Introduction to Physiology for medical and dental students

Transmission and processing of signals in neural pools

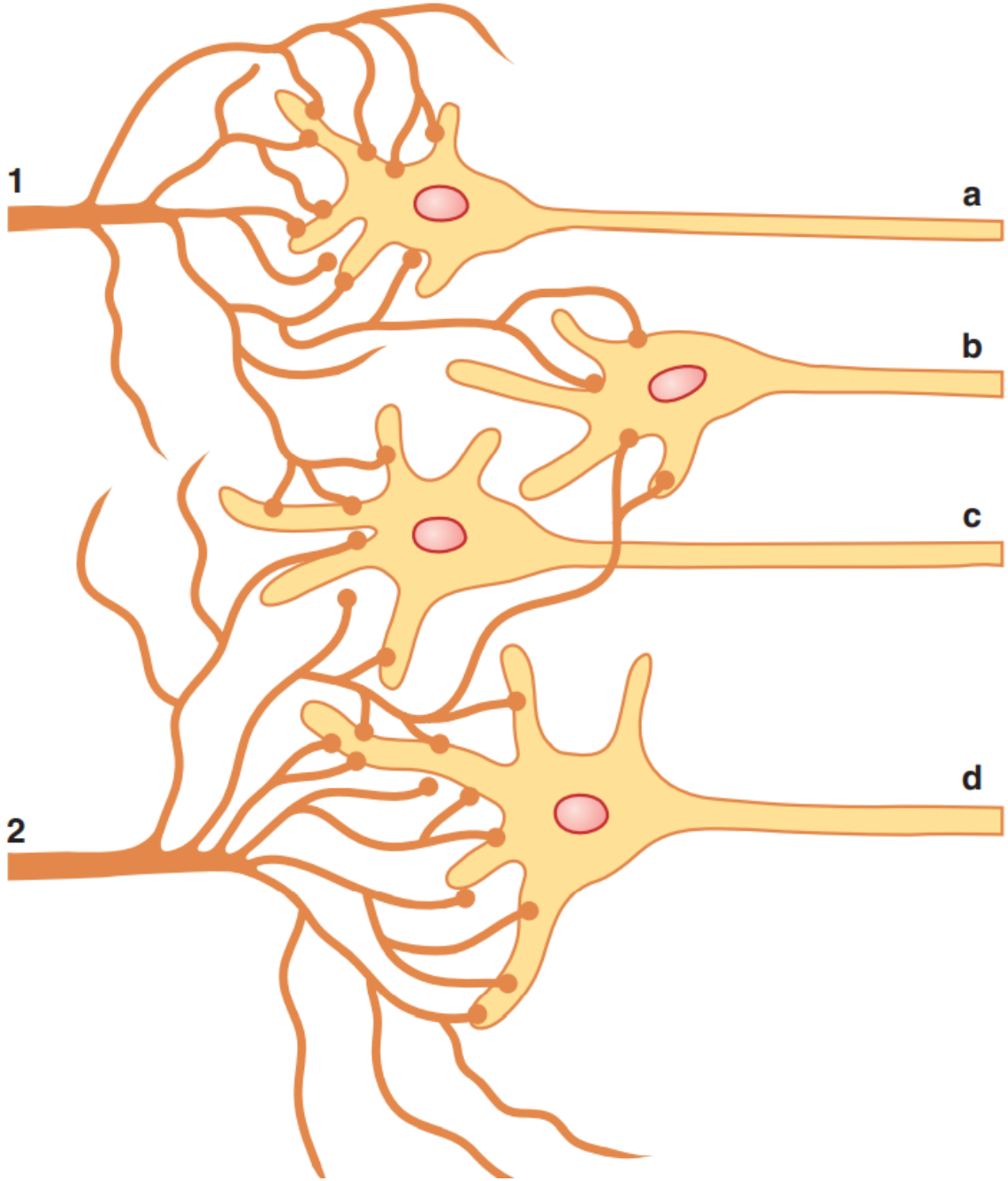
Fatima Ryalat, MD, PhD

Assistant Professor, Physiology and Biochemistry Department, School of Medicine, University of Jordan

