Introduction to Neurophysiology 5

Neural circuits

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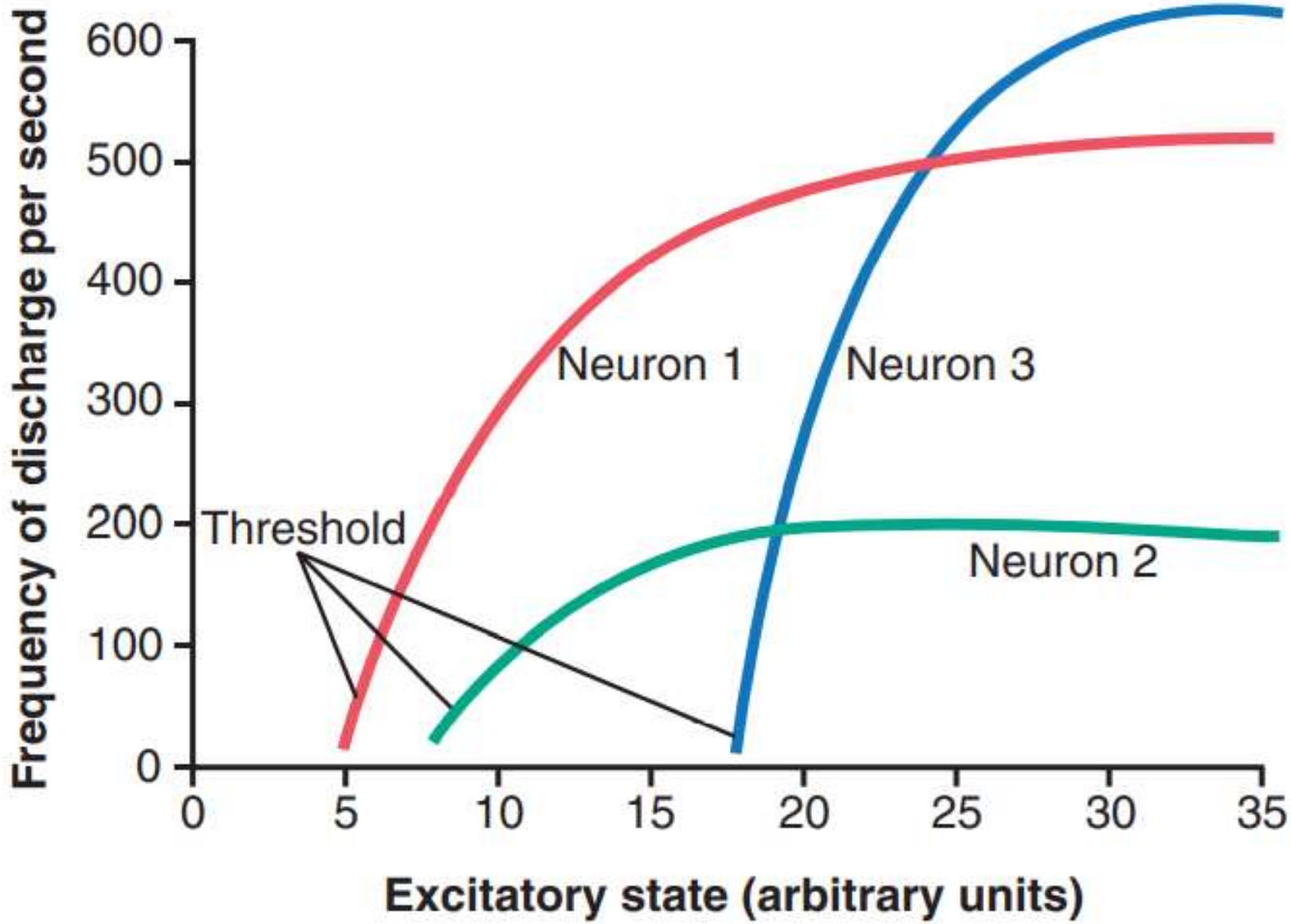
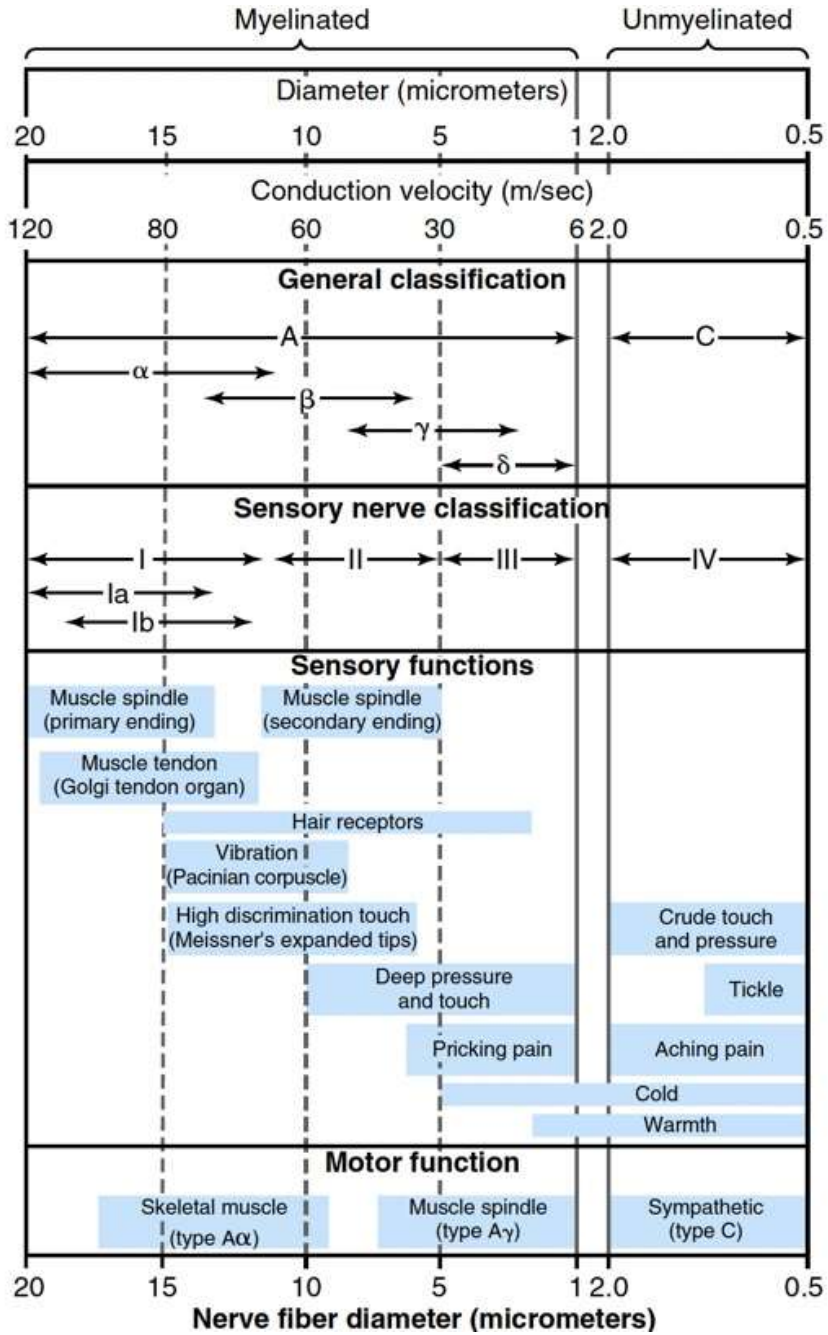
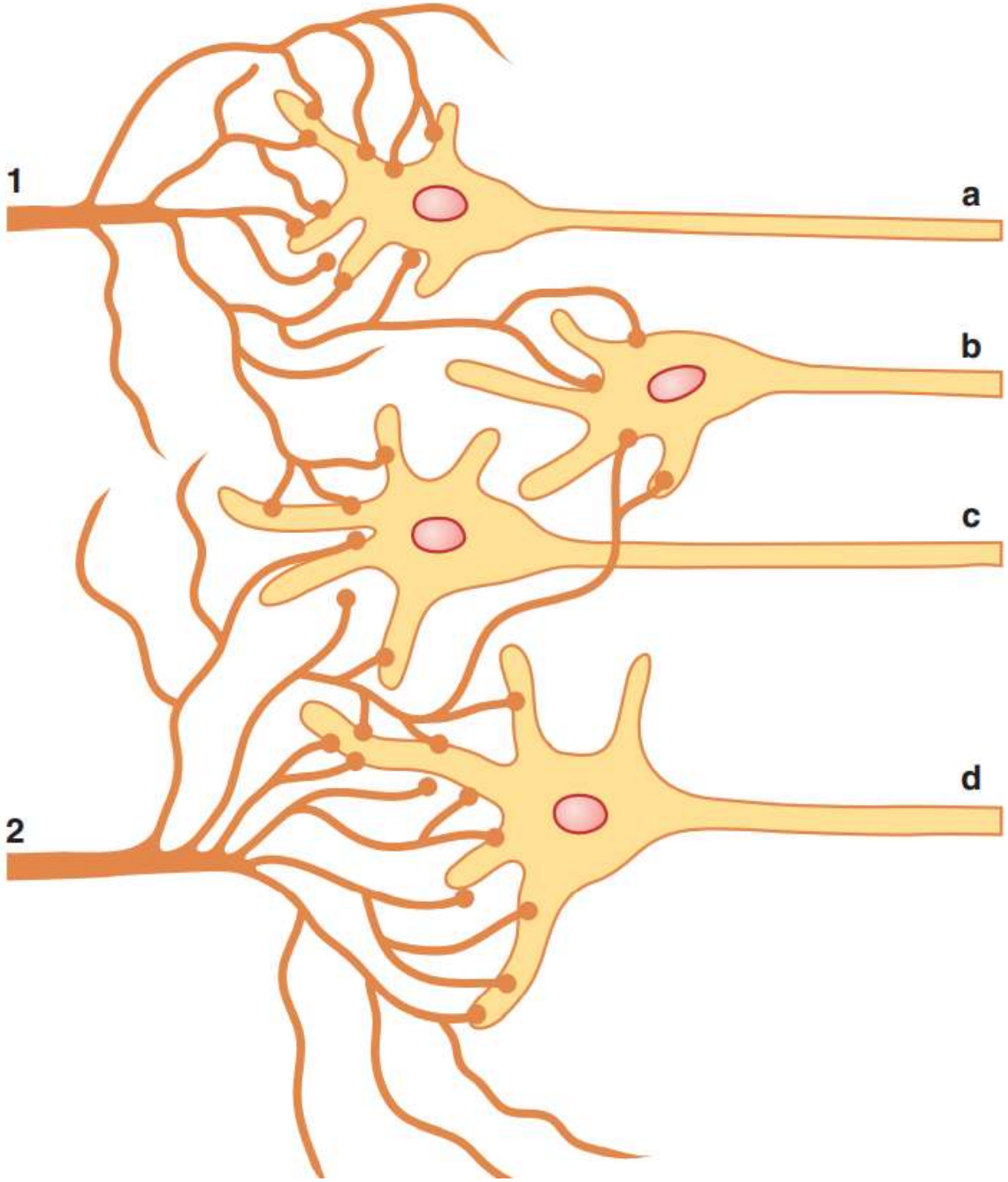
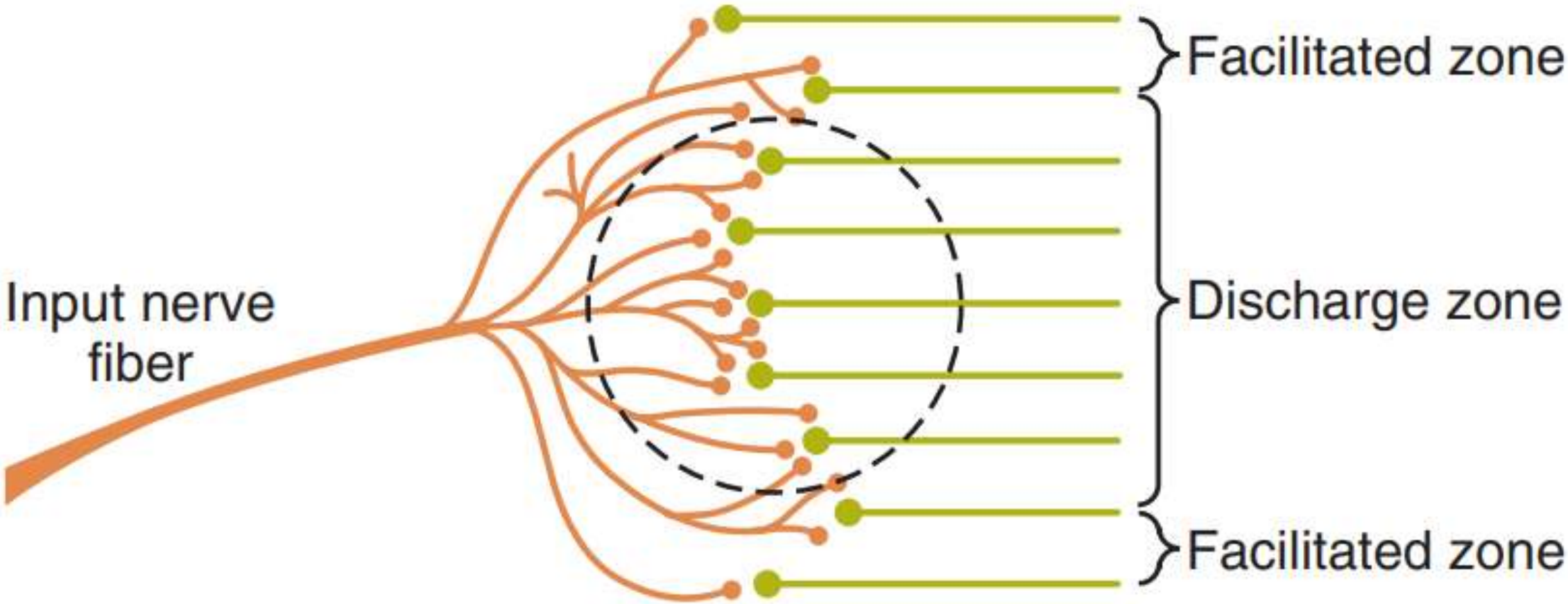

