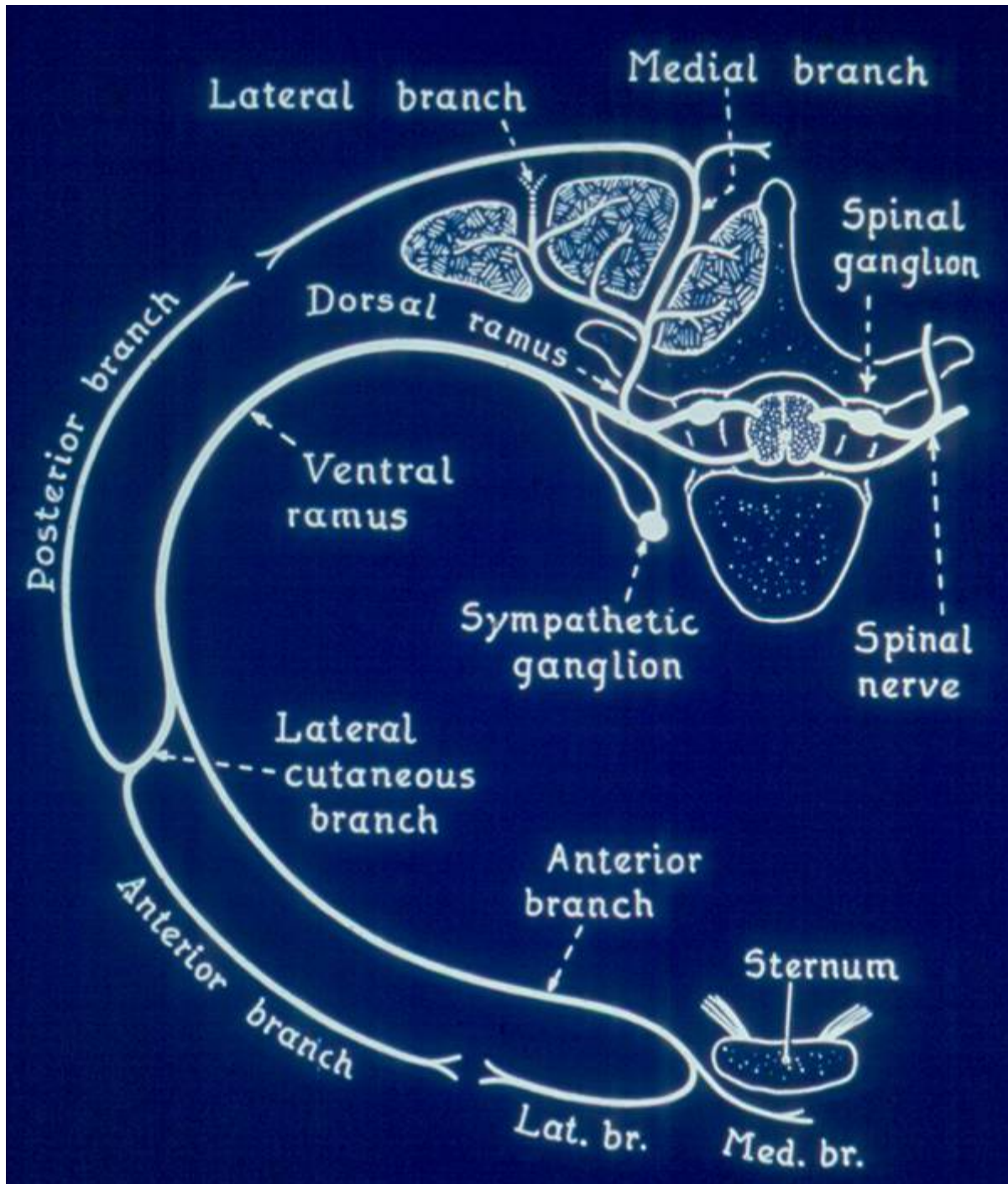
- Neurotransmitters are broken down and recycled VERY quickly (MILLISECONDS).
- This prevents the signal from going on forever.
- Some NEUROTOXINS prevent the breakdown of neurotransmitters, so they keep firing, and when stuck in firing mode, this is one type of **PARALYSIS**.