Neuronal pools

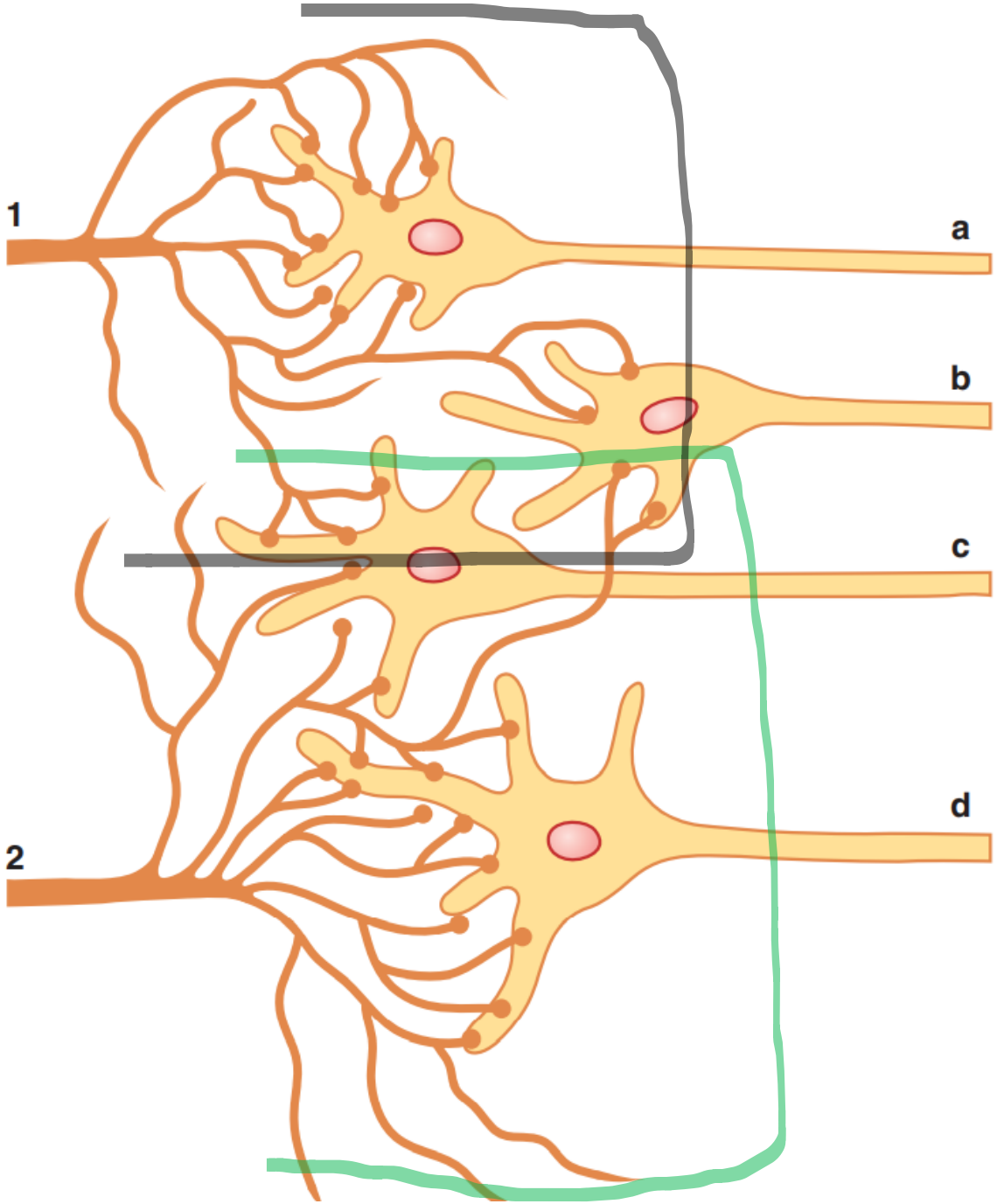
- Functional groups of neurons occurring in the grey matter of the brain and spinal cord, which process and integrate incoming information received from other sources, such as the sense organs, and transmit the processed information to other destinations. (oxfordreference.com)