Frequency of discharge per second
600
500
400
300
200
100
0
Threshold
Neuron 1
Neuron 3
Neuron 2
0
5
10
15
20
25
30
35
Excitatory state (arbitrary units)


Myelinated
Unmyelinated
Diameter (micrometers)
20
15
10
5
1
2.0
0.5
Conduction velocity (m/sec)
120
80
60
30
6
2.0
0.5
General classification
A
C
α
β
γ
δ
Sensory nerve classification
I
II
III
IV
Ia
Ib
Sensory functions
Muscle spindle (primary ending)
Muscle spindle (secondary ending)
Muscle tendon (Golgi tendon organ)
Hair receptors
Vibration (Pacinian corpuscle)
High discrimination touch (Meissner's expanded tips)
Crude touch and pressure
Deep pressure and touch
Tickle
Pricking pain
Aching pain
Cold
Warmth
Motor function
Skeletal muscle (type Aα)
Muscle spindle (type Aγ)
Sympathetic (type C)
20
15
10
5
1
2.0
0.5
Nerve fiber diameter (micrometers)

Stimulatory field:

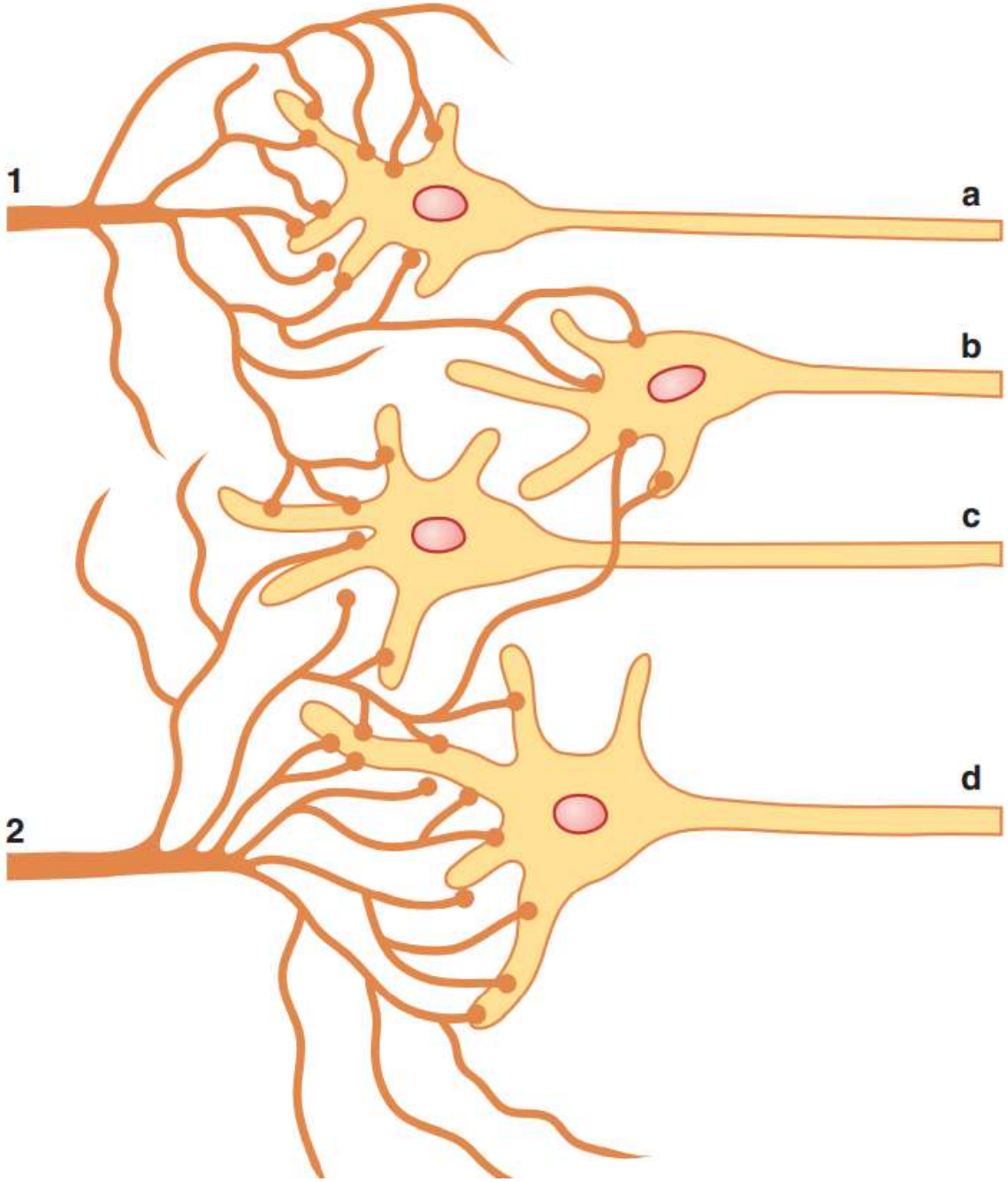
The neuronal area stimulated by each incoming nerve fiber.