ORGANIZATION OF THE VOLUNTARY NERVOUS SYSTEM

**ORGANIZATON
OF A BASIC
SEGMENTAL
NERVE**







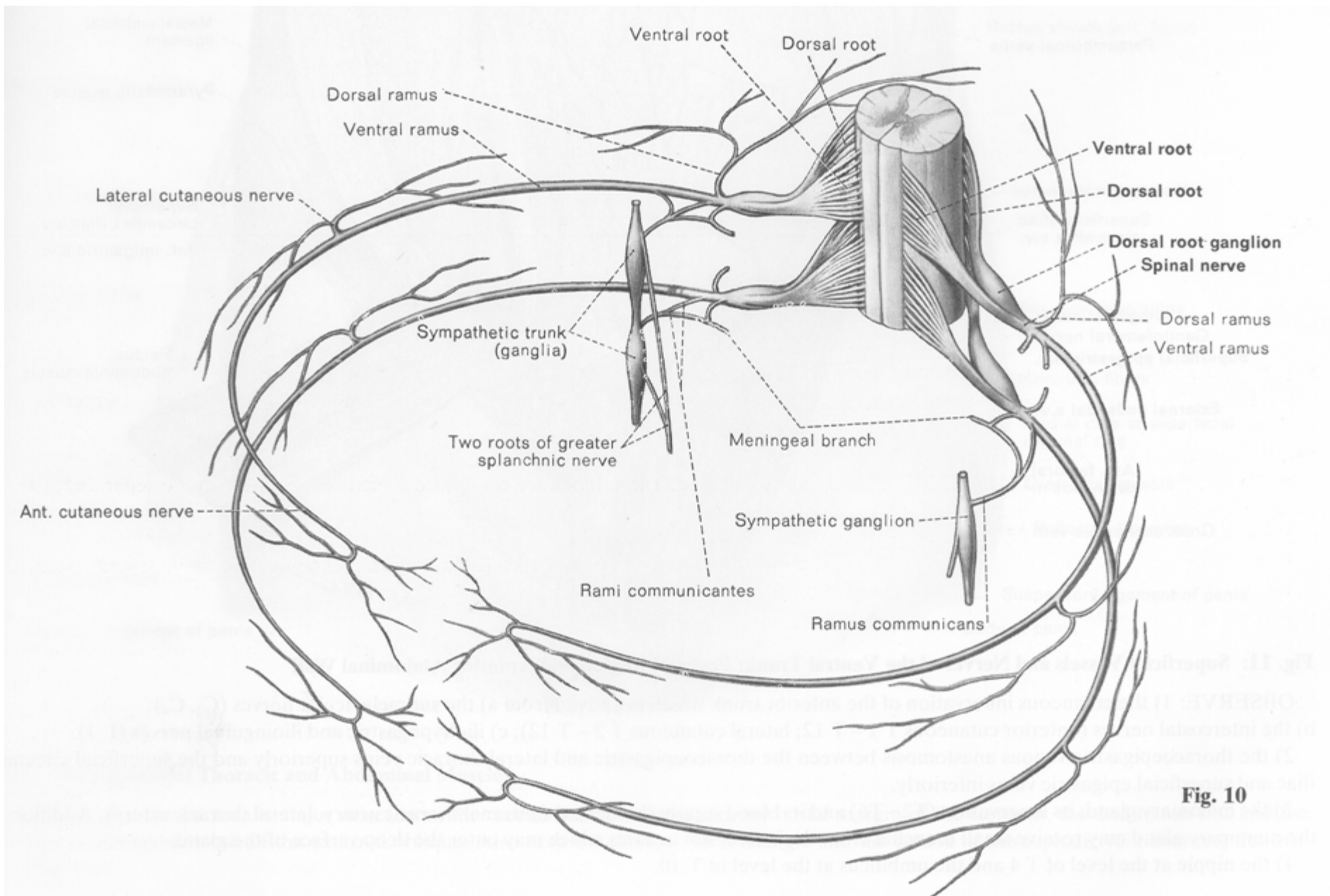