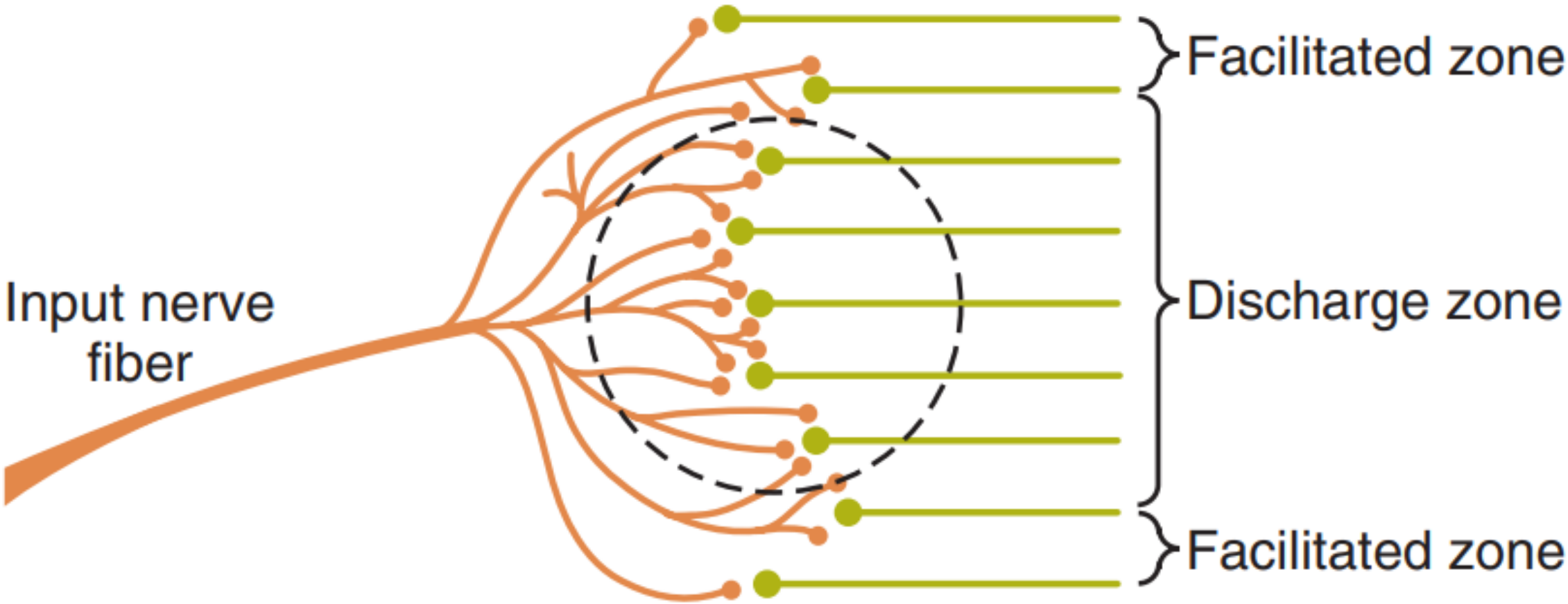
- Each neuronal pool has its own special organization that causes it to process signals in its own unique way and perform certain function.