Input nerve fiber
Facilitated zone
Discharge zone
Facilitated zone

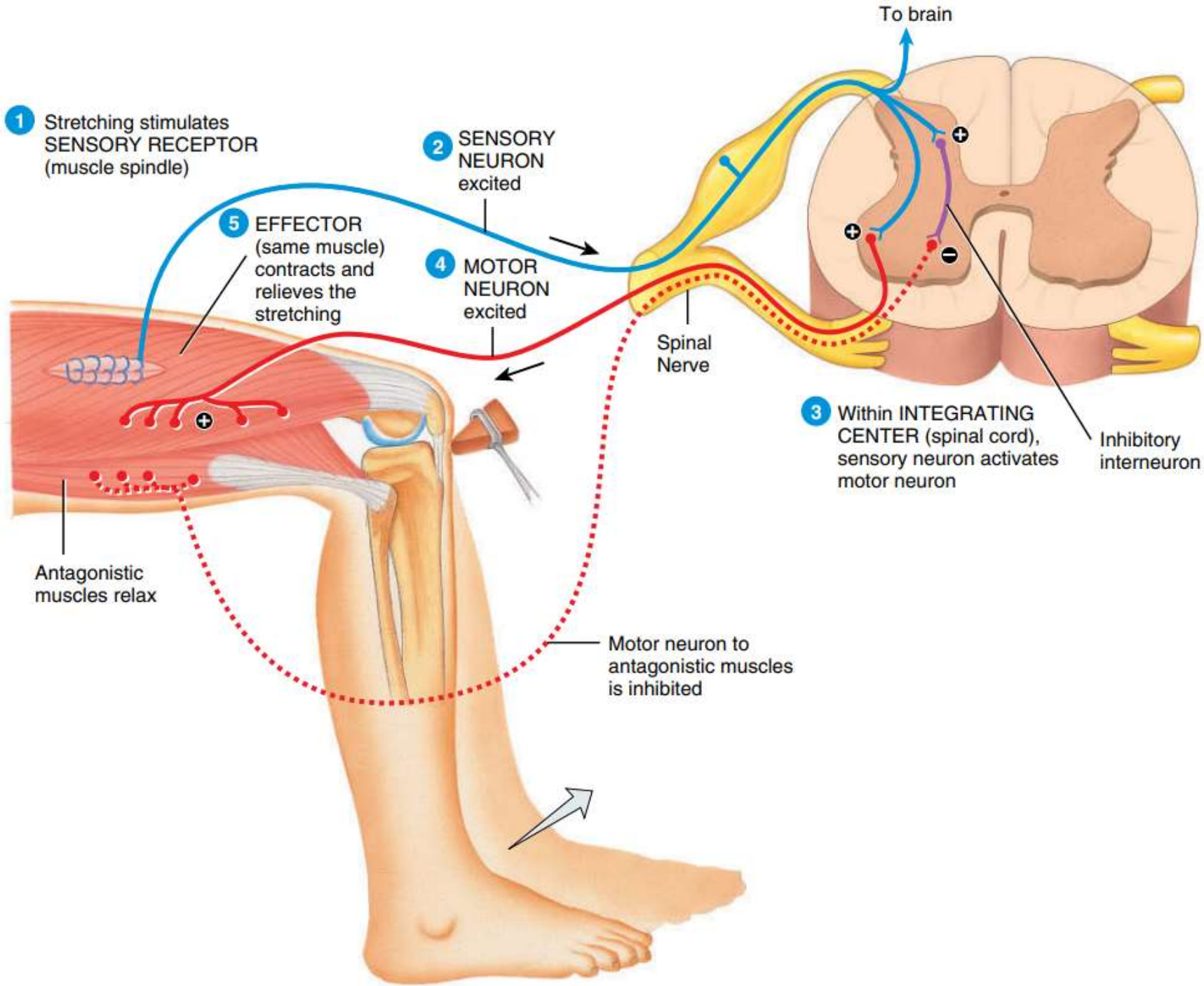
Inhibitory zone:

Greatest inhibition in the center of the zone.



Neuronal circuits

- A group of interconnected neurons that perform certain function.

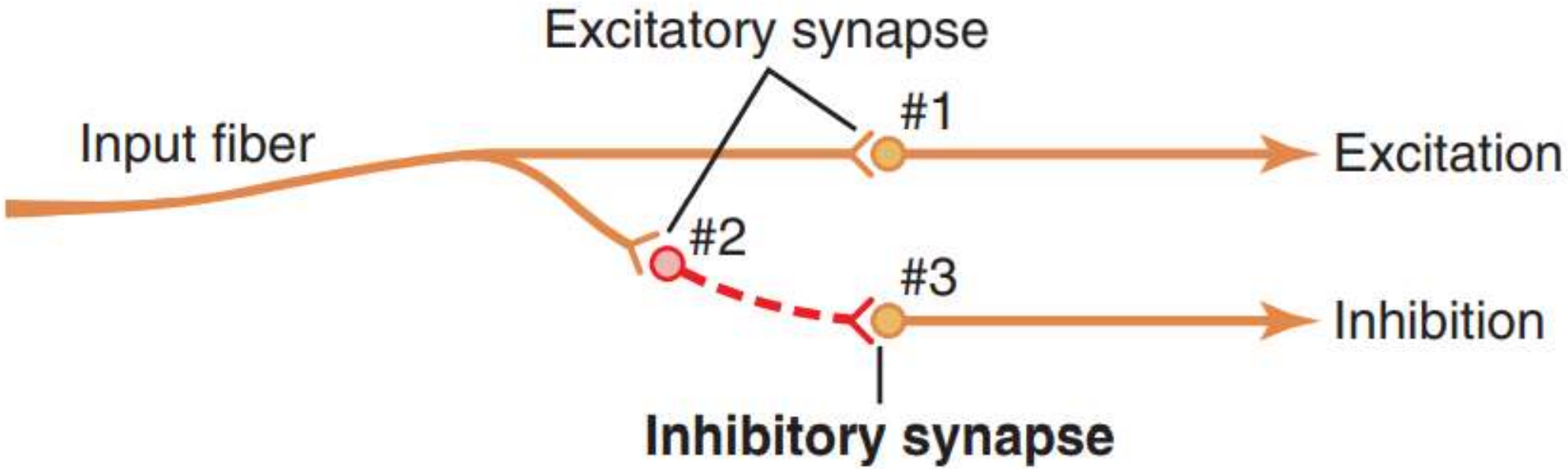

To brain
1 Stretching stimulates SENSORY RECEPTOR (muscle spindle)
2 SENSORY NEURON excited
5 EFFECTOR (same muscle) contracts and relieves the stretching
4 MOTOR NEURON excited
Spinal Nerve
3 Within INTEGRATING CENTER (spinal cord), sensory neuron activates motor neuron
Inhibitory interneuron
Antagonistic muscles relax
Motor neuron to antagonistic muscles is inhibited

