Brain and Nervous System
Gleitman *et al*. (2011), Chapter 3, Part 1

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Psych 9A / Psy Beh 11A
January 21, 2014

Chapter Topics

- The Organism as a Machine
- Building Blocks of the Nervous System
- Communication among Neurons
- Communication through the Bloodstream

- Methods for Studying the Nervous System
- The Architecture of the Nervous System
- The Cerebral Cortex
- Plasticity

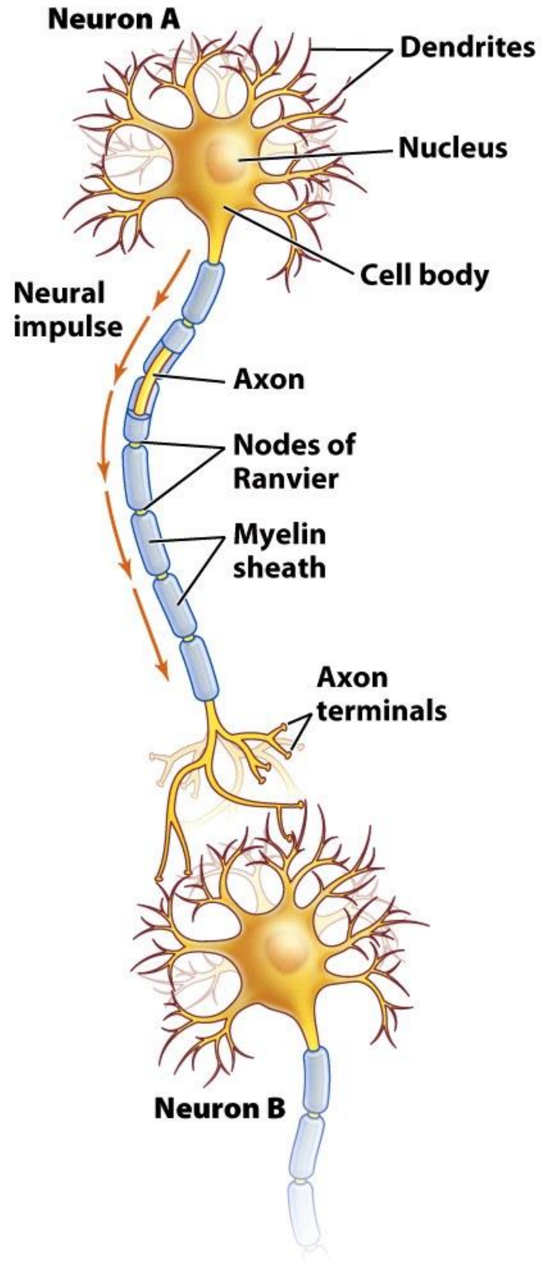
The Organism as a Machine

- Descartes: energy from the outside is reflected by the nervous system back to an organism's muscles (*reflex*)
    - a stimulus excites a sense organ
    - which transmits excitation up to the brain
    - which relays the excitation down to a muscle or gland
    - producing action
- Descartes: The ability to choose different actions in response to a stimulus depends on activity of the *soul.*
- Modern neuroscience research seeks more mechanistic accounts.

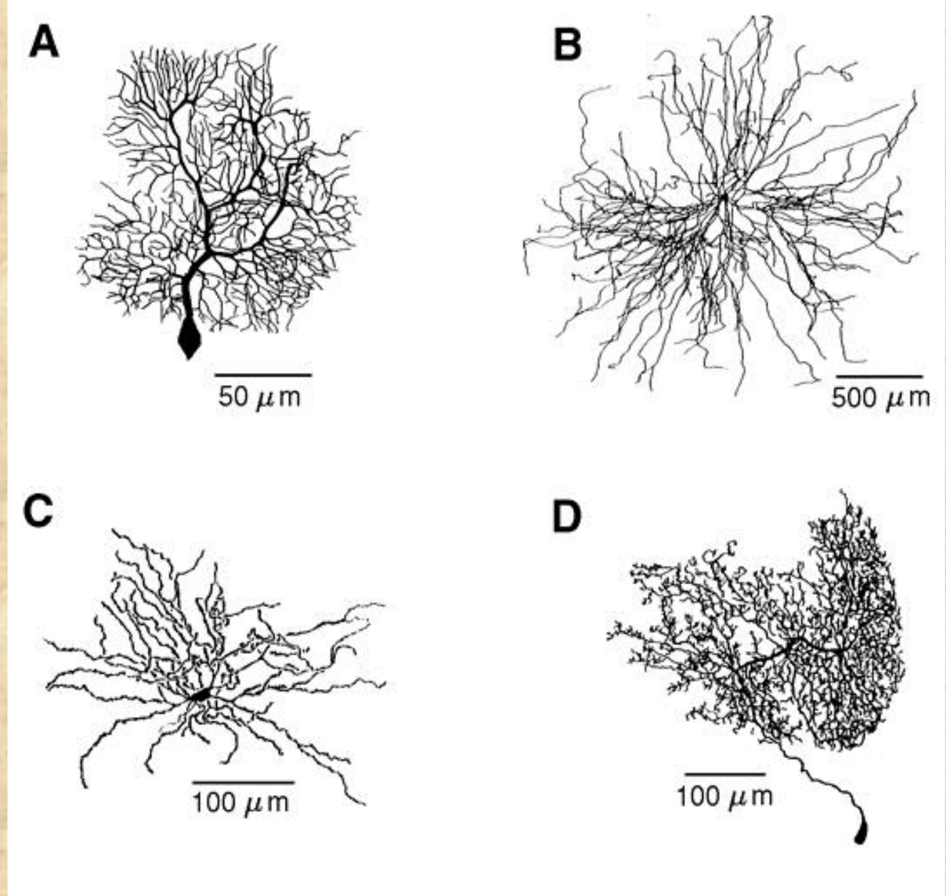
Rene Descartes
(1596-1650)

Building Blocks of the Nervous System

- The basic unit of communication in the nervous system is the *neuron.*
- Neurons have:
  - *dendrites*
  - a *cell body*
  - and an *axon*
- Our nervous systems have on the order of 100 billion neurons.
- There are *many* kinds of neurons. A simple classification:
  - sensory neurons
  - motoneurons
  - interneurons