1
2
a
b
c
d

Stimulatory field:

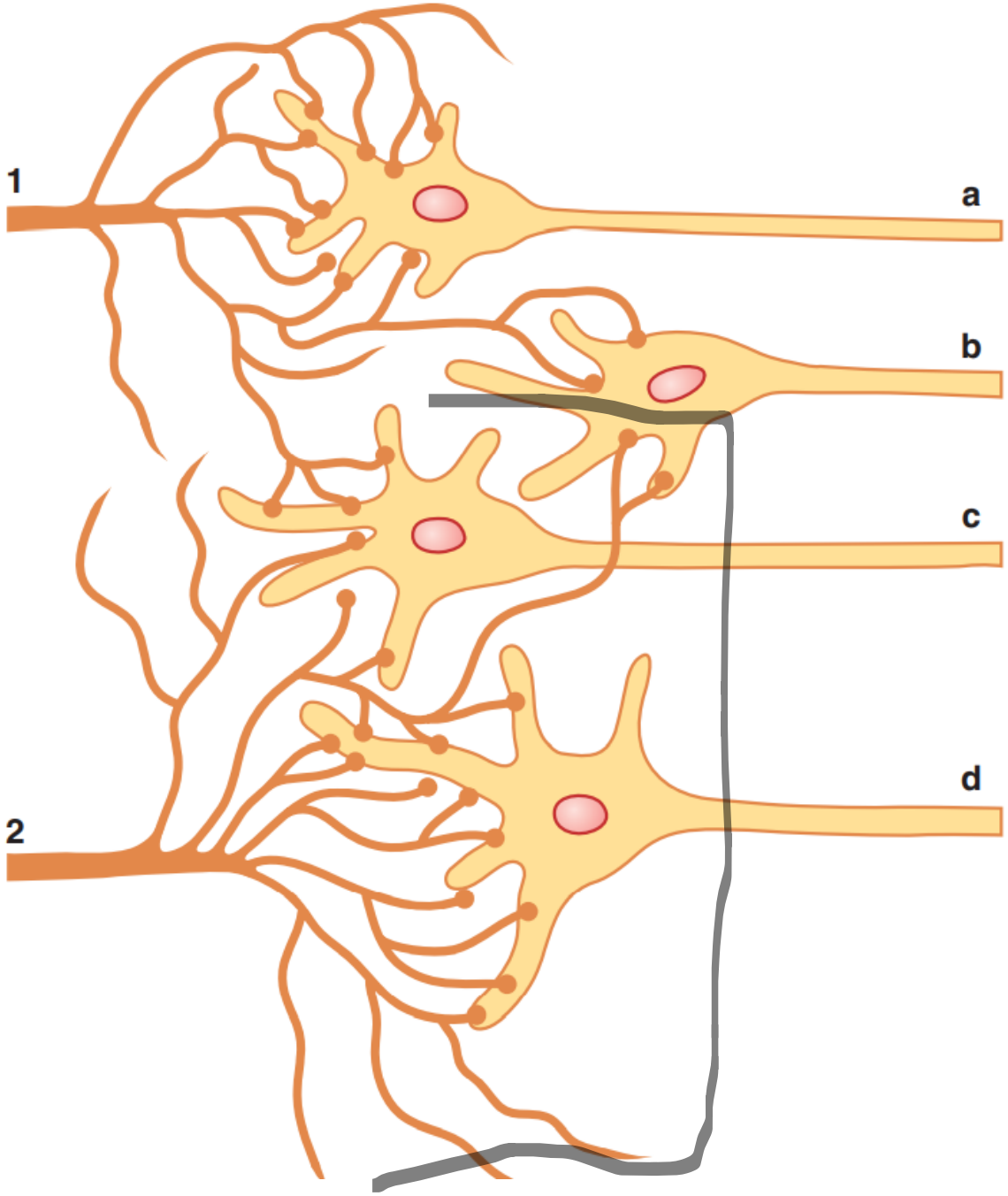
The neuronal area stimulated by each incoming nerve fiber.