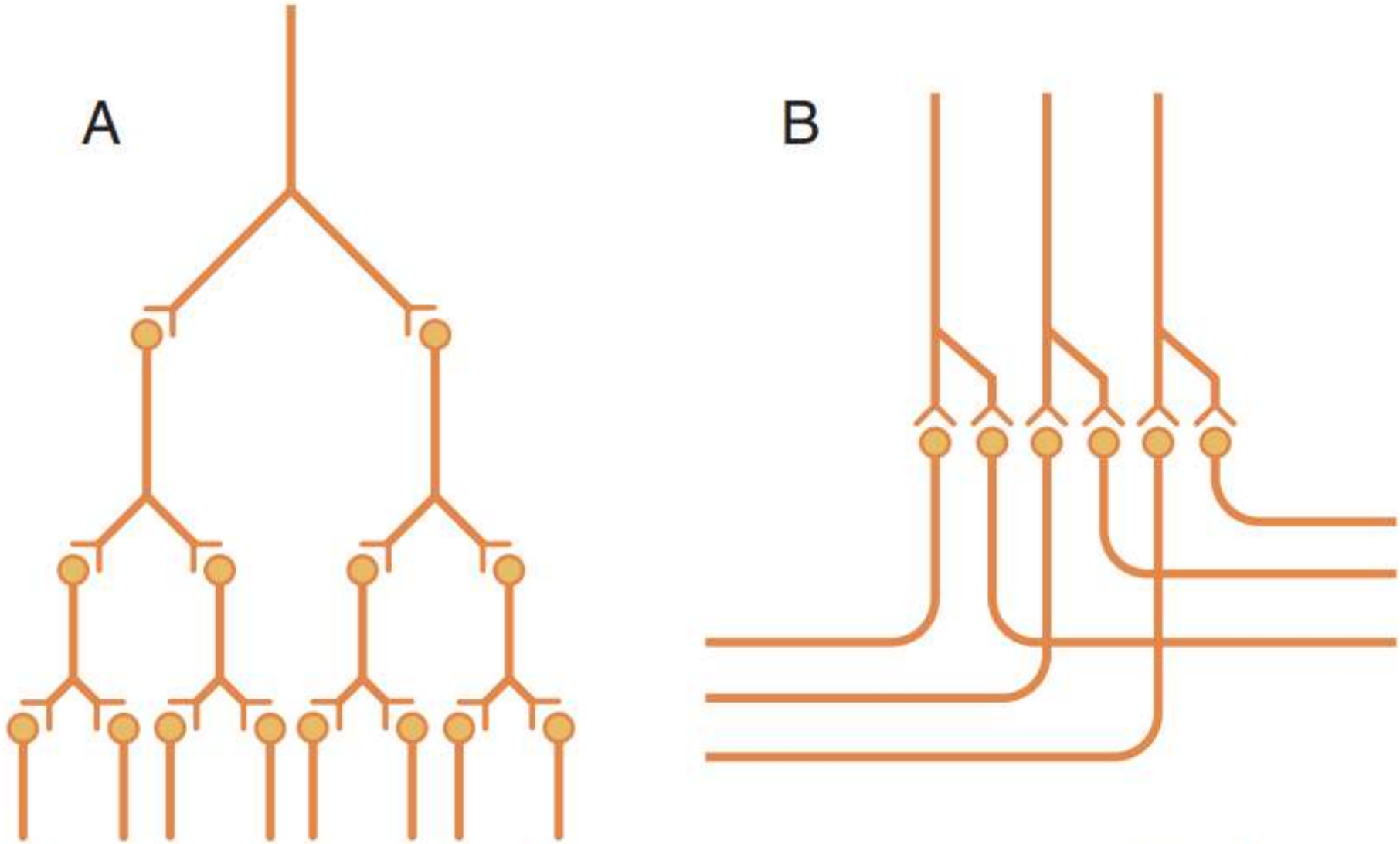
Reciprocal inhibition

- Sometimes an incoming signal to a neuronal pool causes an output excitatory signal going in one direction and at the same time an inhibitory signal going elsewhere.

- This type of circuit is characteristic for controlling all antagonistic pairs of muscles.