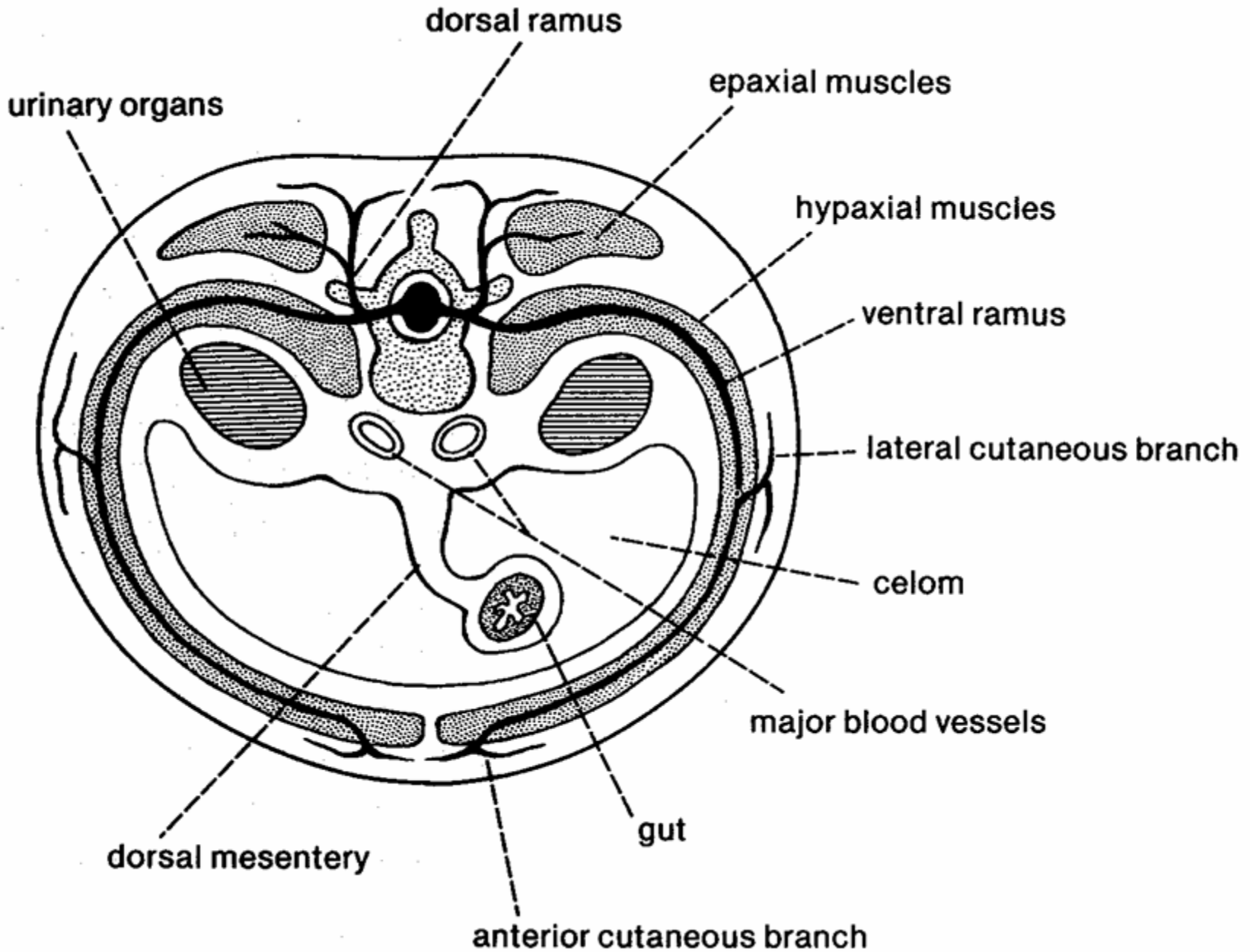
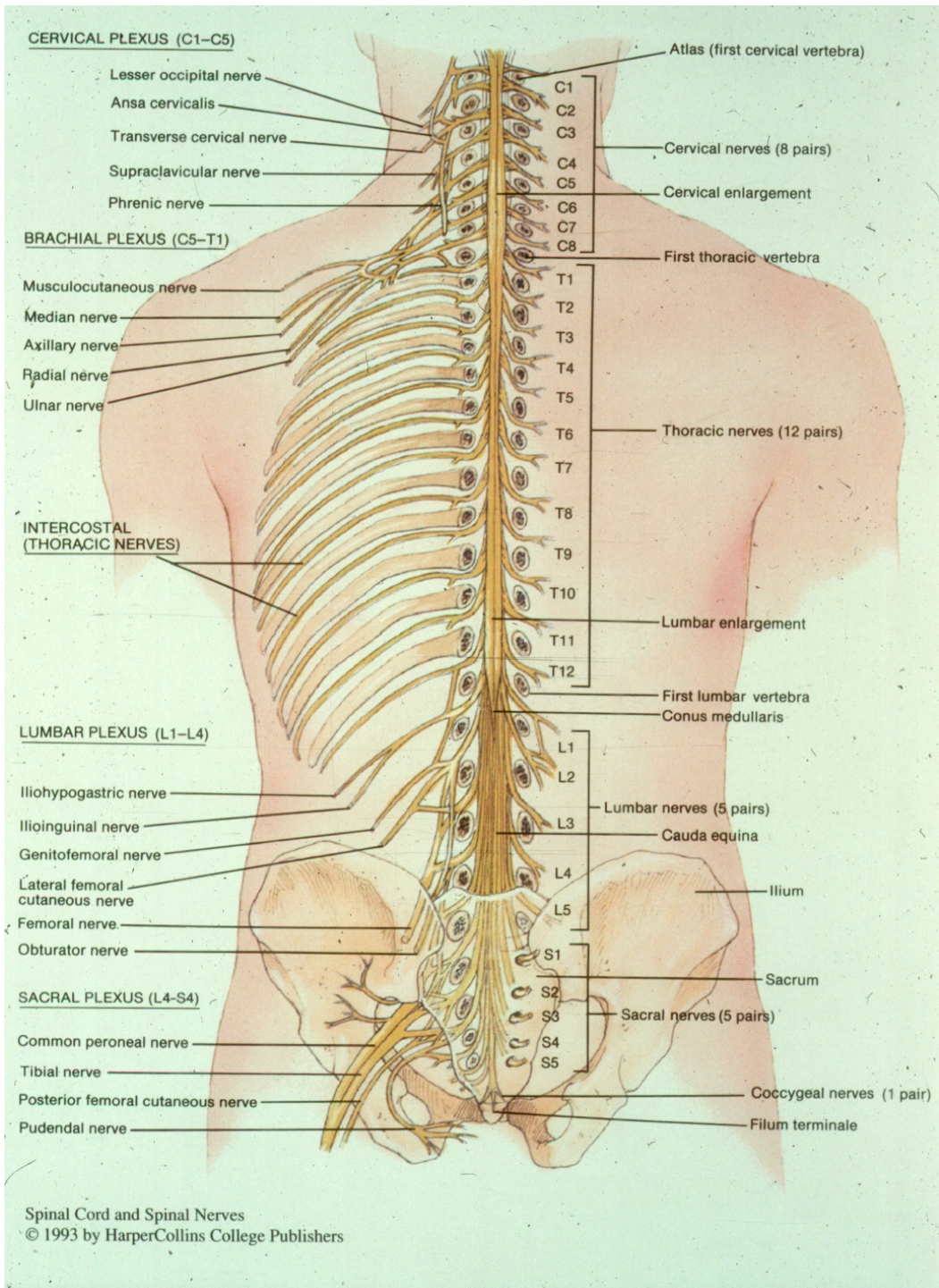