Input nerve fiber
Facilitated zone
Discharge zone
Facilitated zone

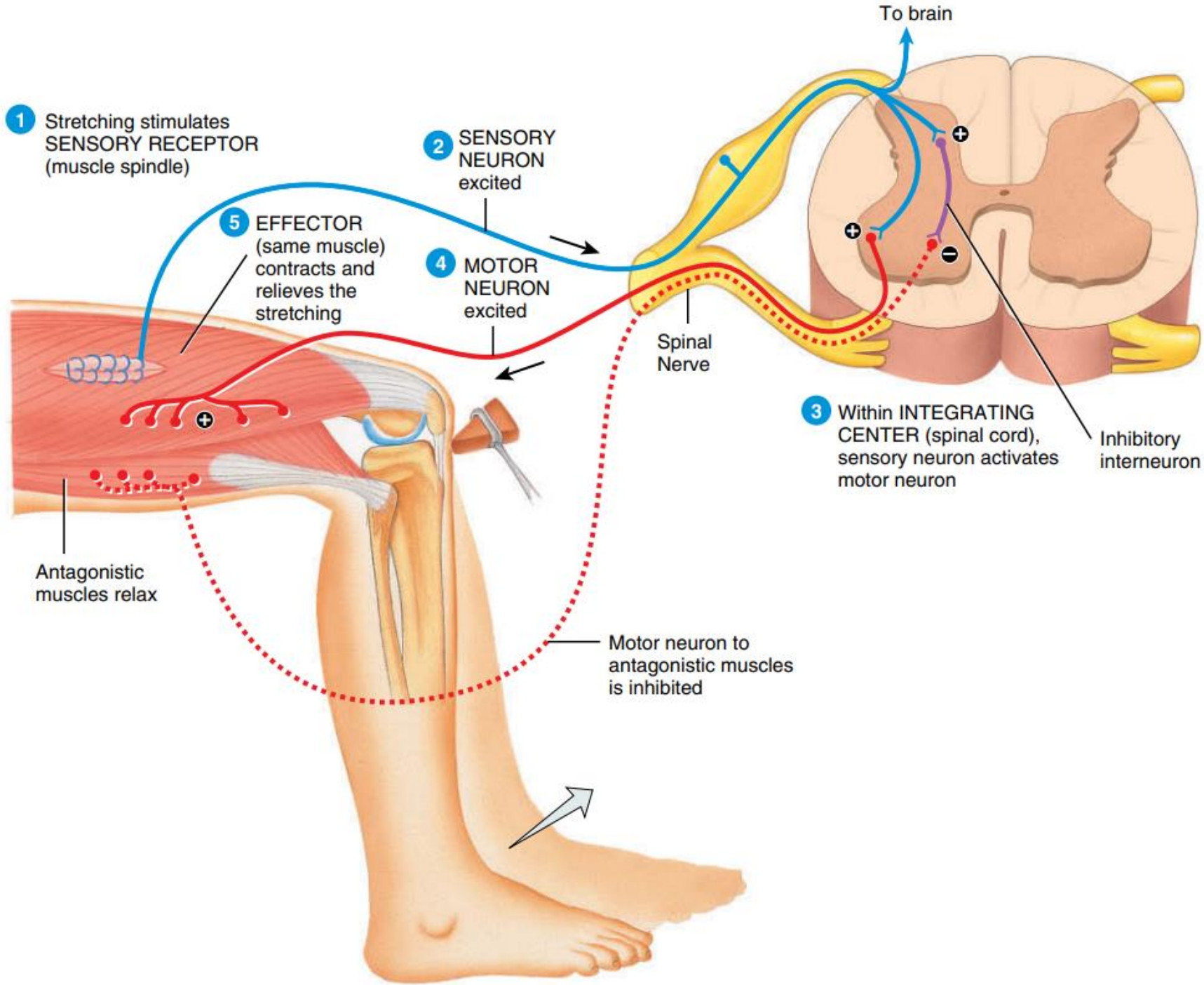
Inhibitory zone:

Greatest inhibition in the center of the zone.