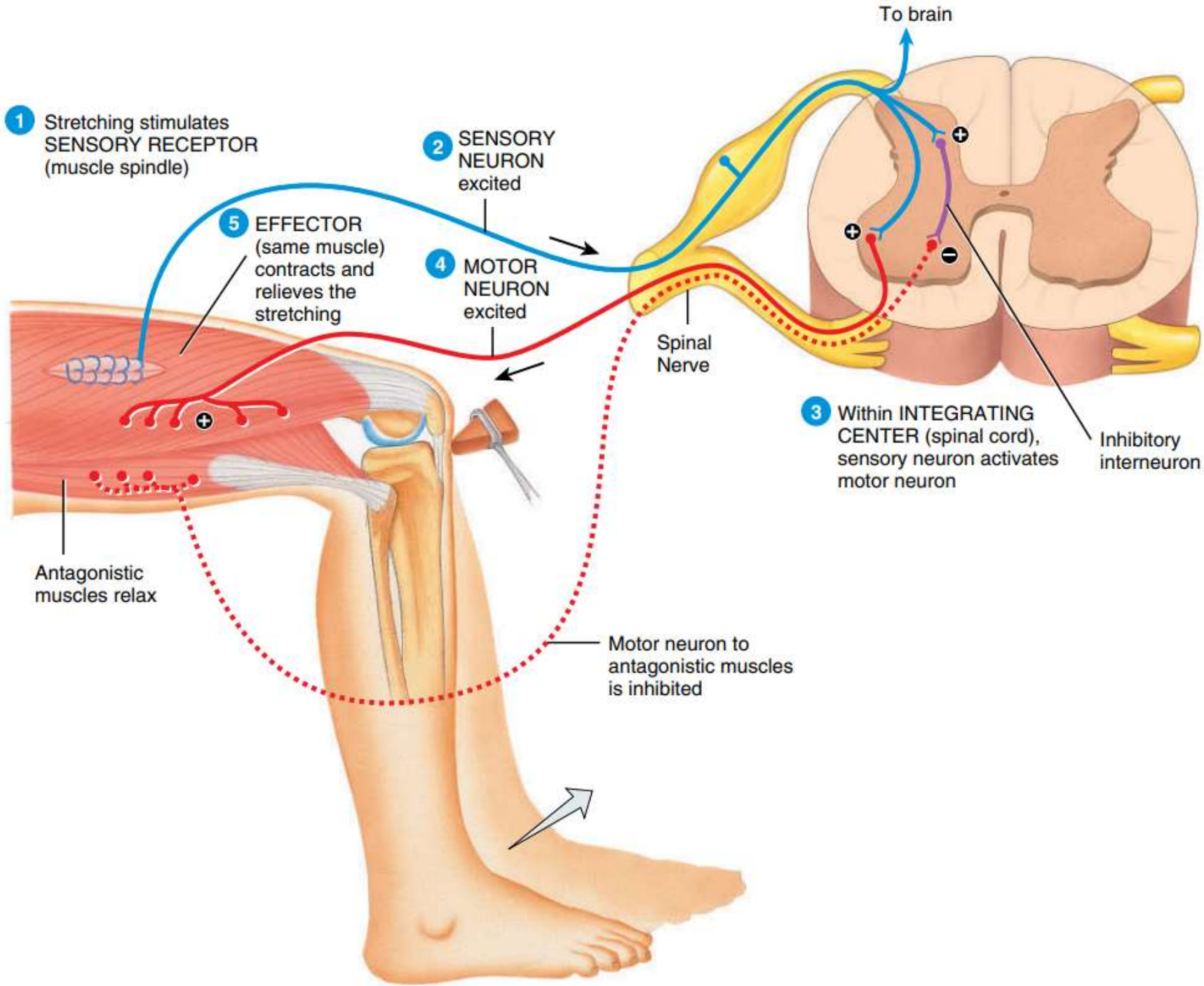
Reciprocal inhibition





Divergence in same tract

Divergence into multiple tracts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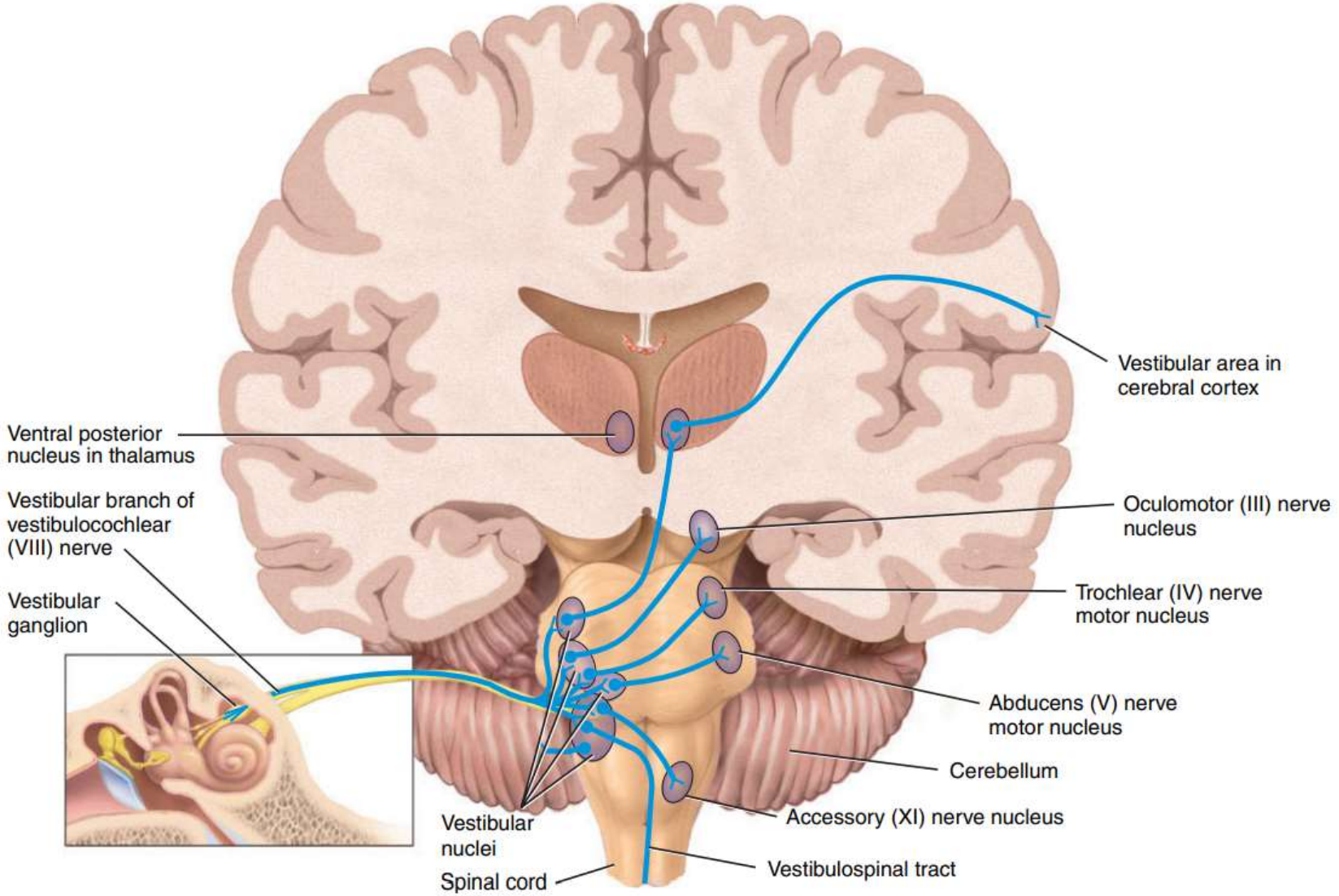
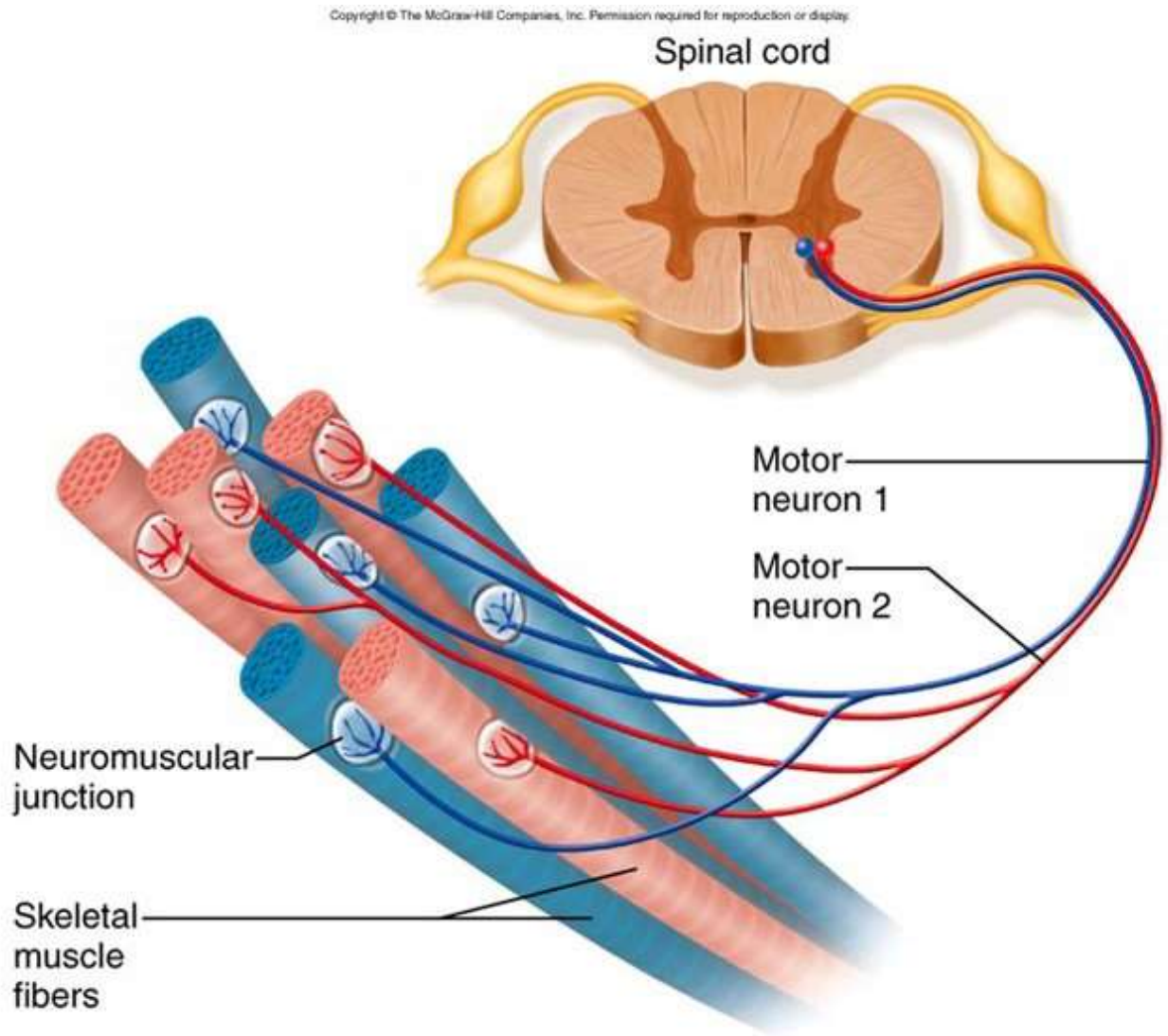


Amplifying divergence

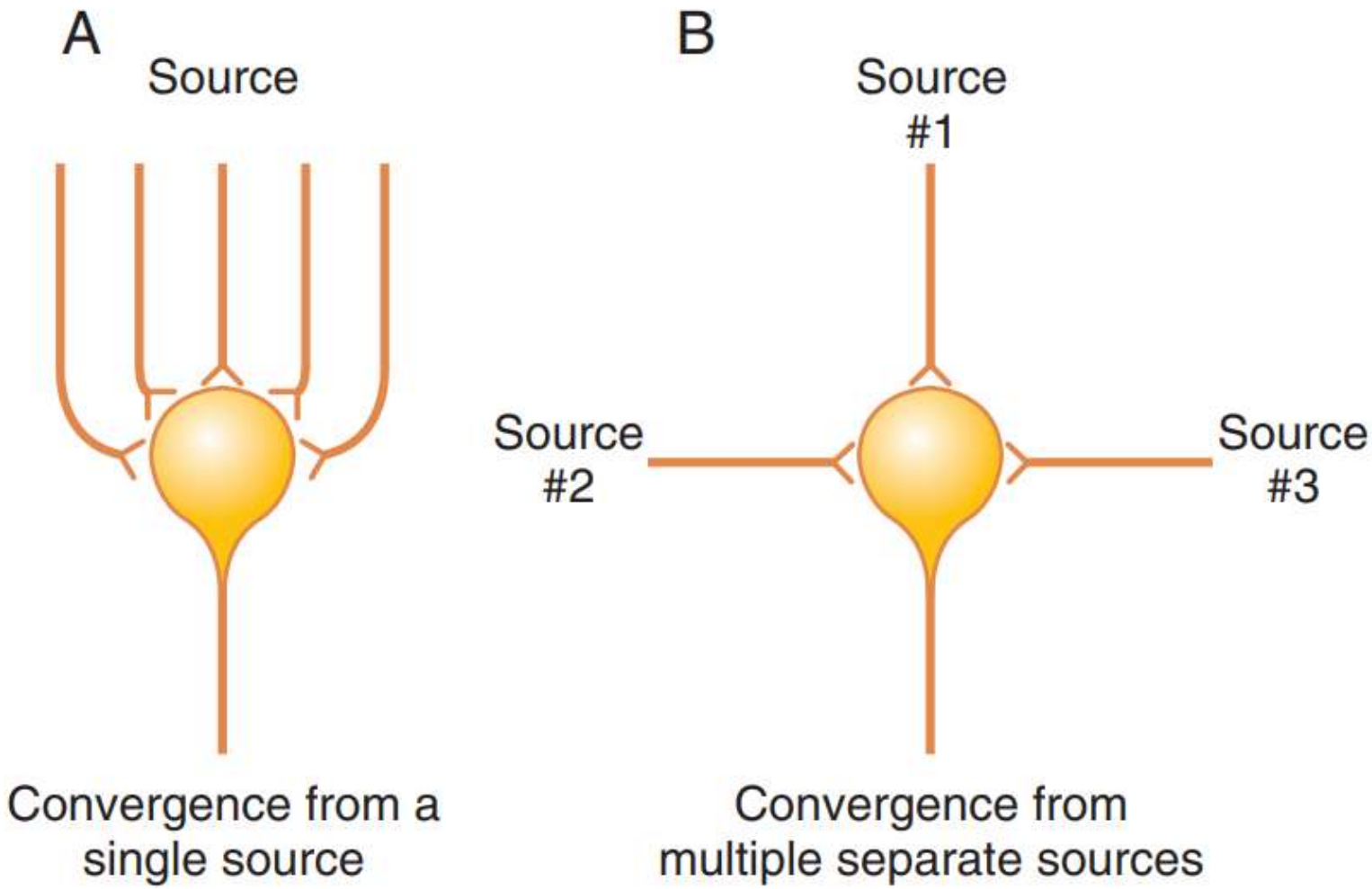
- Amplifying divergence means simply that an input signal spreads to an increasing number of neurons as it passes through successive orders of neurons in its path.