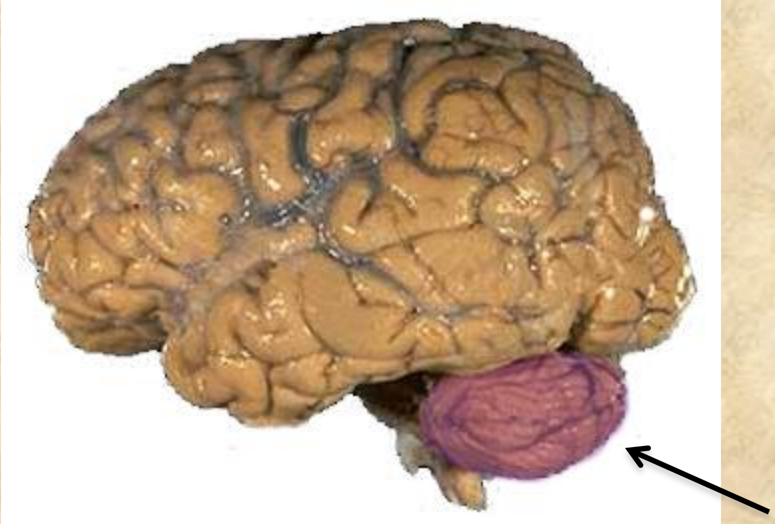


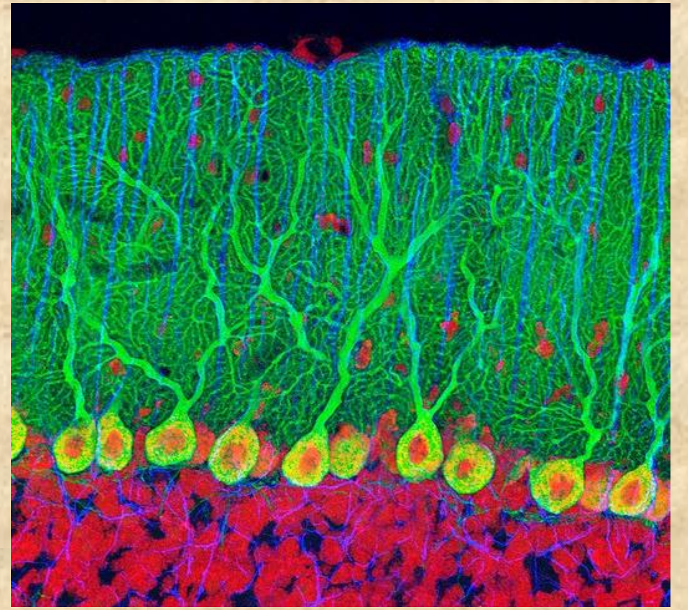
Psychology, 8/e Figure 3.3

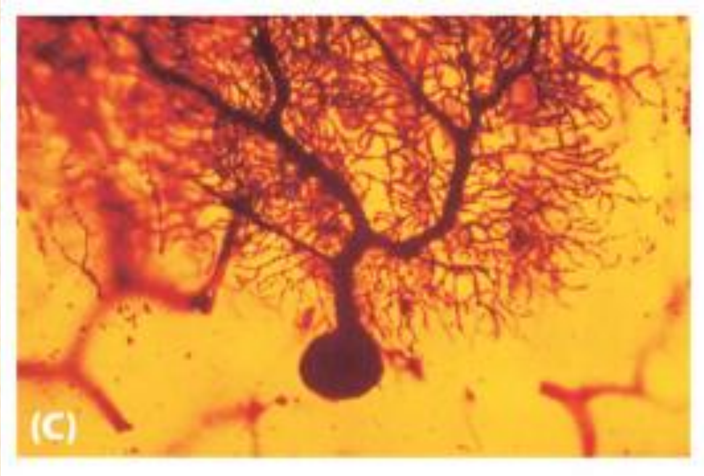


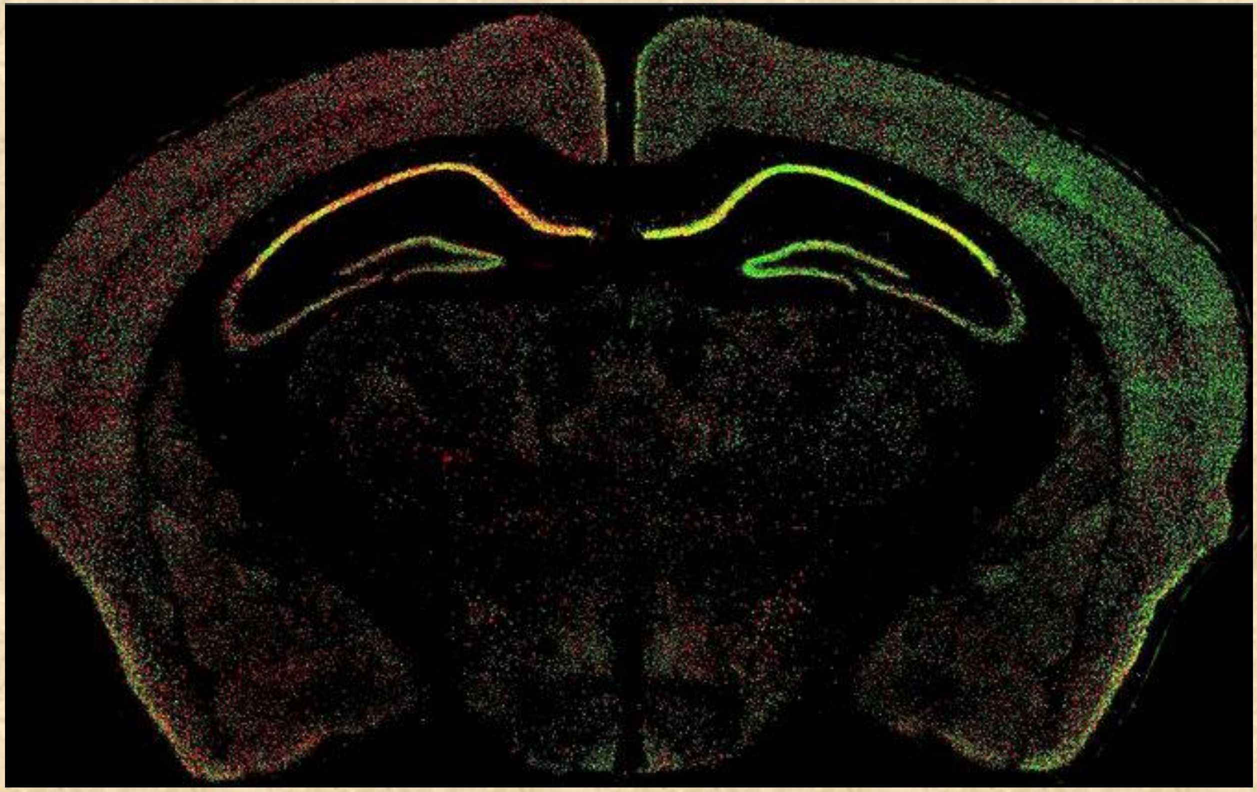
a. Purkinje cell (cerebellum). b. Alpha-motoneuron (spinal cord).
c. Spiny neuron (striatum). d. Axonless interneuron (locust nervous system).

Purkinje cells (cerebellum)









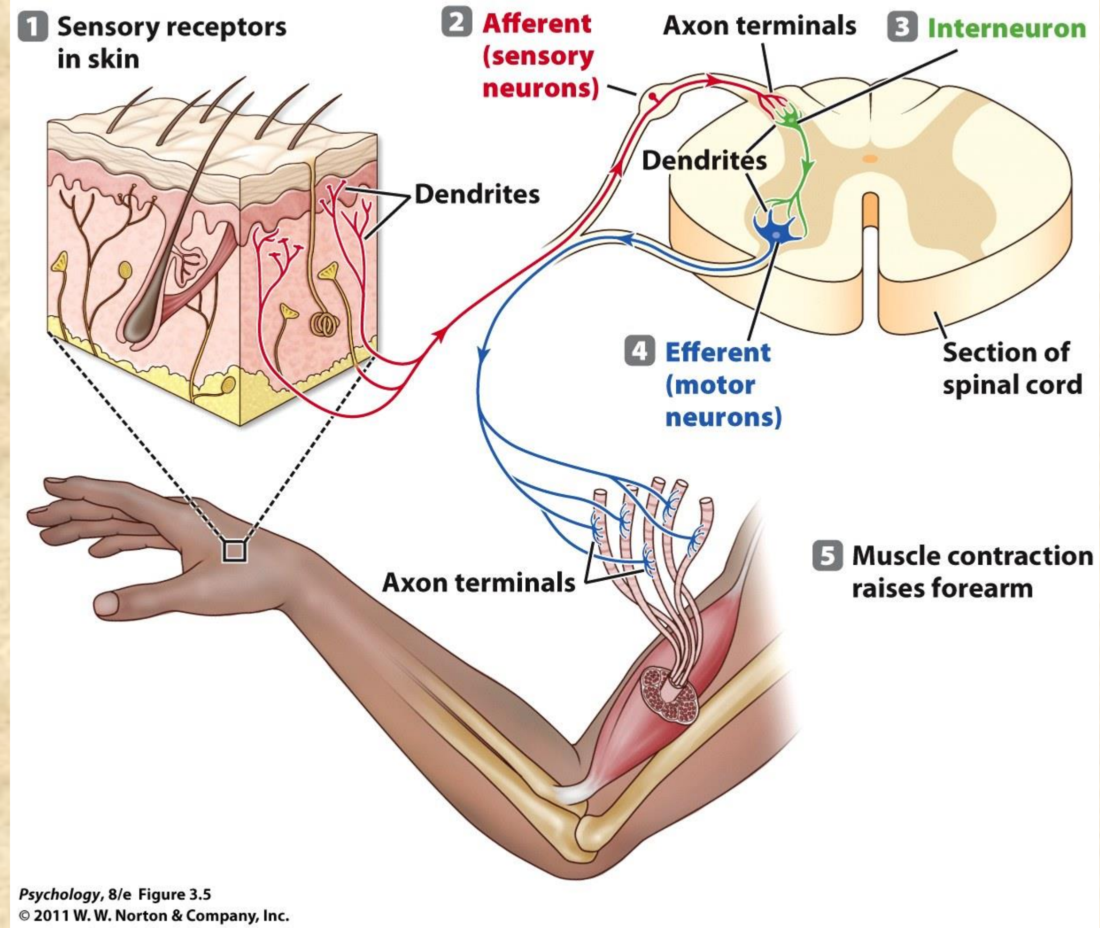
NYTimes January 21, 2014:
In a female mouse's brain, a left-to-right pattern in the silencing of the X chromosome. These patterns may influence how individual brains function. Hao Wu and Jeremy Nathans/Cell Press
http://www.nytimes.com/2014/01/21/science/seeing-x-chromosomes-in-a-new-light.html

Afferent (towards the central nervous system: CNS)

Efferent (away from or out of the CNS)

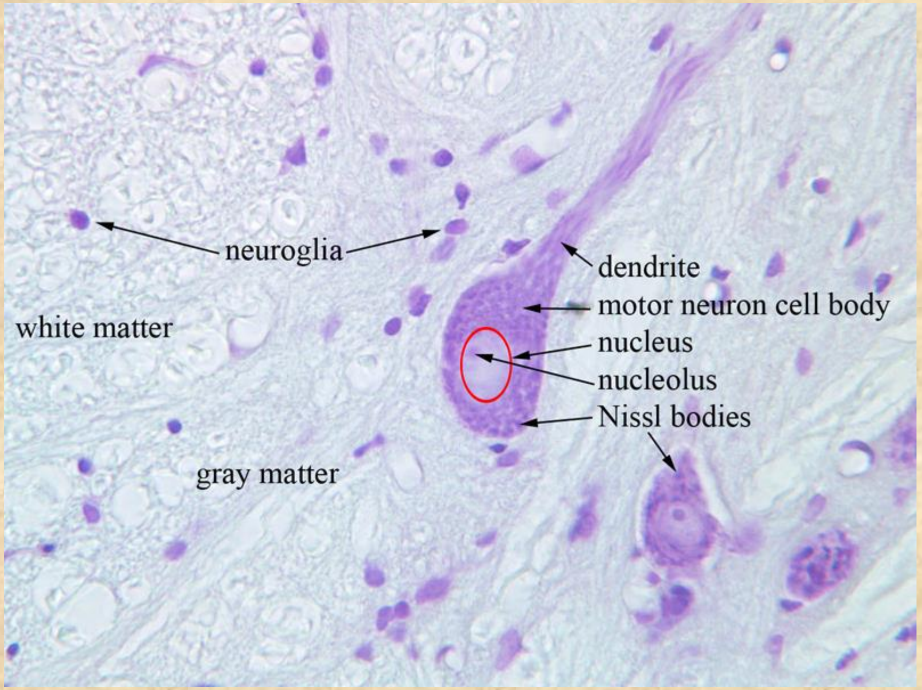
Many simple reflexes rely on circuits within the spine: no need for brain involvement.