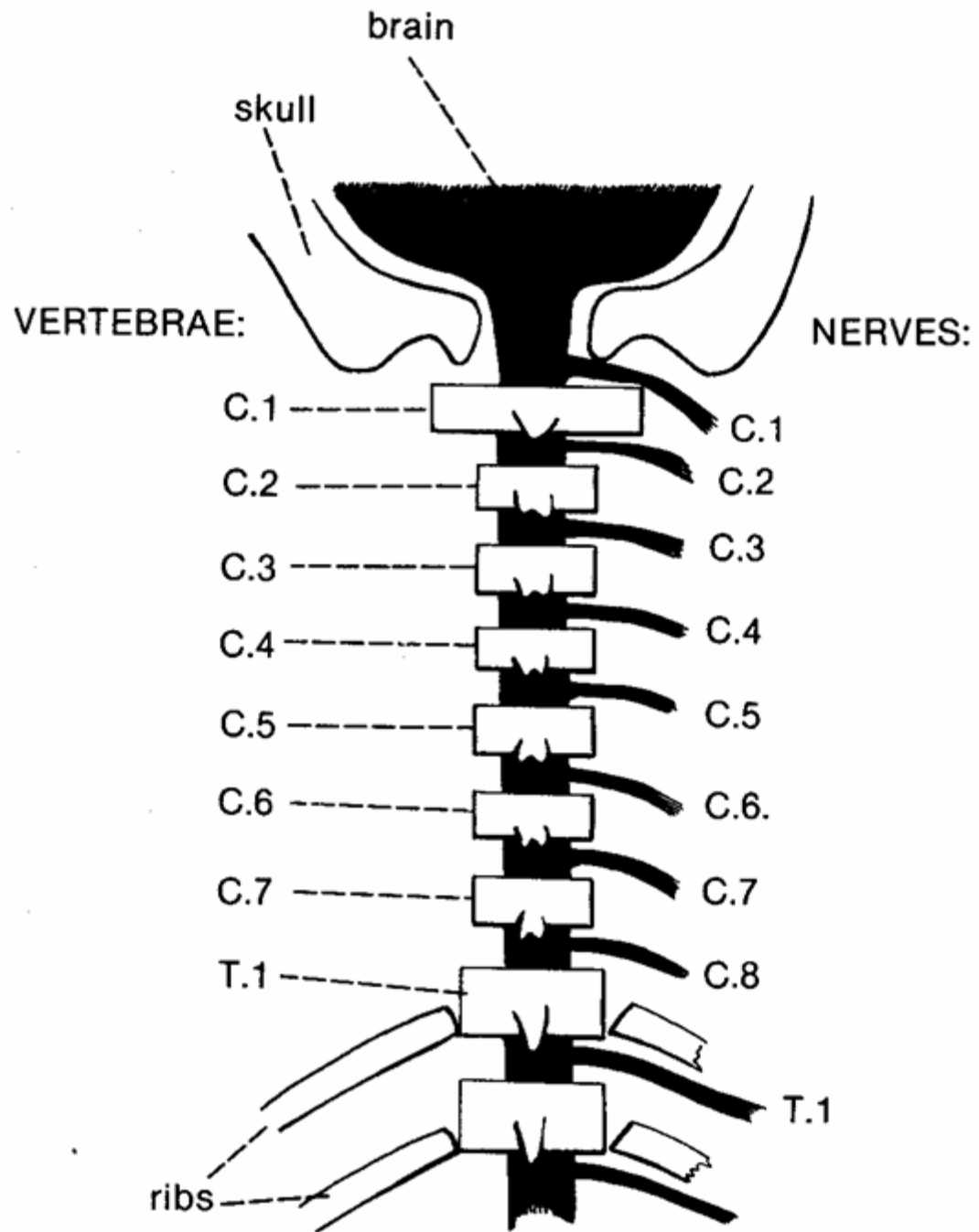


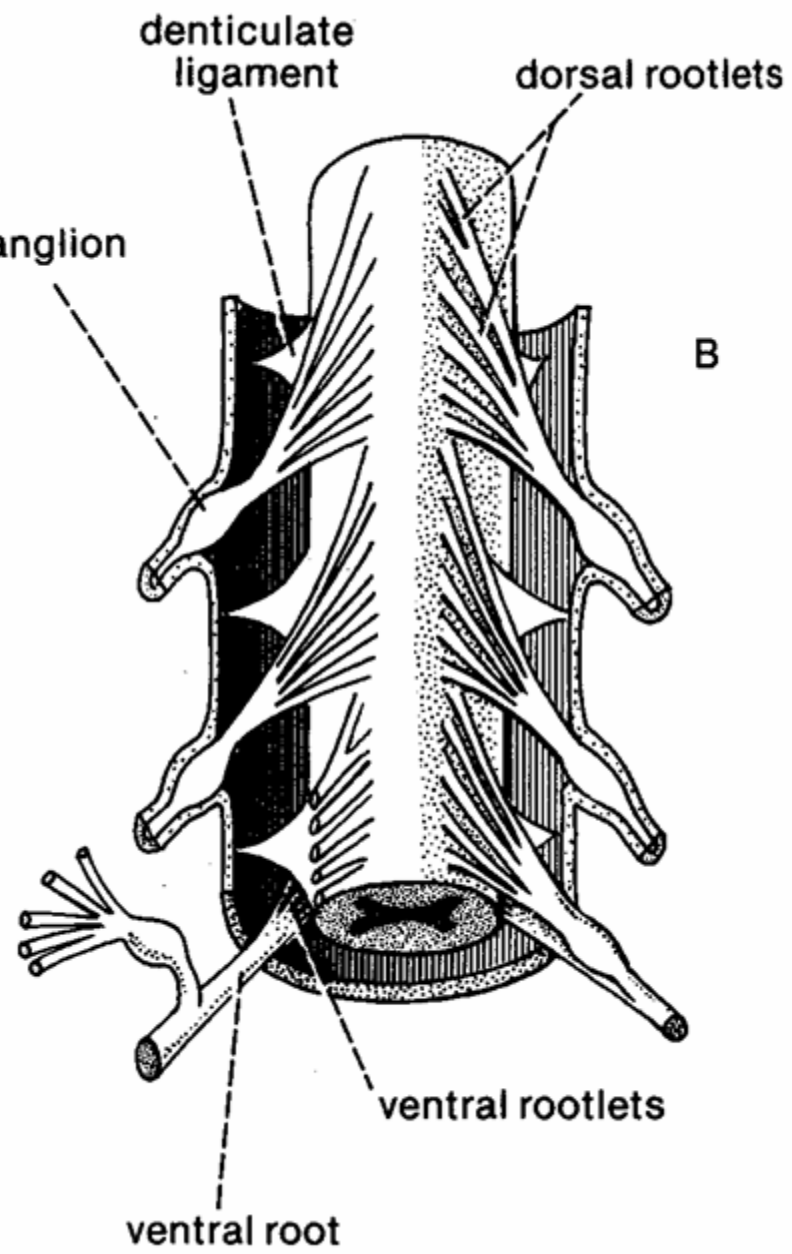