Amplifying divergence

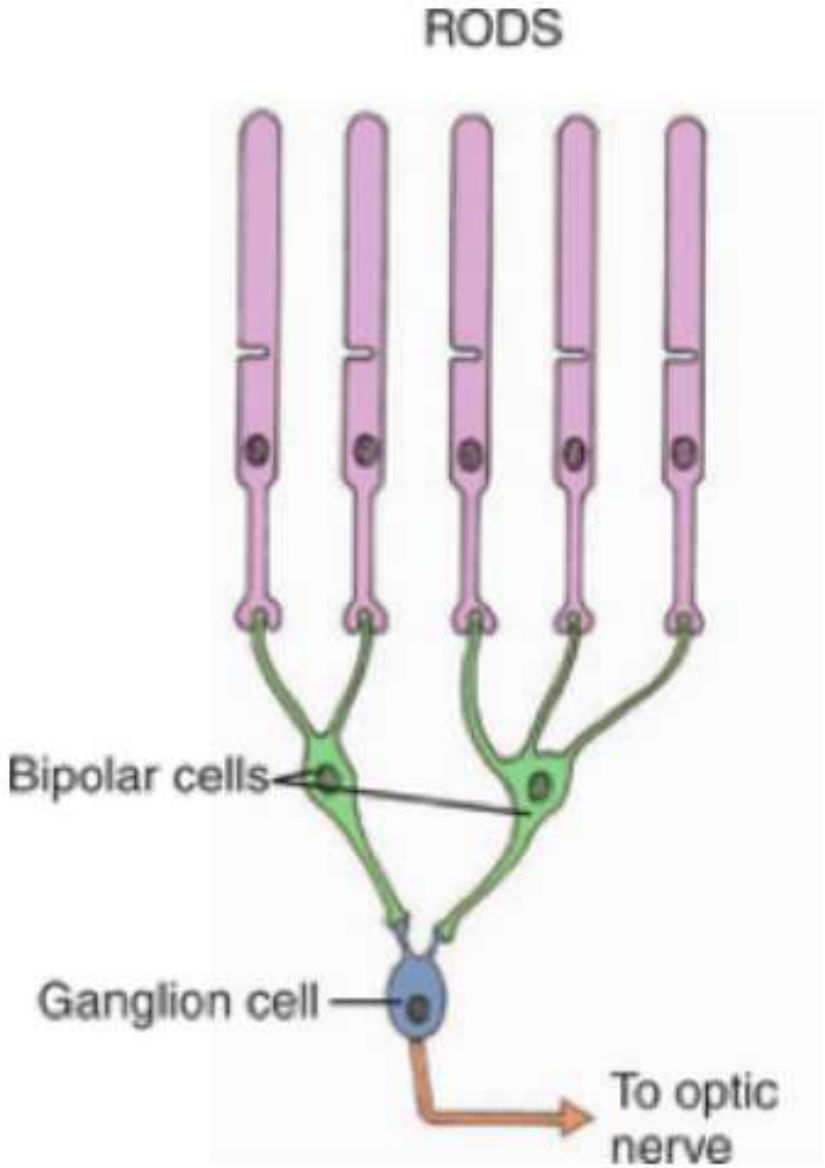


Convergence

- Convergence means signals from multiple inputs uniting to excite a single neuron.
- The importance of this type is summation.
- Convergence is one of the important means by which the central nervous system correlates, summates, and sorts different types of information


A
Source
B
Source
#1
Source
#2
Source
#3
Convergence from a
single source
Convergence from
multiple separate sources

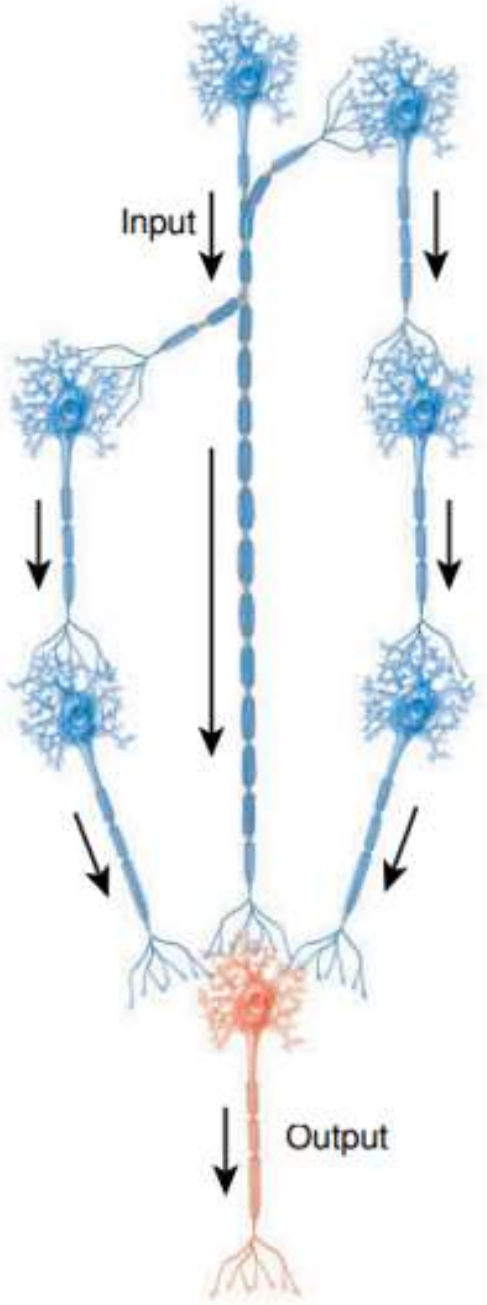
Convergence in photoreceptors (Rods)



http://veteriankey.com/retina/

Parallel afterdischarge

- Continued firing after the stimulus has stopped, so prolonged output discharge.
- a neuron inputs to several chains of neurons.
- Each chain is made up of a different number of neurons, but their signals converge onto one output neuron.
- Reach output at varying times.
- No feedback loop as in the reverberating circuit.



Saladin, K. *Human anatomy* (3rd ed.). McGraw-Hill. p. 364. ISBN 9780071222075.

Reverberatory (Oscillatory) circuits

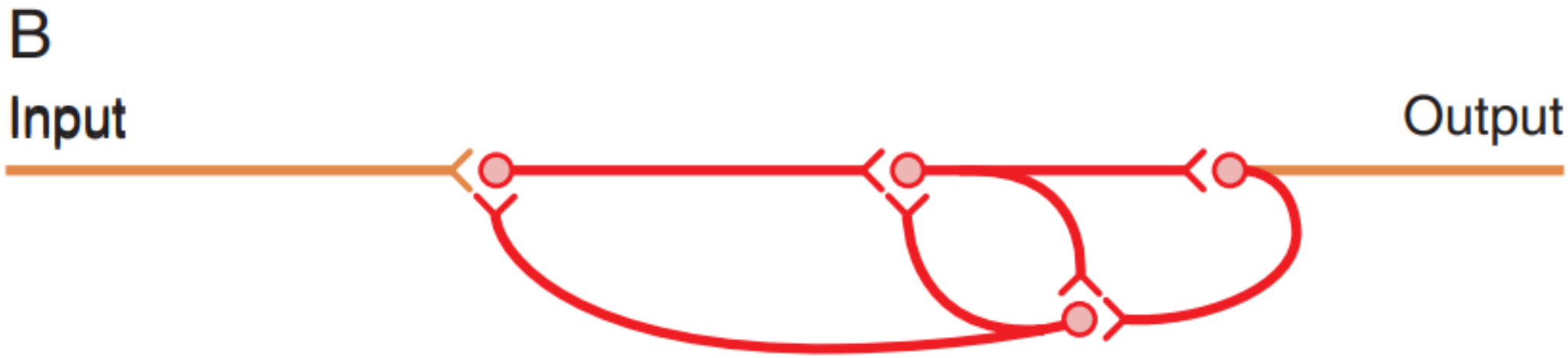
- One of the most important circuits in the nervous system.
- Caused by positive feedback within the neuronal circuit that feeds back to re-excite the input of the same circuit.
- Consequently, once stimulated, the circuit may discharge repetitively for a long time.