This provides rapid responses in urgent situations (*e.g.*, burning one's finger on a stove)

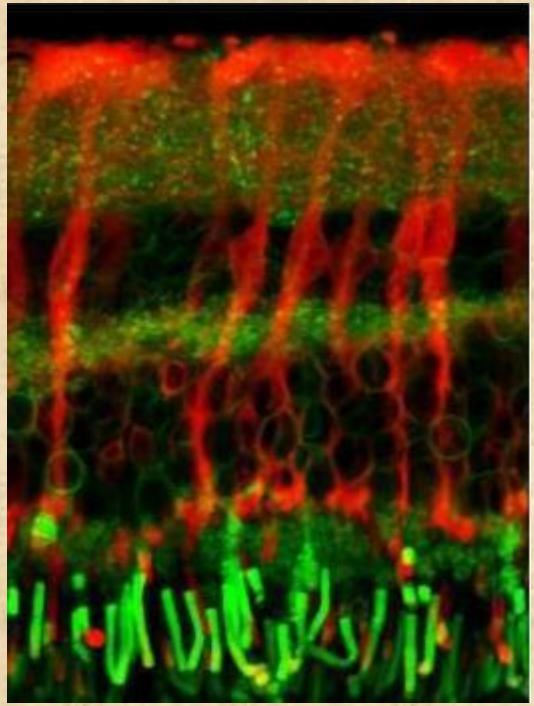


The Nervous System

- Most neurons are *interneurons* that connect to other interneurons.
- The nervous system also contains *glia*:
  - These cells have many functions, both during development and in supporting the function of the mature nervous system.
  - They may also constitute a separate, slow signal system.
  - *Oligodendrocytes*: produce myelin sheaths for neuron axons (white matter)
  - *Astrocytes*: help to mop up excess neurotransmitter, help to meet neuron metabolic needs (*e.g.*, local blood flow regulation)



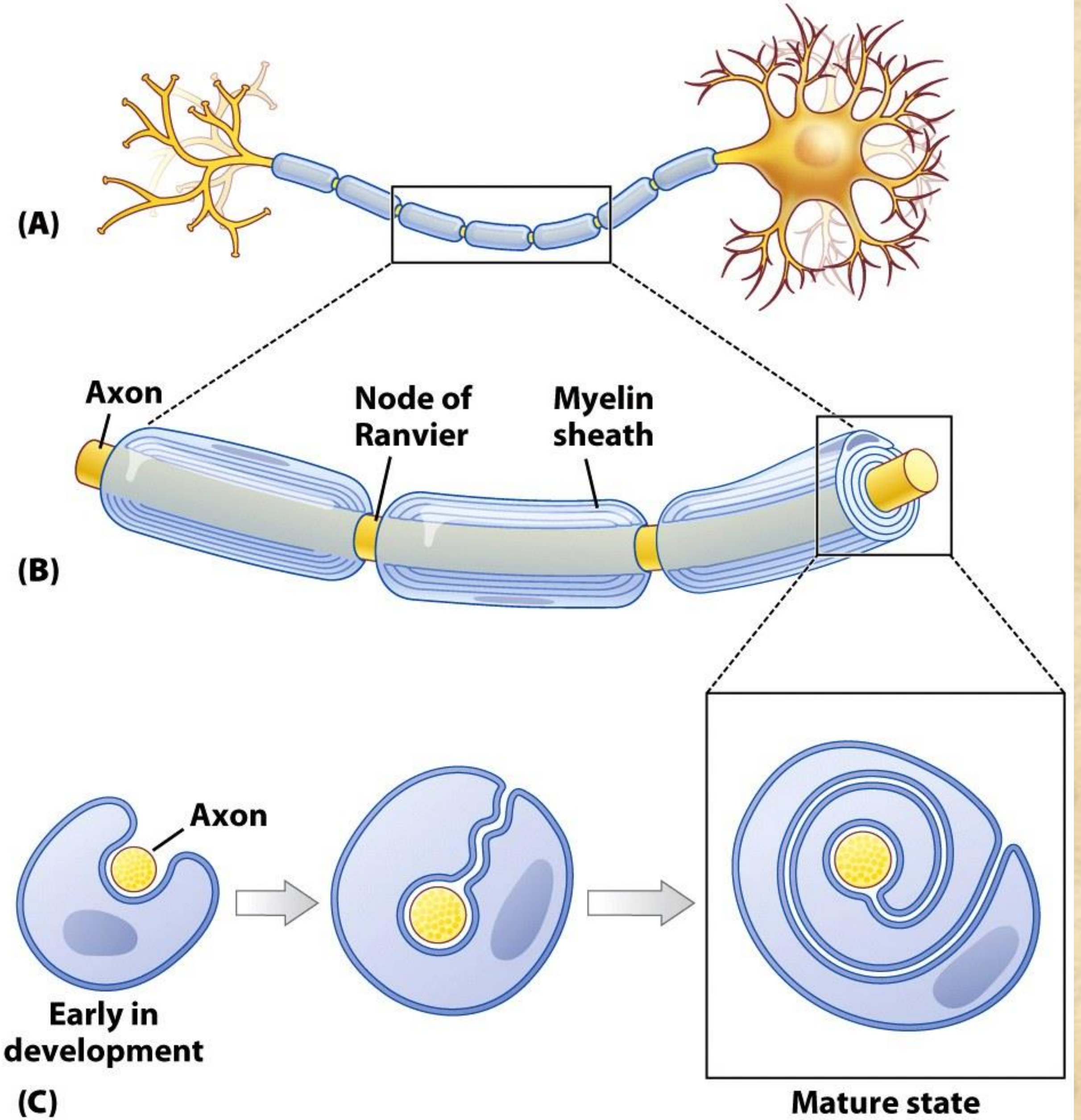
Glia in spinal cord dorsal horn



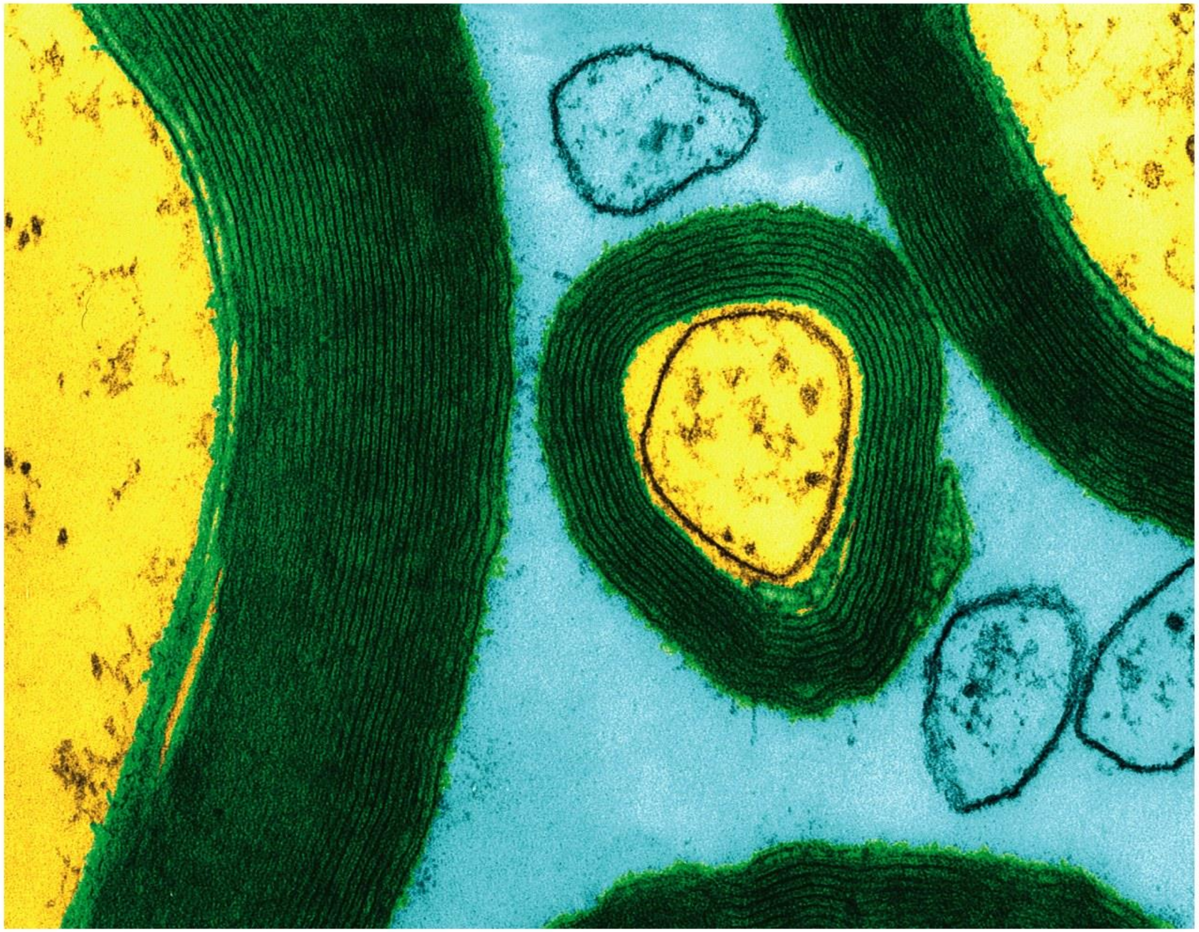
Müller cells (retina)

Oligodendrocytes are glial cells which provide myelin sheathes for neuron axons.