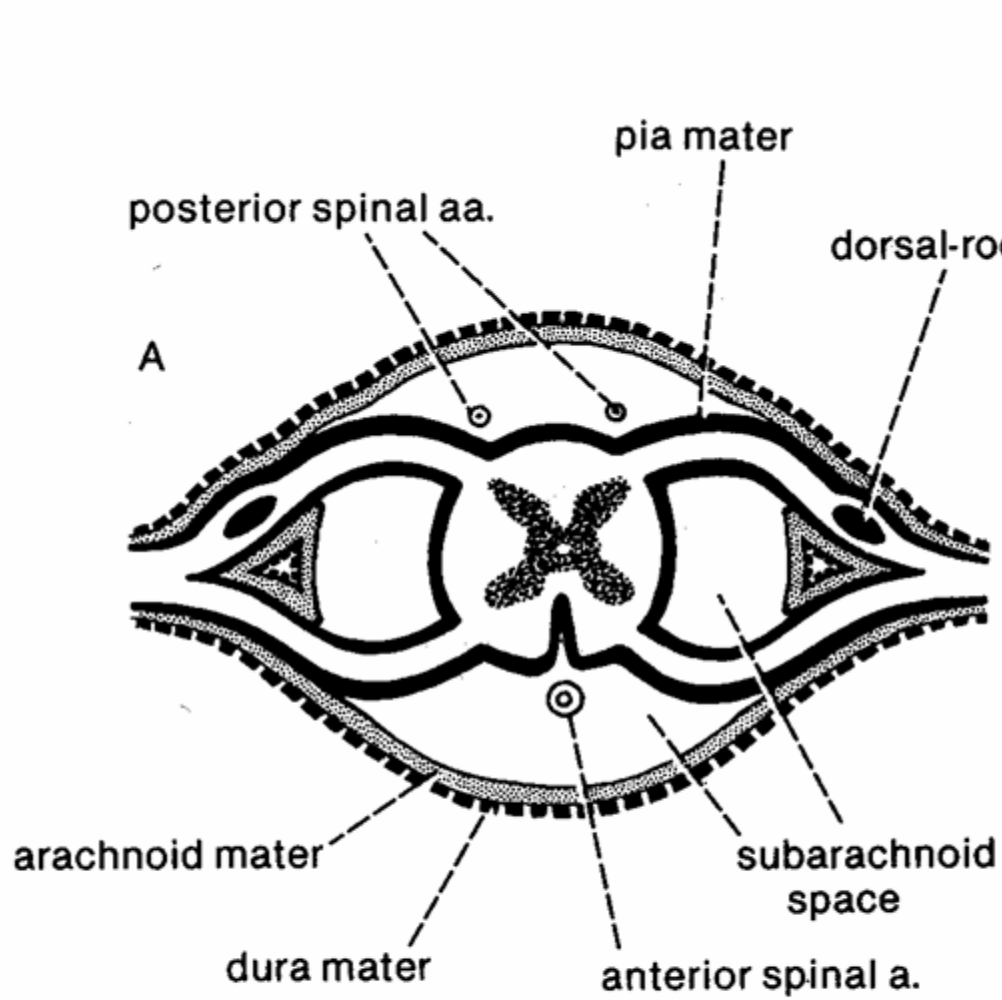
Fig. 10