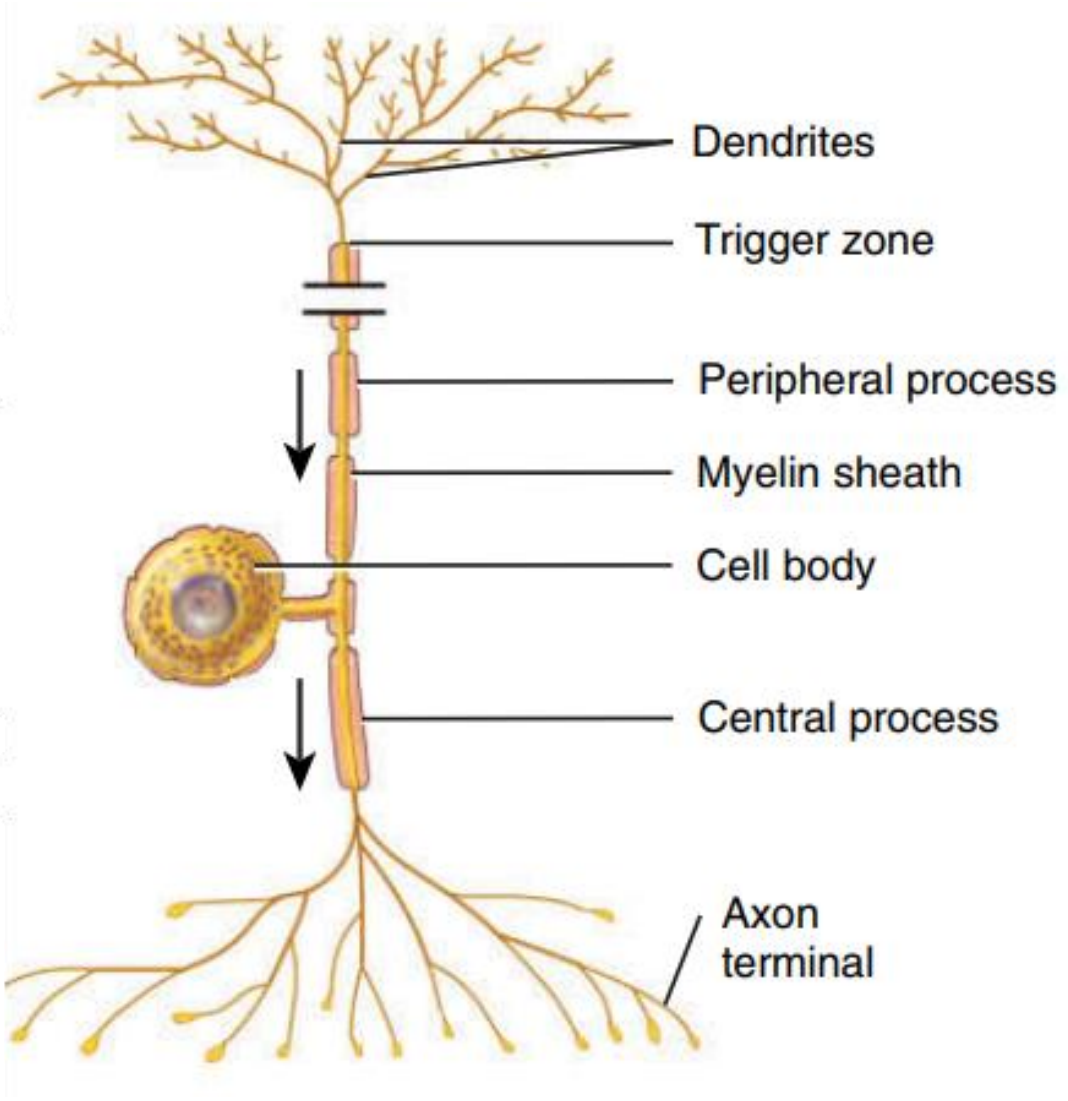
Neuronal circuits

- 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