This sheathing provides faster transmission of information along the axon’s length.

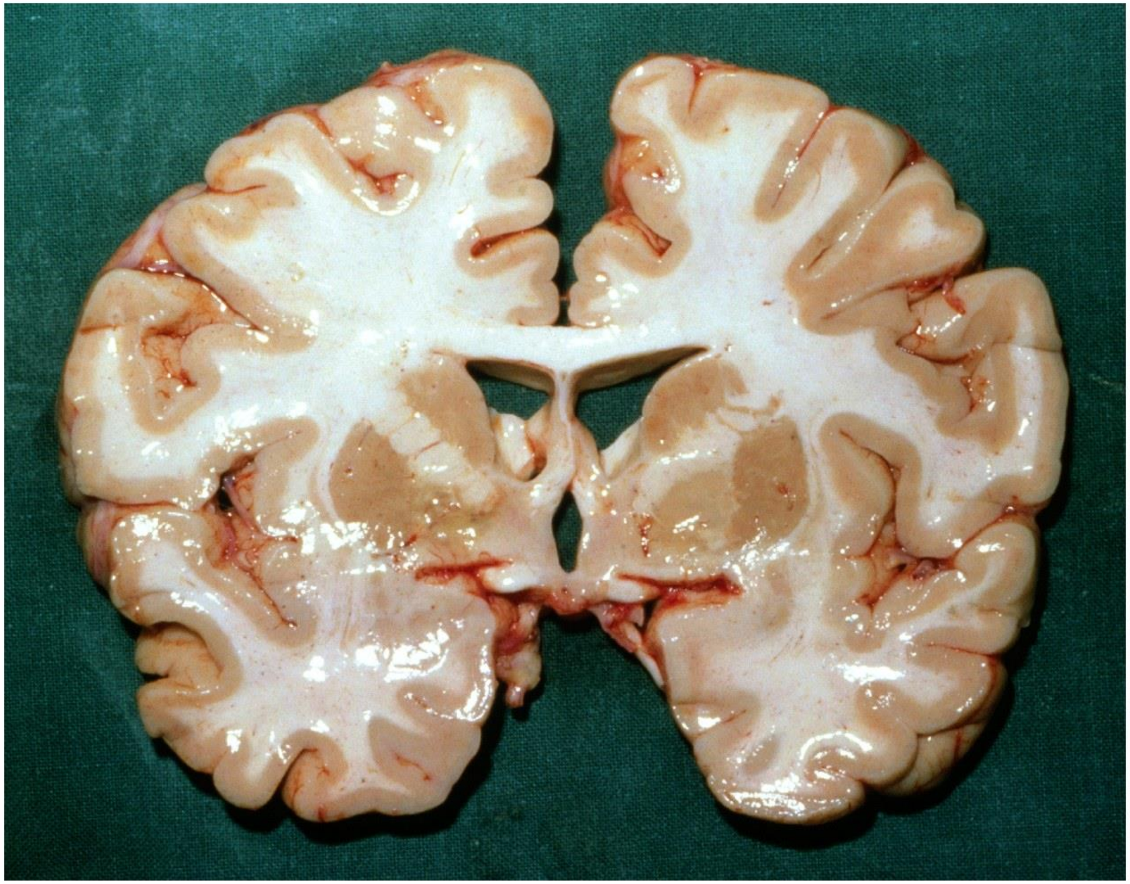


Psychology, 8/e Figure 3.7a-c



Psychology, 8/e Figure 3.7d

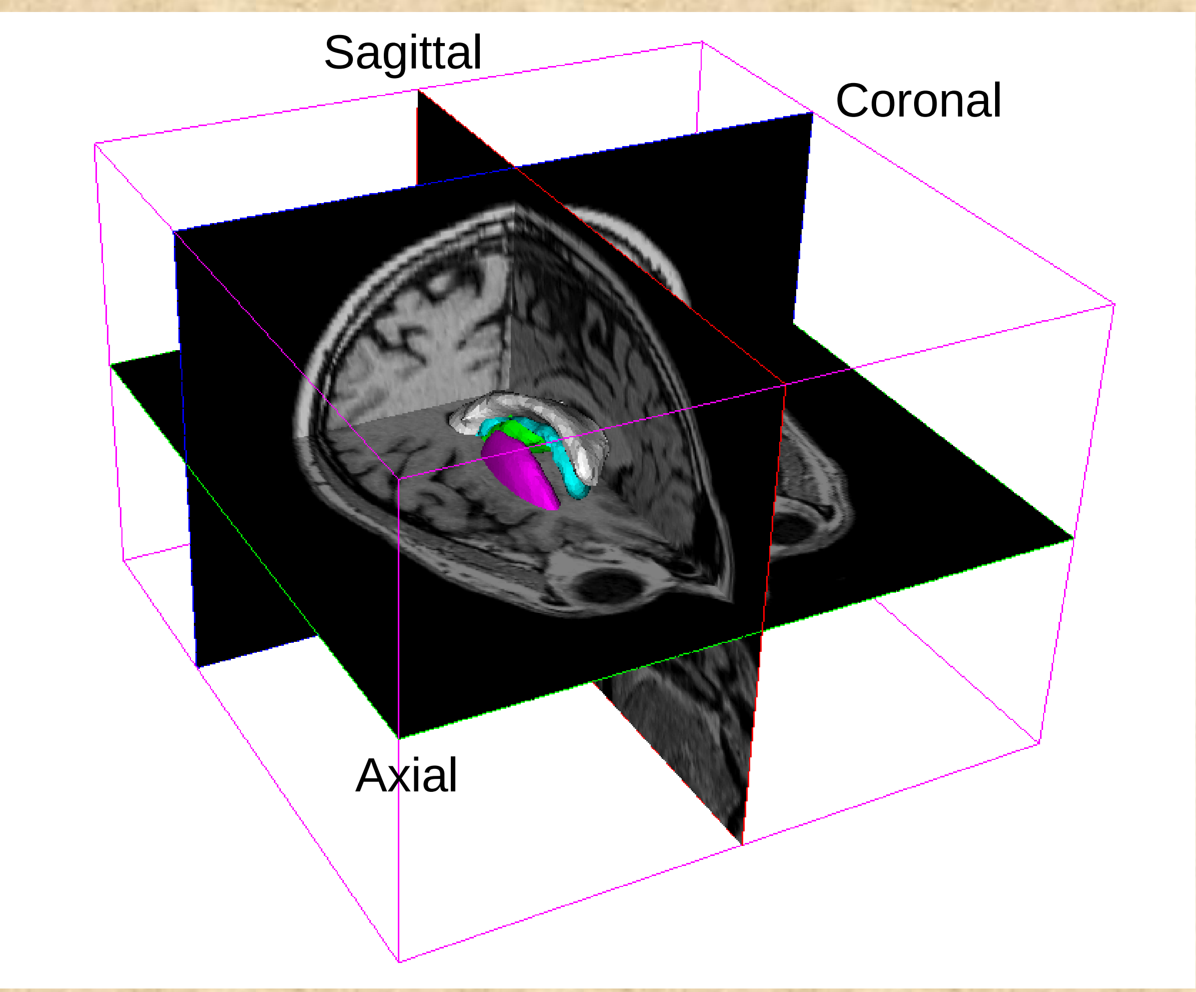
Myelin sheaths about axons (cross-section). These are damaged in multiple sclerosis: demyelination.



Psychology, 8/e Figure 3.8

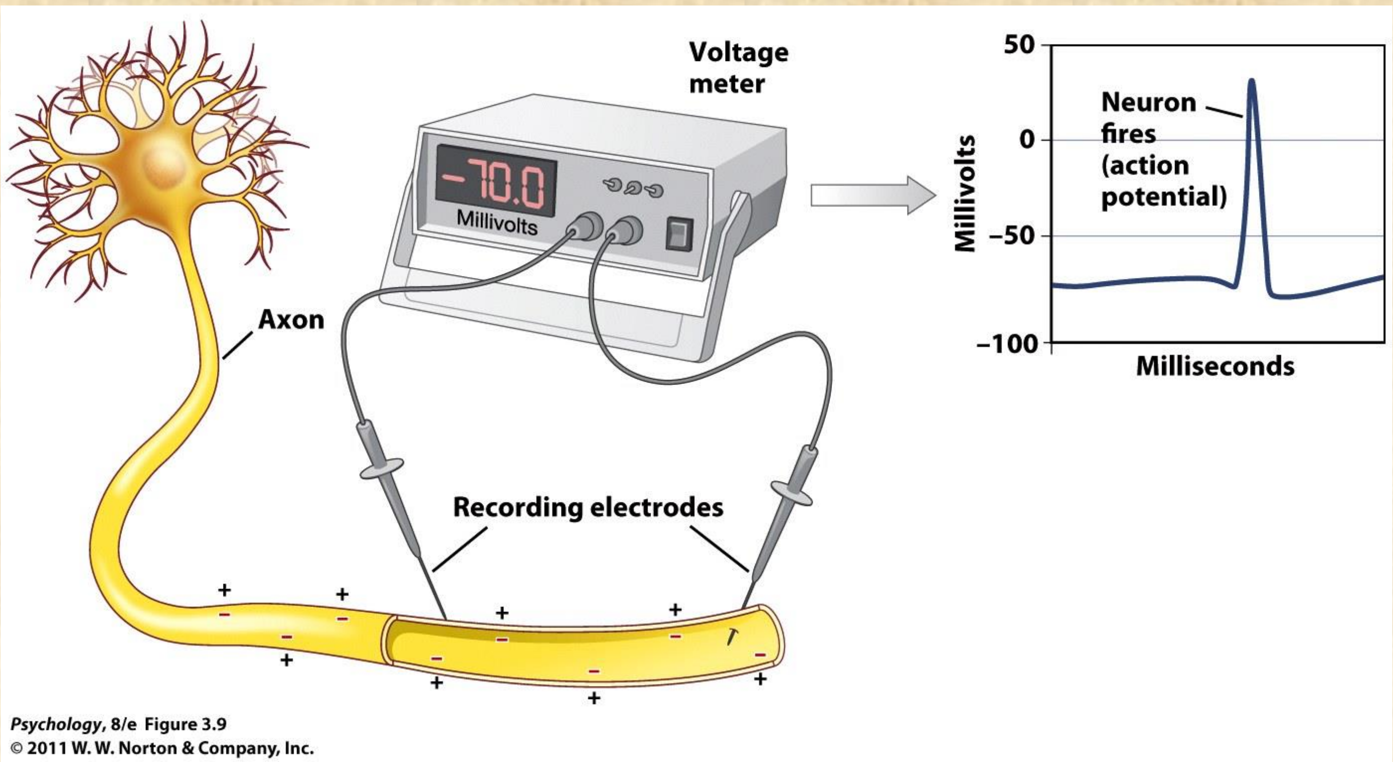
White matter: myelinated axons carrying information from neurons in one area of the brain to another. Gray matter: cell bodies, dendrites and unmyelinated axons.