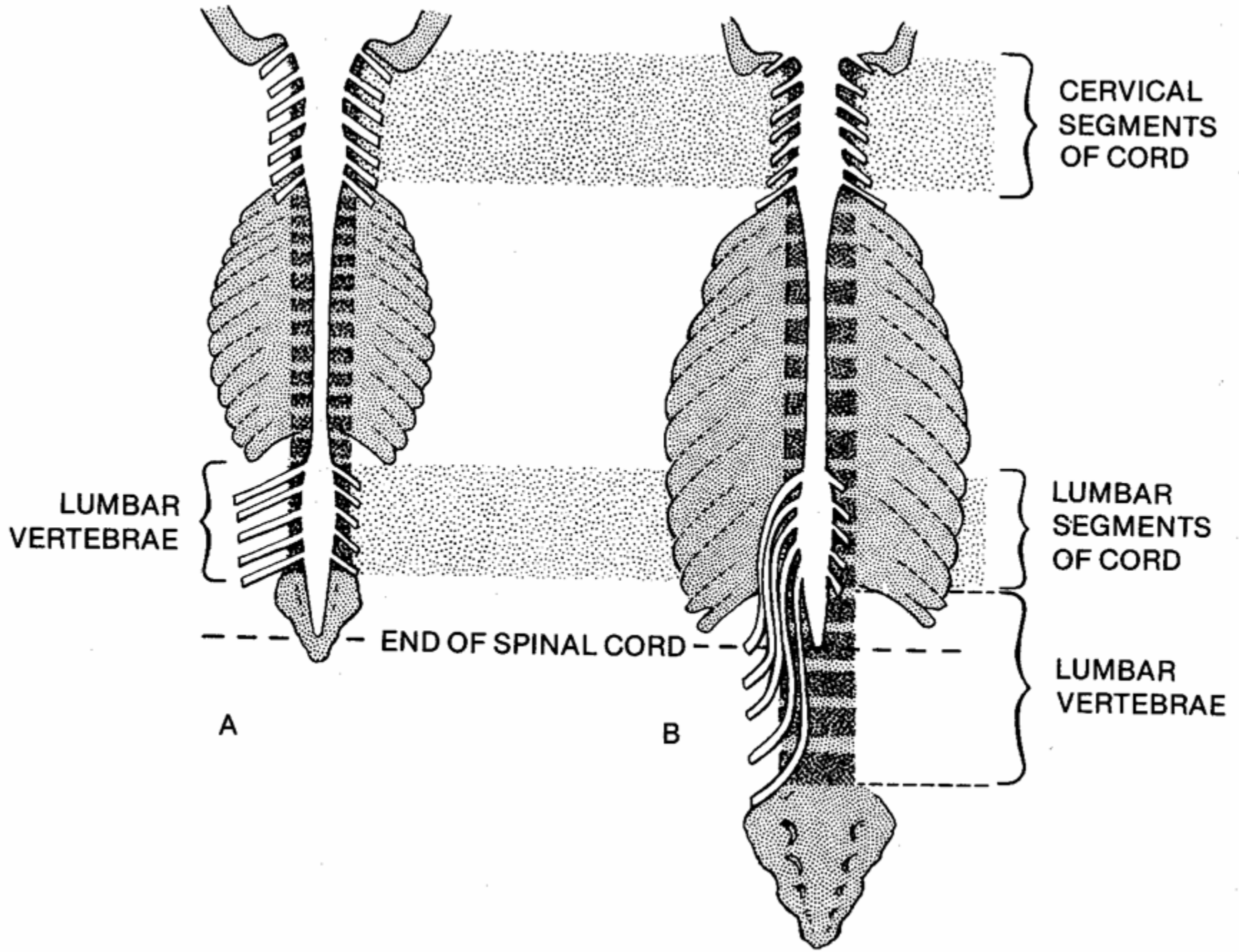
(You should be able to draw something like this!)