Reverberatory circuits

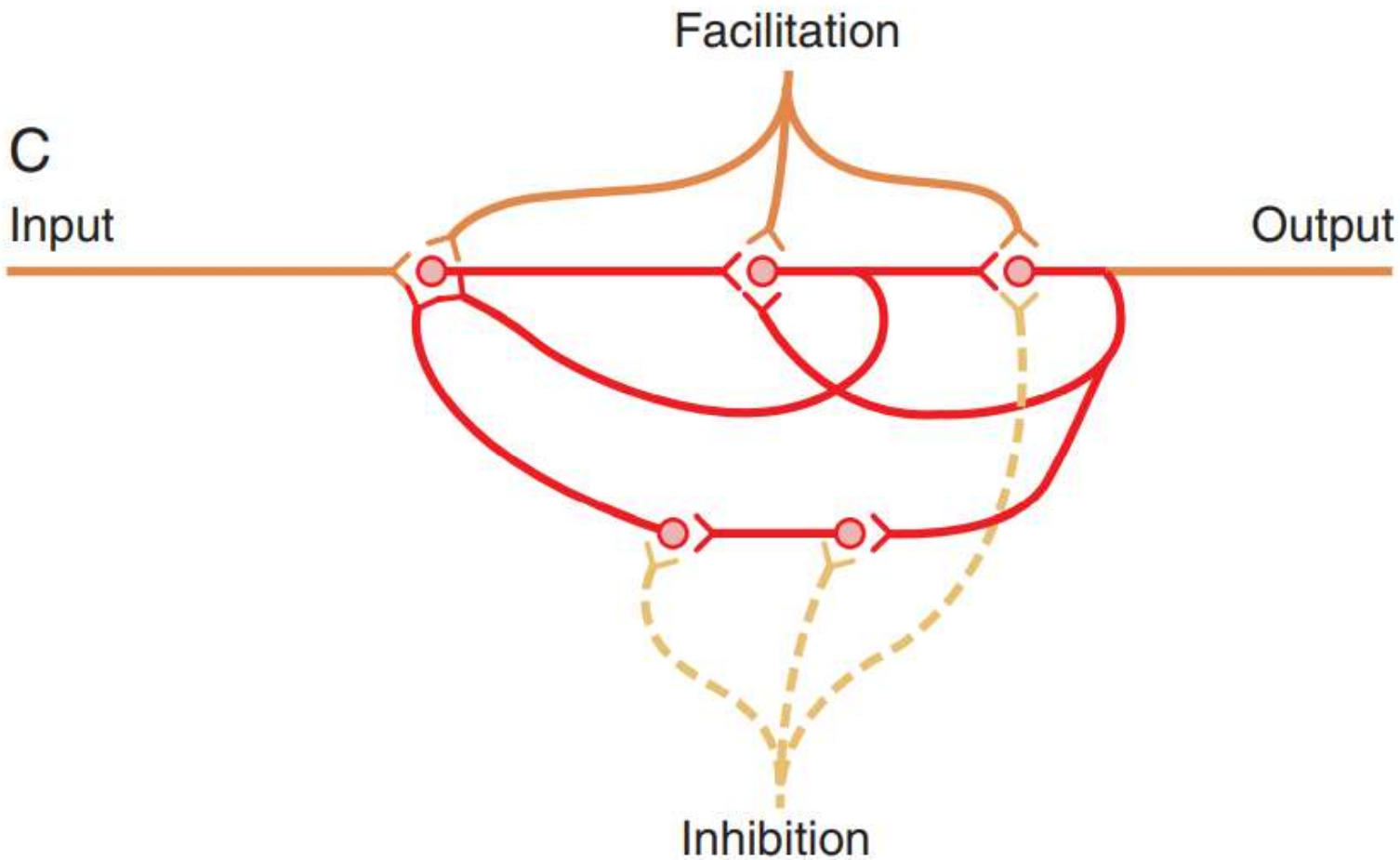
The output neuron sends a collateral nerve fiber back to its own dendrites or soma to restimulate itself.

Reverberatory circuits

A few additional neurons in the feedback circuit, which causes a longer delay between initial discharge and the feedback signal.



A facilitatory signal enhances the intensity and frequency of reverberation, whereas an inhibitory signal depresses or stops the reverberation.



Continuous signal output

- Some neuronal circuits emit output signals continuously, even without excitatory input signals.

- At least two mechanisms can cause this effect:
- (1) continuous intrinsic neuronal discharge
- (2) continuous reverberatory signals

Stability of neuronal circuits

- Almost every part of the brain connects either directly or indirectly with every other part, which creates a serious challenge.

- Two basic mechanisms that stabilize the central nervous system:

- (1) inhibitory circuits
- (2) fatigue of synapses.

Stability of neuronal circuits

INHIBITORY CIRCUITS

Two types of inhibitory circuits in widespread areas of the brain help prevent excessive spread of signals:

(1) inhibitory feedback circuits that return from the termini of pathways back to the initial excitatory neurons of the same pathways (like in sensory nervous pathways).

Stability of neuronal circuits

INHIBITORY CIRCUITS

(2) some neuronal pools that exert gross inhibitory control over widespread areas of the brain (for instance, many of the basal nuclei exert inhibitory influences throughout the muscle control system).

Fatigue of synaptic transmission

- Depletion of transmitter stores.
- Progressive inactivation of postsynaptic membrane receptors.
- Slow development of abnormal concentrations of ions inside the postsynaptic neuronal cell.

Effect of alkalosis on synaptic transmission

- **Most neurons are highly responsive to changes in pH** of the surrounding interstitial fluids.

- **Alkalosis increases neuronal excitability** and may cause cerebral **epileptic seizures**.

- In a person who is predisposed to epileptic seizures, even a short period of hyperventilation, which lowers CO2 and elevates the pH, may precipitate an epileptic attack.

Effect of acidosis on synaptic transmission

- Conversely, **acidosis greatly depresses neuronal activity**; a fall in pH may cause a comatose state.

- For instance, in very severe **diabetic or uremic acidosis, coma** almost always develops.

Effect of hypoxia on synaptic transmission

- Neuronal excitability is also highly dependent on an adequate supply of oxygen.
- **Cessation of oxygen for only a few seconds can cause complete inexcitability of some neurons**.
- This effect is observed when the brain’s blood flow is temporarily interrupted because within 3 to 7 seconds, the person becomes unconscious.

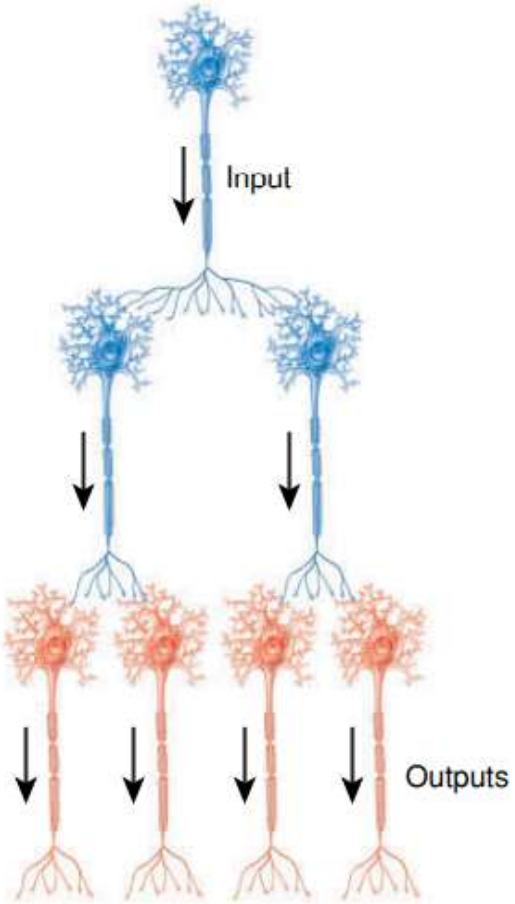
Effect of drugs on synaptic transmission

- Many drugs are known to increase the excitability of neurons, and others are known to decrease excitability.