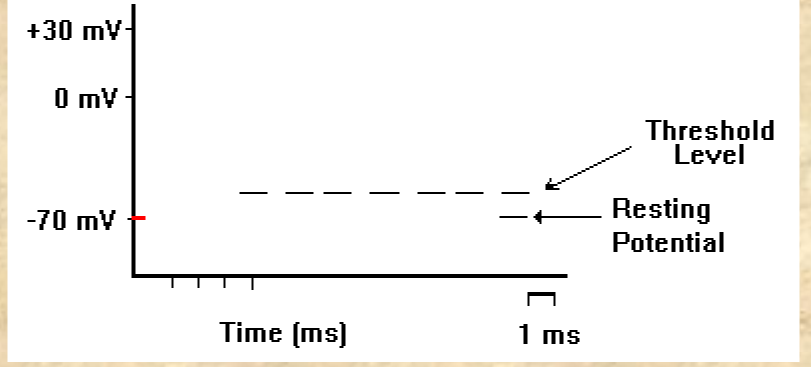
Brain cross-section planes.

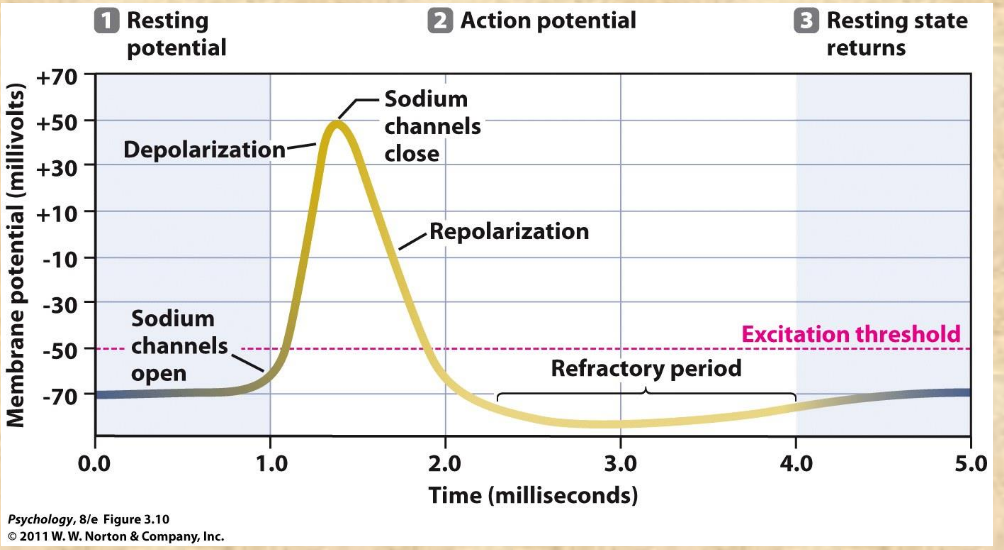


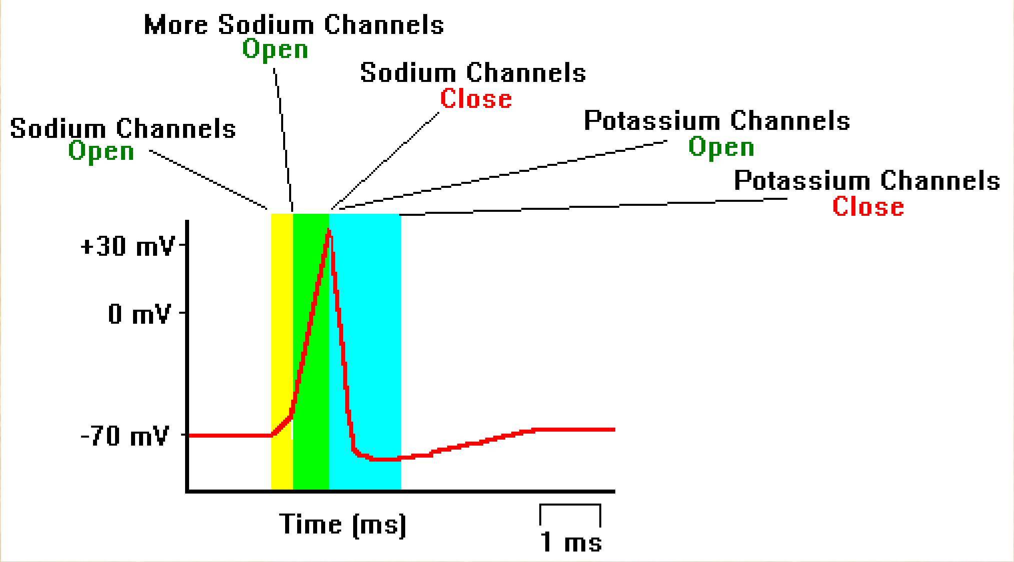
Communication Among Neurons

- *Resting potential:*
  - When the membrane is stable, an excess of positively charged ions is on the outside, resulting in a negative voltage difference across the membrane.
- When the membrane is stimulated, ion channels open:
  - leading to an *action potential.*
    - Ion movement leads to an excess of positively charged particles inside the membrane,
    - which produces a positive voltage swing.
  - The *excitation* spreads, leading to *propagation* of the action potential along the axon.


Voltage meter
-70.0
Millivolts
Axon
Recording electrodes
Neuron fires (action potential)
50
0
−50
−100
Millivolts
Milliseconds
Psychology, 8/e Figure 3.9
© 2011 W. W. Norton & Company, Inc.


+30 mV
0 mV
-70 mV
Threshold Level
Resting Potential
Time (ms)
1 ms





neuron cell membrane *ion pumps* (effects shown here for Na+ and K+)

depolarization (increase in potential: more positive)

hyperpolarization (decrease in potential: more negative)