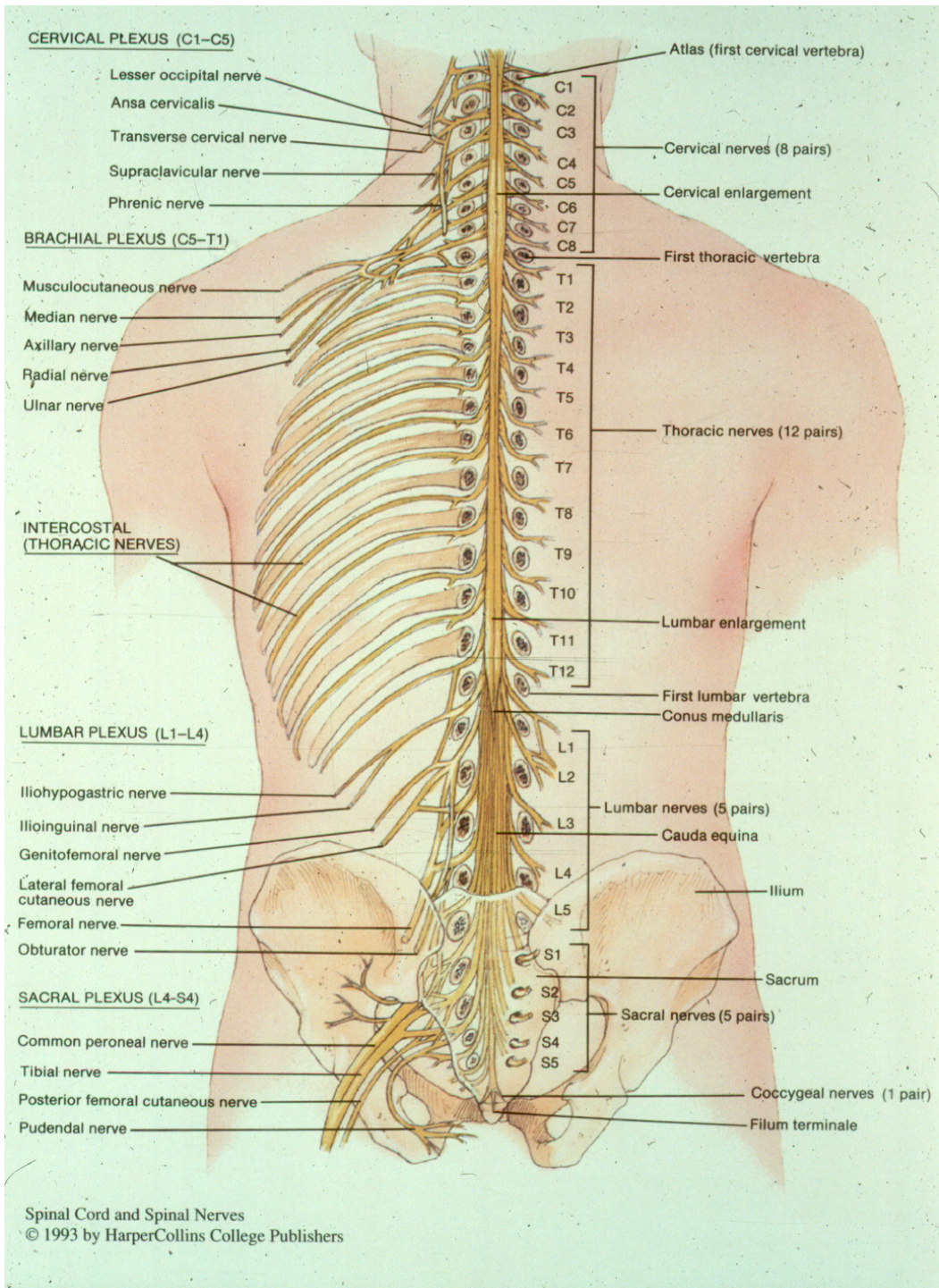












nerve roots (forming cauda equina)