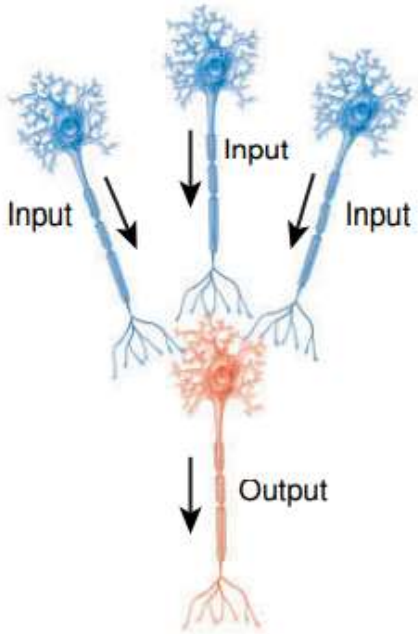
- For instance, **caffeine, theophylline, and theobromine**, which are found in coffee, tea, and cocoa, respectively, all **increase neuronal excitability**, presumably by reducing the threshold for excitation of neurons.

Effect of drugs on synaptic transmission

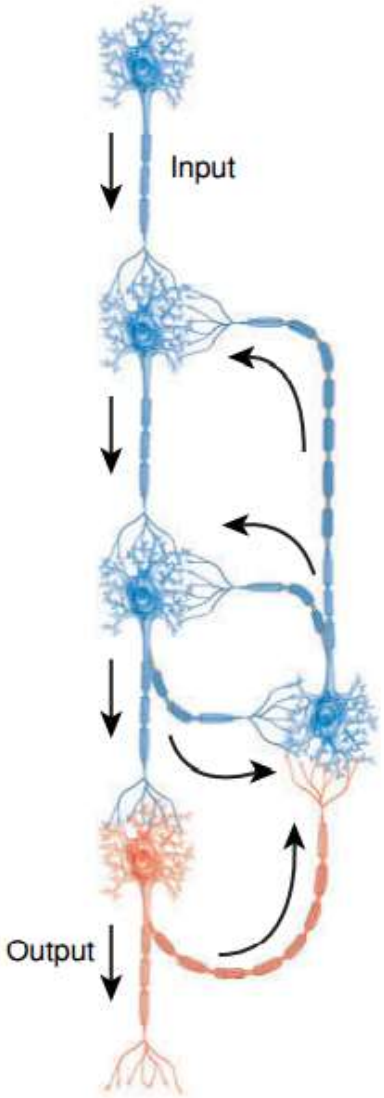
- Most **anesthetics** increase the neuronal membrane threshold for excitation and thereby **decrease synaptic transmission** at many points in the nervous system.


Input
Outputs

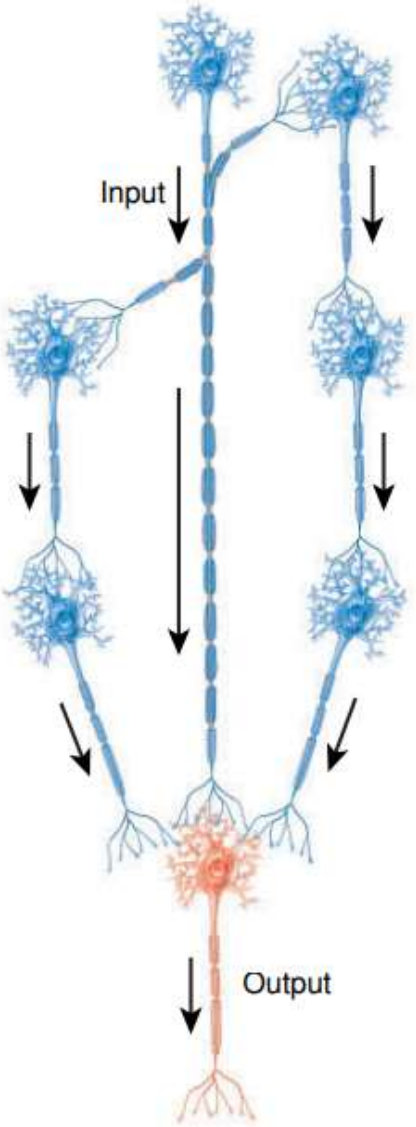
A


Input
Input
Input
Output

B

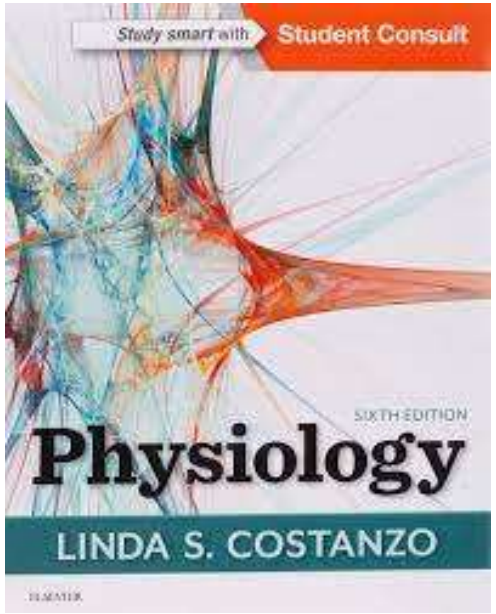

Input
Output

C


Input
Output

D

References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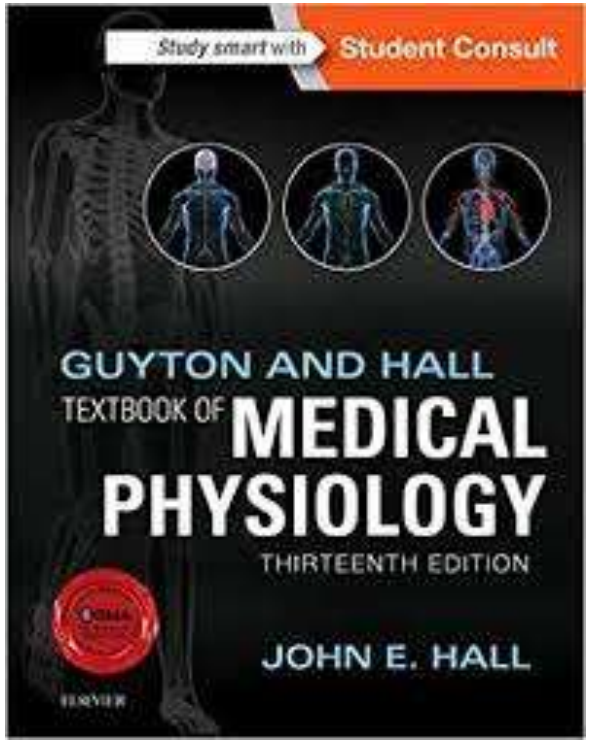
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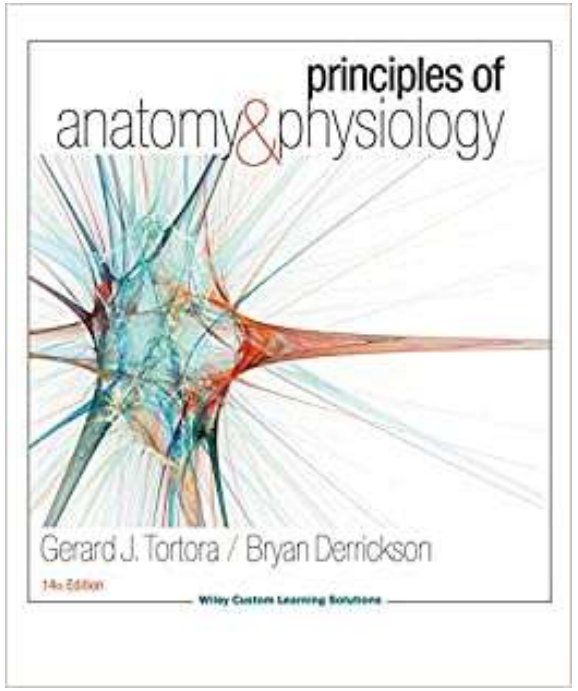
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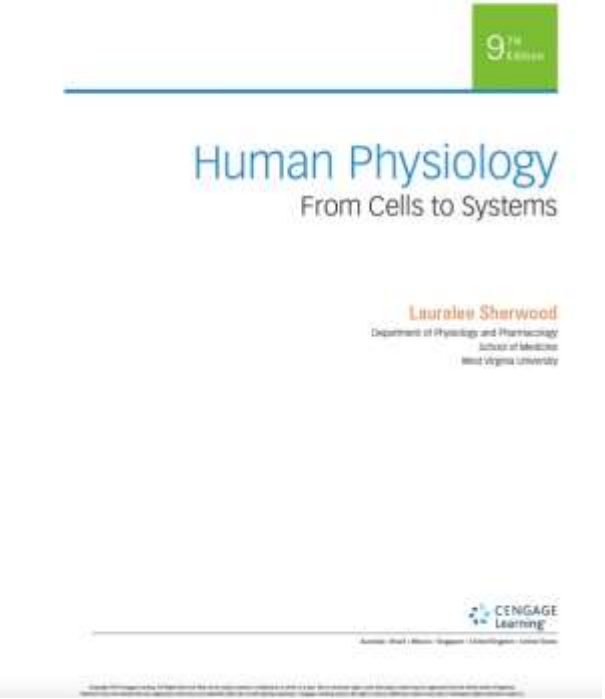
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