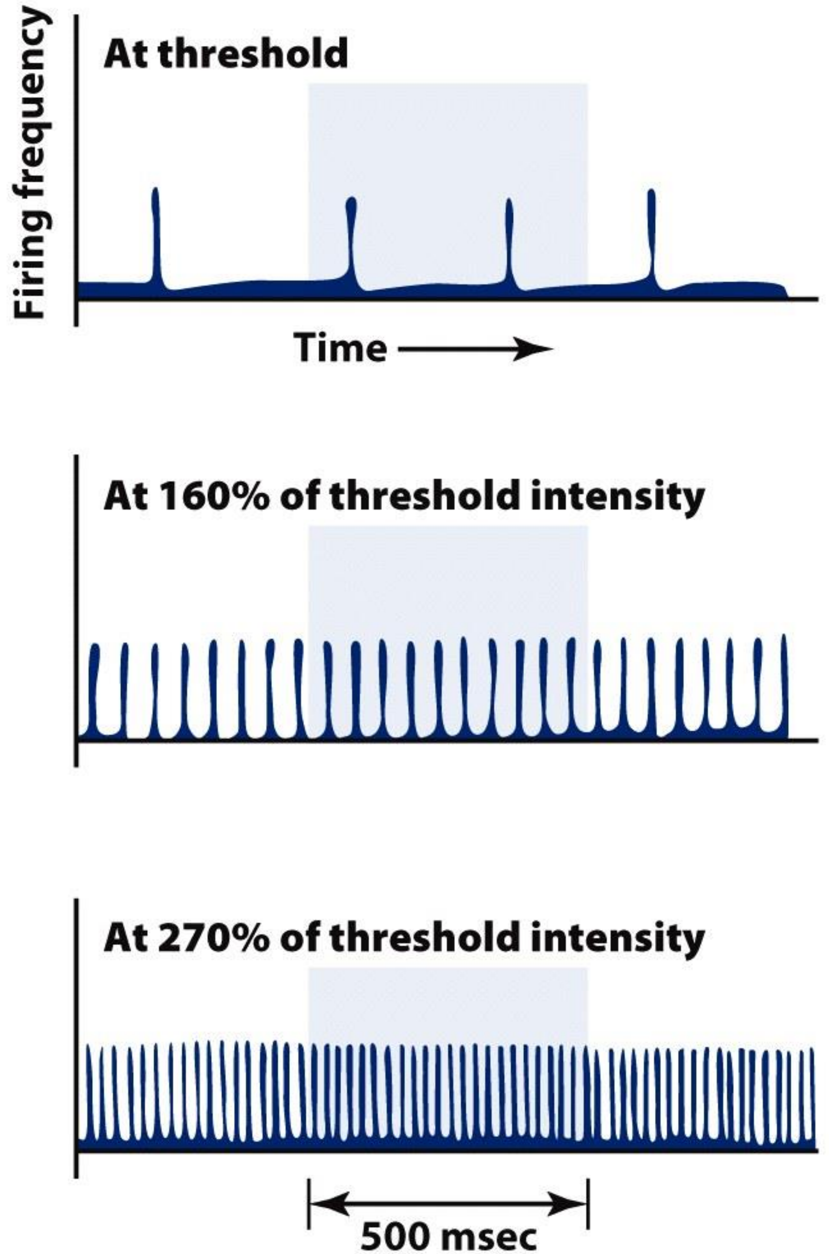
Communication Among Neurons

- Propagation is much faster if the axon is *myelinated:*
  - *Depolarization* proceeds down the axon by a number of skips or jumps (from one *Node of Ranvier* to the next), a process termed *saltatory conduction*

- The action potential obeys the *all-or-none law:*
  - Once it is launched, further increases in stimulus intensity have no effect on its magnitude.
  - How then can stimulus intensity be coded if all action potentials are the same (for any given neuron)?

One way to code stimulus intensity:

the more intense the stimulus, the more frequent the action potentials: a greater *firing rate*, the more frequent are the *spikes*



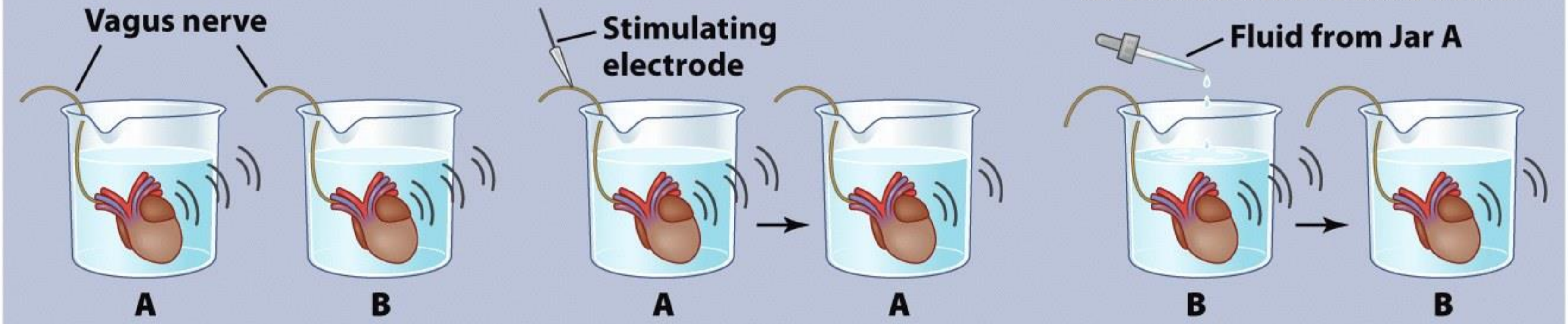
Psychology, 8/e Figure 3.12

3.13 SCIENTIFIC METHOD: What kind of signal do neurons use to communicate: electrical, mechanical, or chemical?

PREDICTION: If the signal from the vagus nerve to the heart is either *electrical* or *mechanical*, then activity in this nerve, and the sending of the signal, won't affect the fluid surrounding the heart. But if the signal is *chemical*, some of the signaling substance might diffuse into the fluid.

Method

1. Loewi placed two still-beating frog hearts (with vagus nerves attached) into jars of saline solution, A and B.
2. With an electrode, he stimulated the vagus nerve of the heart in Jar A to slow its beating.
3. To see whether Jar A's fluid now contained traces of a chemical signal from the nerve, he transferred a sample of Jar A's fluid into Jar B. He observed its effect on the second heart.



Results

The heart in Jar B beat slower when he added fluid from Jar A to its bathing solution.

CONCLUSION: The vagus nerve sends *chemical* signals to the heart.

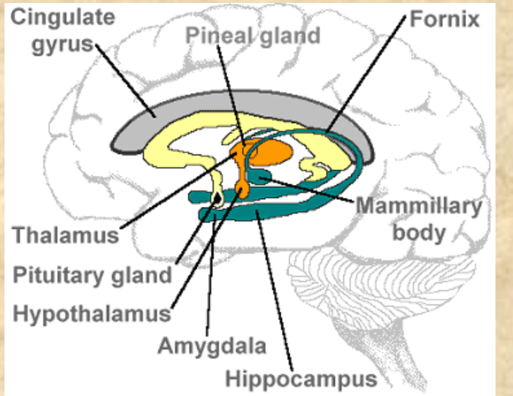
SOURCE STUDY: Loewi, 1921

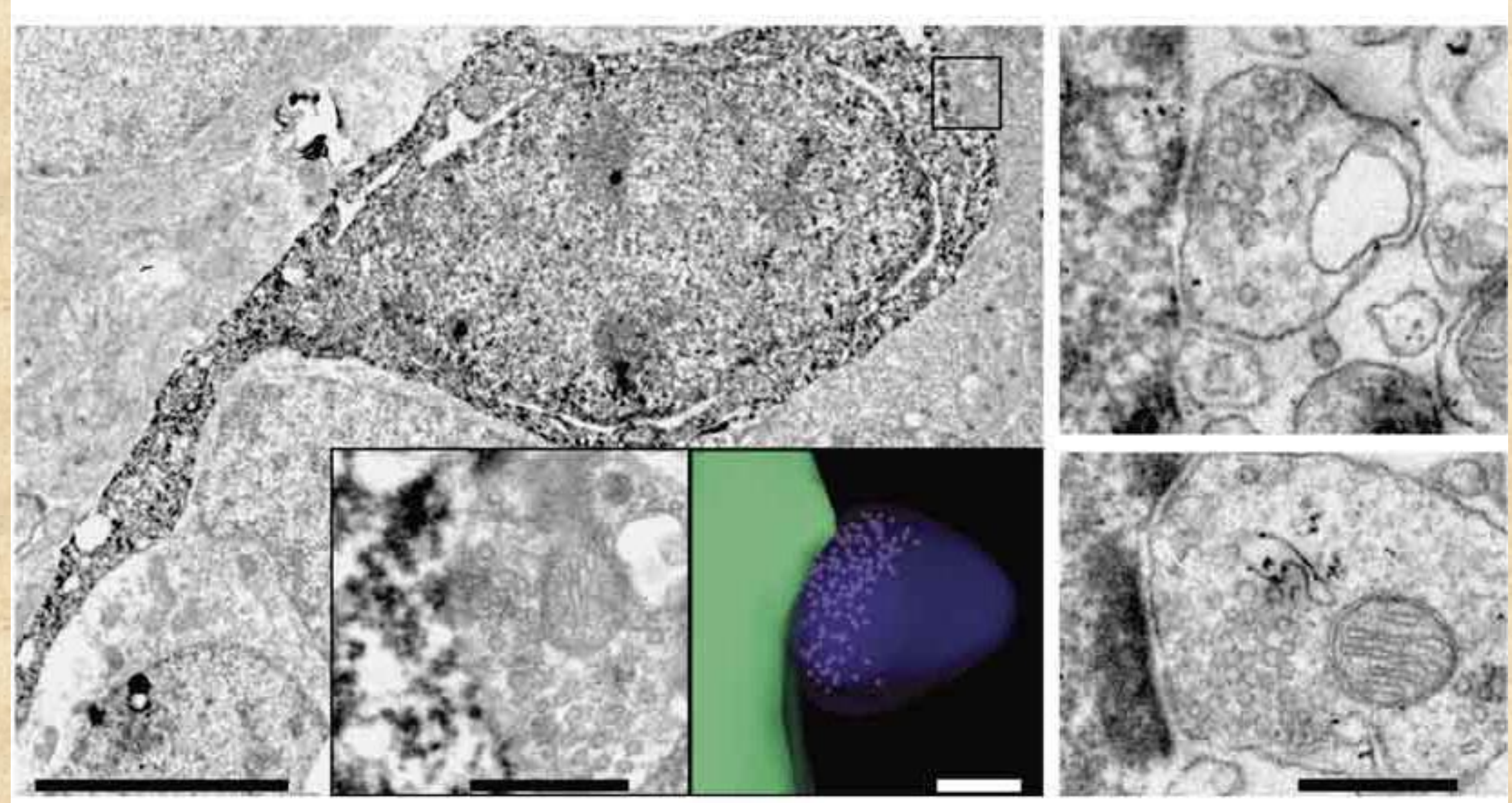
Psychology, 8/e Figure 3.13

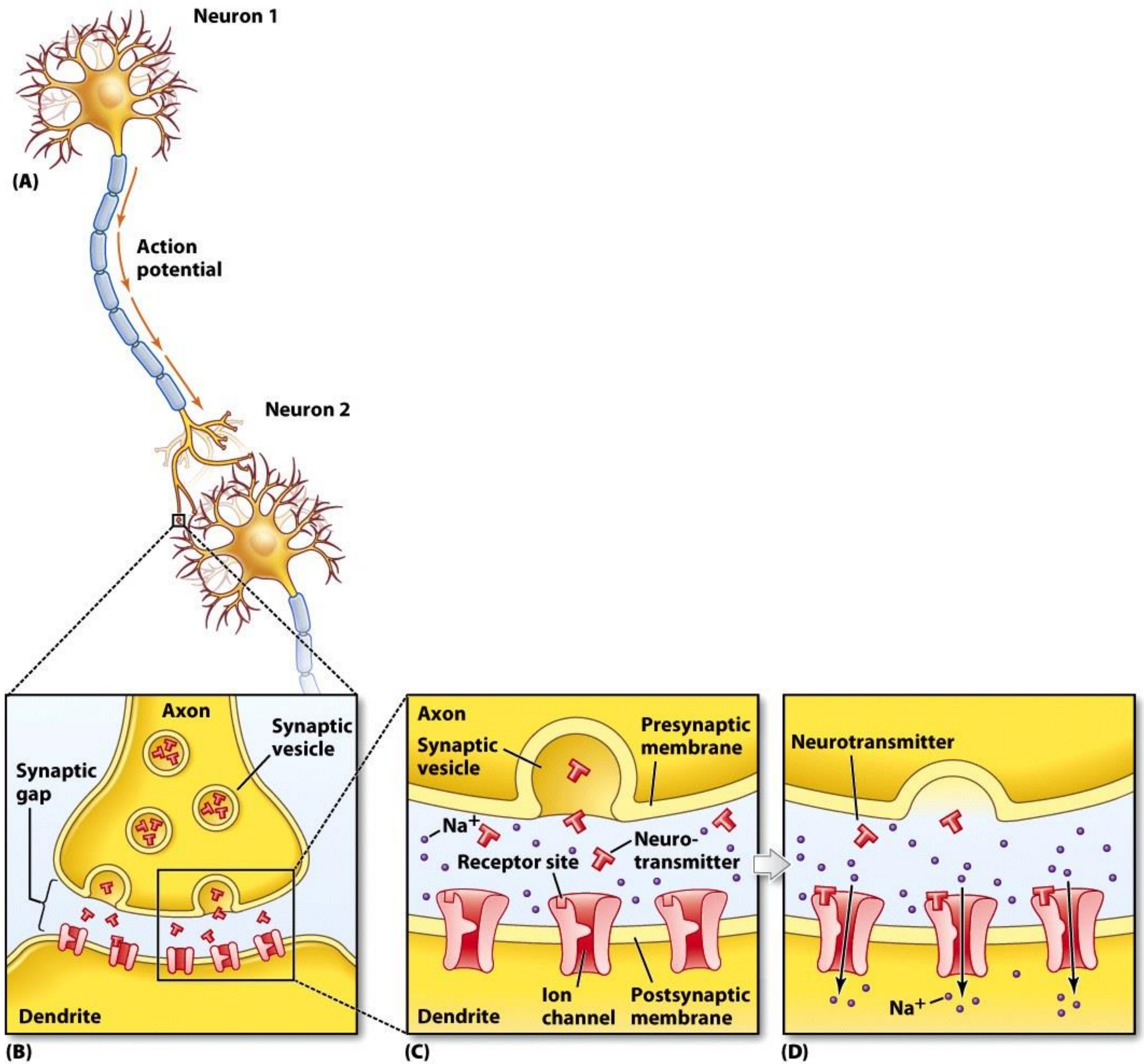
Communication Among Neurons

- *Neurotransmitter* molecules are released by axon terminals at *synapses* made with dendrites (or muscles)
- The neurotransmitter molecules
  - cross the *synapse*
  - latch onto receptors on the postsynaptic cell, which can
  - trigger a response in that further cell

Electron micrographs and reconstructions of synapses (hippocampus dentate granule).
Small round *vesicles* with neurotransmitter molecules are visible in presynaptic axon terminals.







Psychology, 8/e Figure 3.15

Neurotransmitters

- Some transmitters are inactivated shortly after being discharged by “cleanup” enzymes.
- More commonly, neurotransmitters are reused by a process of *synaptic reuptake.*

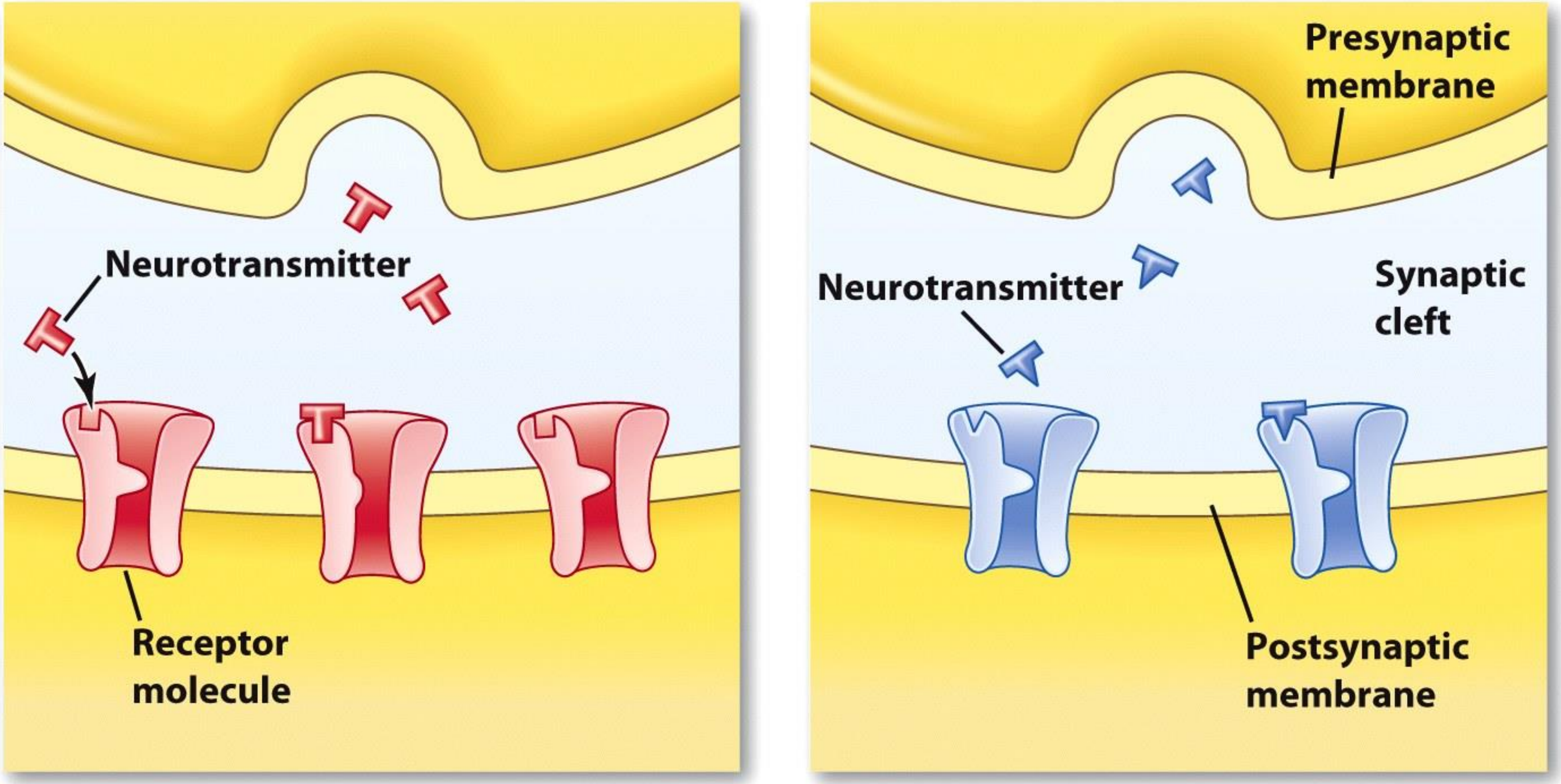
TABLE 3.1 Neurotransmitters

Neurotransmitter	Functions and characteristics
Acetylcholine (ACh)	Released at many synapses and at the junction between nerves and muscles; the release of ACh makes the muscle fibers contract.
Serotonin (5HT, after its formula 5-hydroxytryptamine)	Involved in many of the mechanisms of sleep, mood, and arousal.
Gamma-amino butyric acid (GABA)	The most widely distributed inhibitory transmitter of the central nervous system.
Glutamate	Perhaps the major excitatory transmitter in the brain; plays a crucial role in learning and memory.
Norepinephrine (NE)	Helps control arousal level; influences wakefulness, learning, and memory.
Dopamine (DA)	Influences movement, motivation, emotion.

Psychology, 8/e Table 3.1

Neurotransmitters

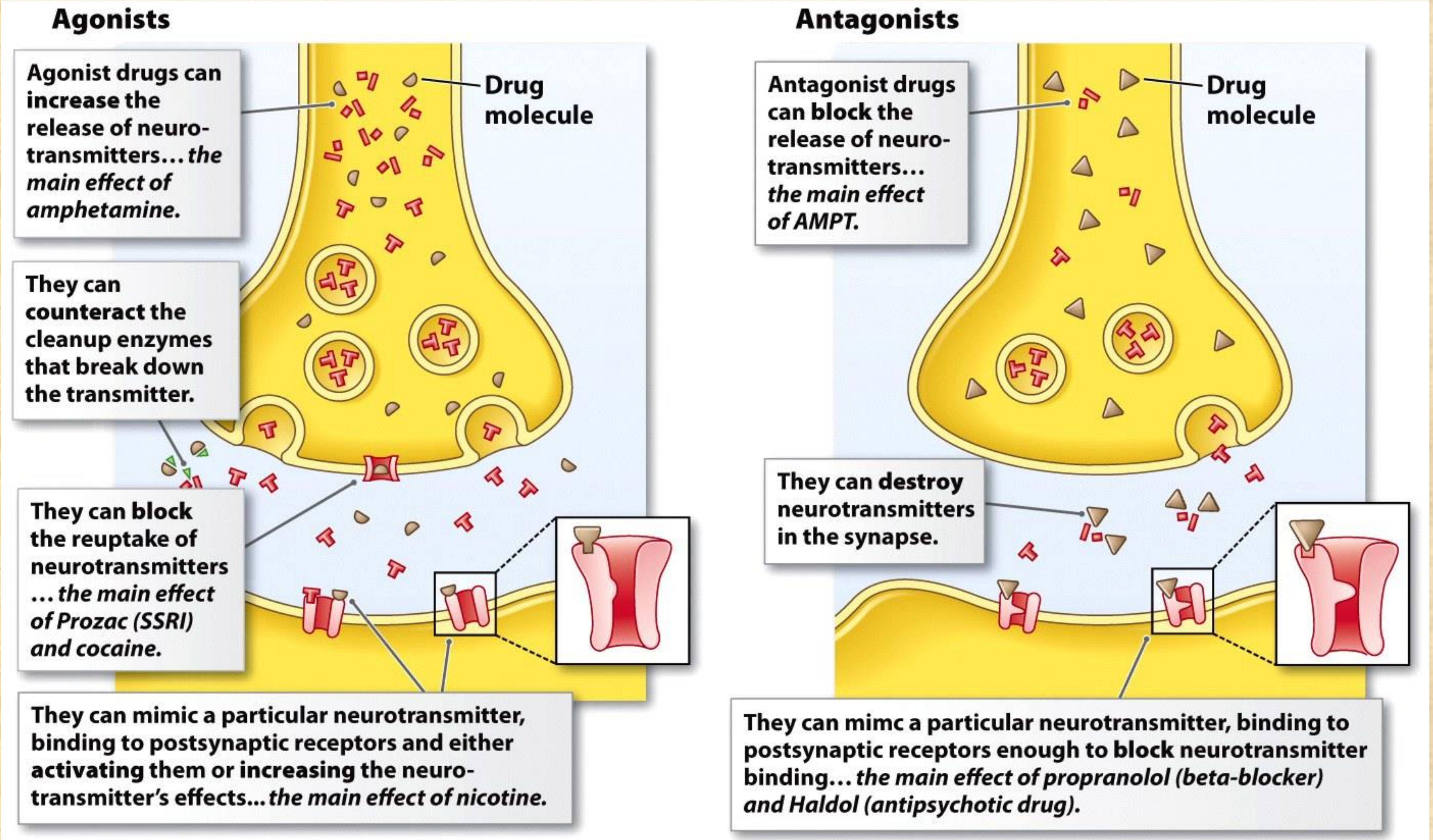
- Some transmitters are inactivated shortly after being discharged by “cleanup” enzymes.
- More commonly, neurotransmitters are reused by a process of *synaptic reuptake.*
- The lock-and-key model proposes that:
  - transmitter molecules will affect the postsynaptic membrane only if the molecule’s shape fits into certain synaptic receptor molecules.



Psychology, 8/e Figure 3.16

Drugs & Neurotransmitters

- Drugs called *agonists* can enhance a neurotransmitter's effect; *antagonists* impede its effect.
- Drugs work by:
  - blocking the transmitter's synaptic reuptake
  - counteracting the cleanup enzyme
  - mimicking the transmitter's action



Psychology, 8/e Figure 3.17

nicotine – ACH; prozac – serotonin; AMPT – tyrosine / catecholamine synthesis; amphetamine - norepinephrine, dopamine; propranolol – norepinephrine; cocaine – serotonin/norepinephrine/dopamine; Haldol - dopamine

The Bloodstream

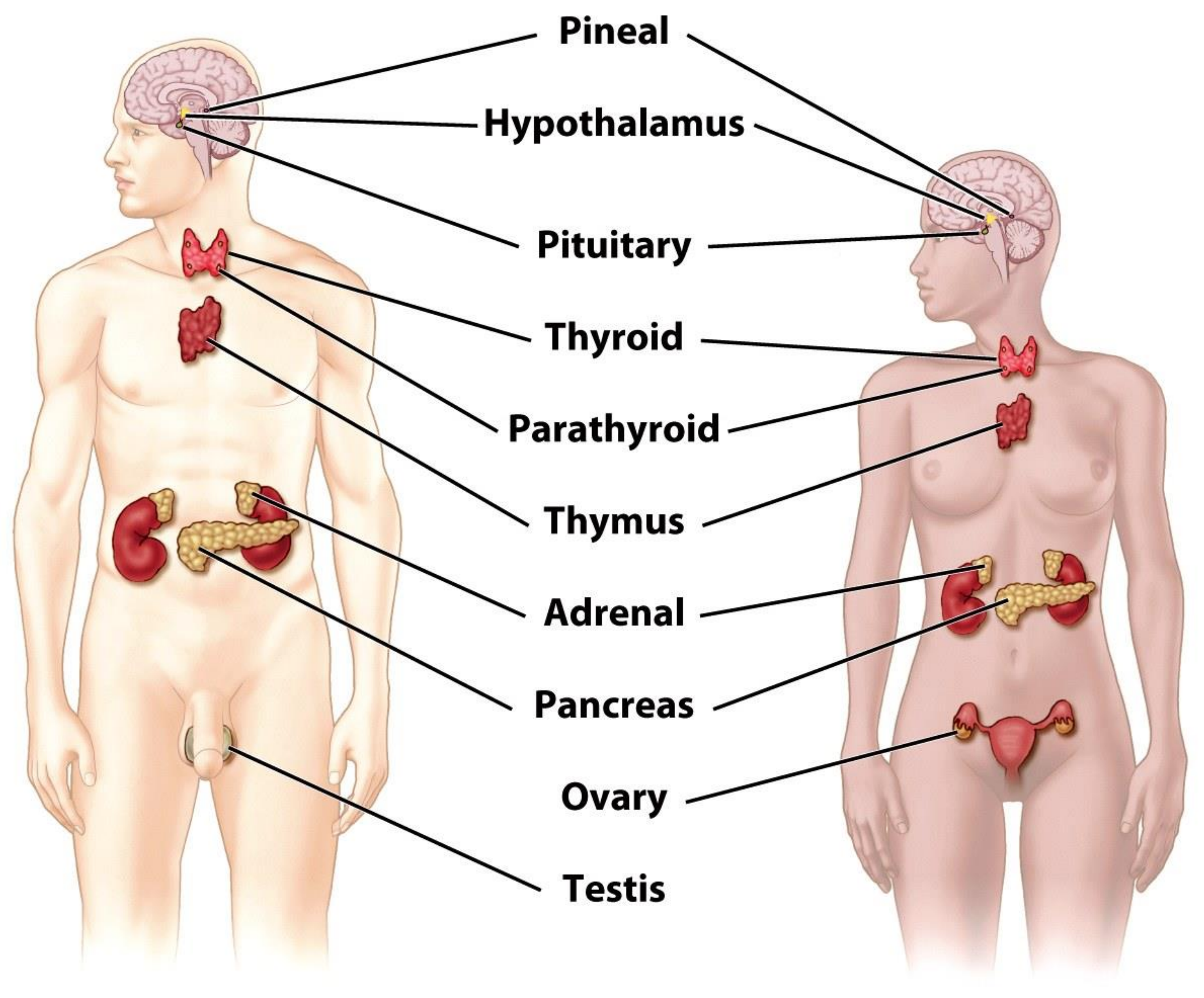
- Blood circulation:
  - brings oxygen and energy (glucose molecules) to the nutrient-hungry brain
  - aids communication by carrying hormones secreted by the *endocrine glands* to various target organs

TABLE 3.2

The Main Endocrine Glands and Some of Their Functions

Gland	Function(s) of the released hormones
Anterior pituitary	Often called the body's master gland because it triggers hormone secretion in many of the other endocrine glands.
Posterior pituitary	Prevents loss of water through kidney.
Thyroid	Affects metabolic rate.
Islet cells in pancreas	Affects utilization of glucose.
Adrenal cortex	Has various effects on metabolism, immunity, and response to stress; has some effects on sexual behavior.
Adrenal medulla	Increases sugar output of liver; stimulates various internal organs.
Ovaries	One set of hormones (estrogen) produces female sex characteristics and is relevant to sexual behavior. Another hormone (progesterone) prepares uterus for implantation of embryo.
Testes	Produces male sex characteristics; relevant to sexual arousal.

Psychology, 8/e Table 3.2



Psychology, 8/e Figure 3.18

The Bloodstream

- Blood circulation:
  - brings oxygen and energy (glucose molecules) to the nutrient-hungry brain
  - aids communication by carrying hormones secreted by the *endocrine glands* to various target organs

- The endocrine system has much in common with the chemical communication between neurons:
  - suggesting these types of communication share an evolutionary origin

Action potential propagation along a neuron's axon with a focus on sodium ion (Na+) channel activity.