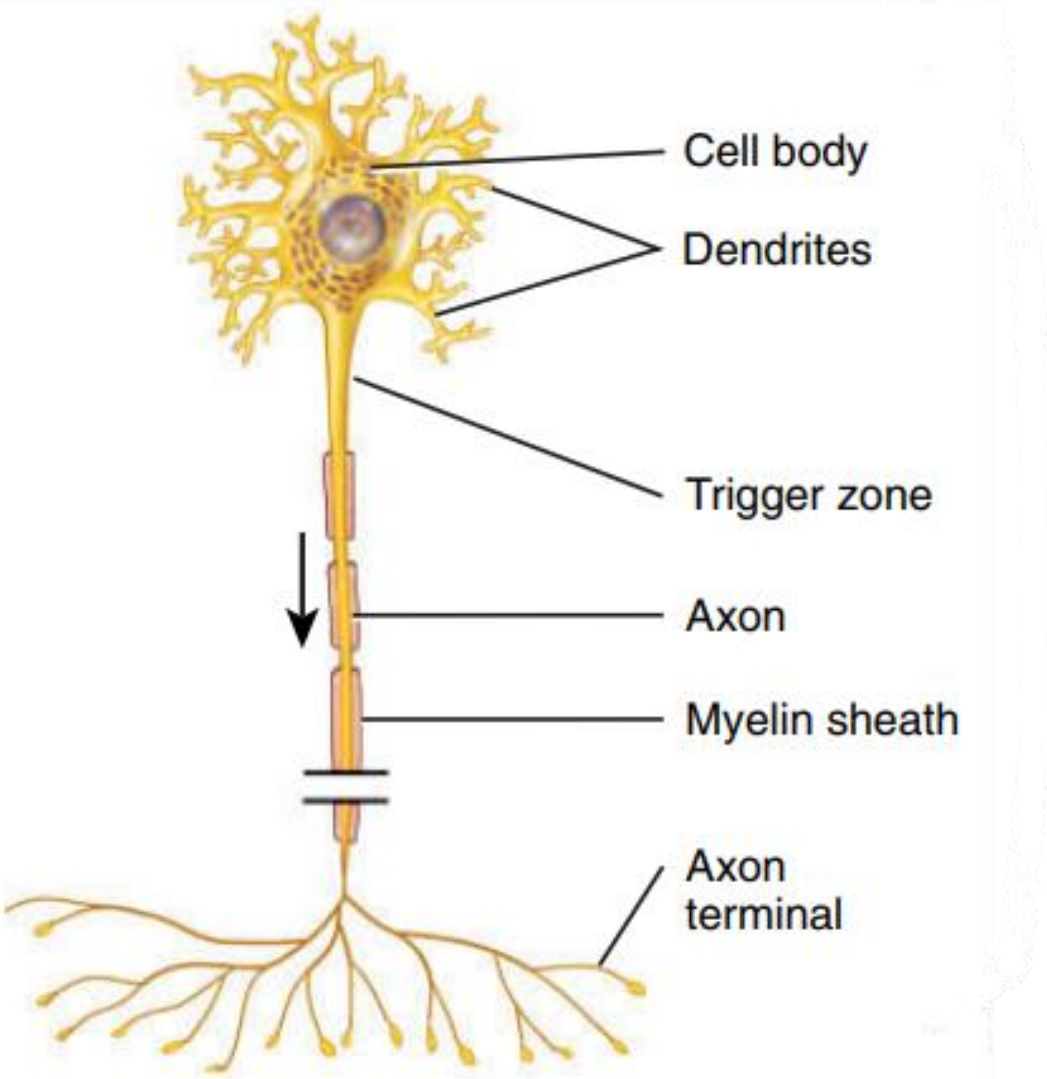
Stretch reflex

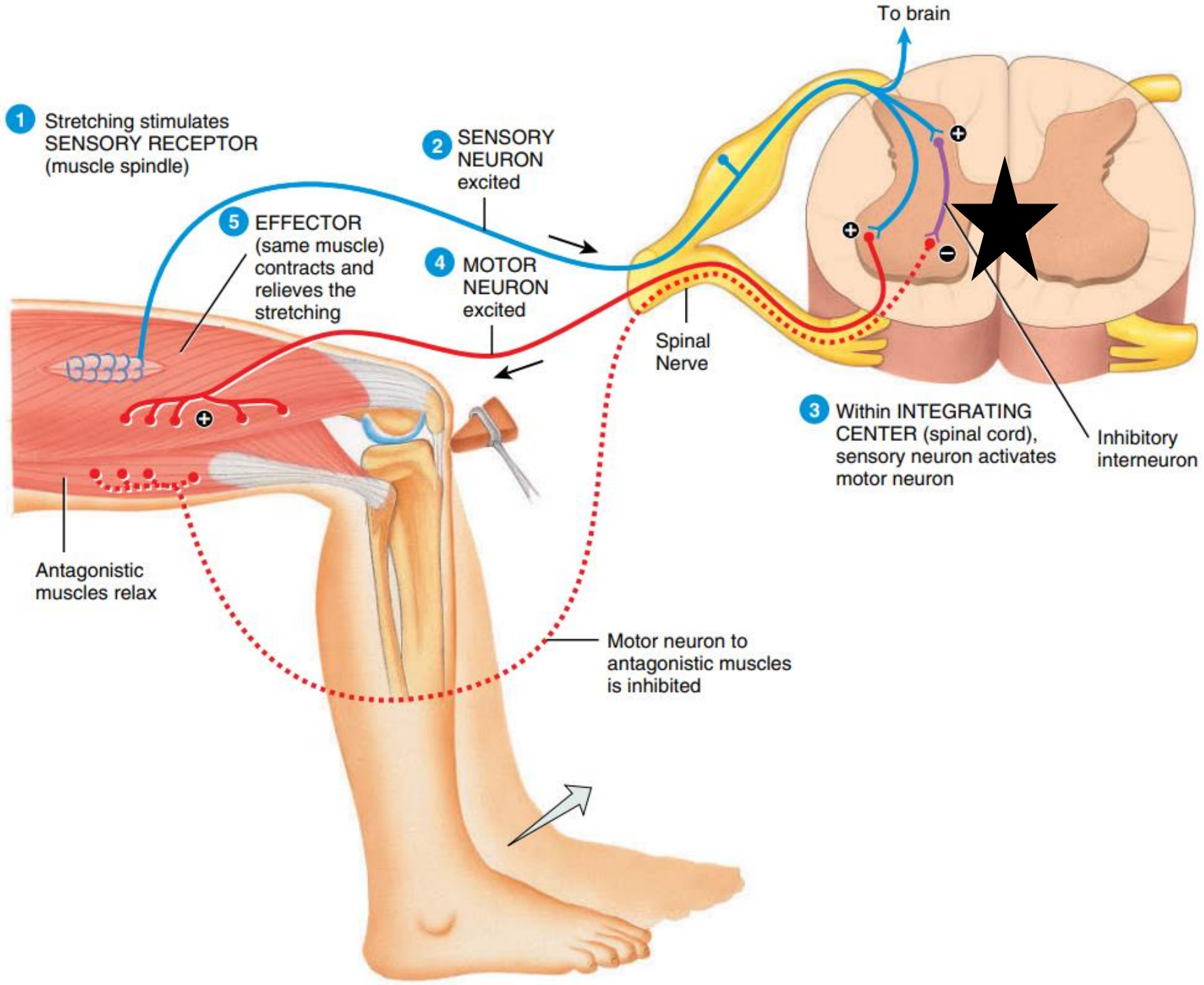
- Sensory neuron
- Unipolar



Stretch reflex

- Motor neurons
- Multipolar



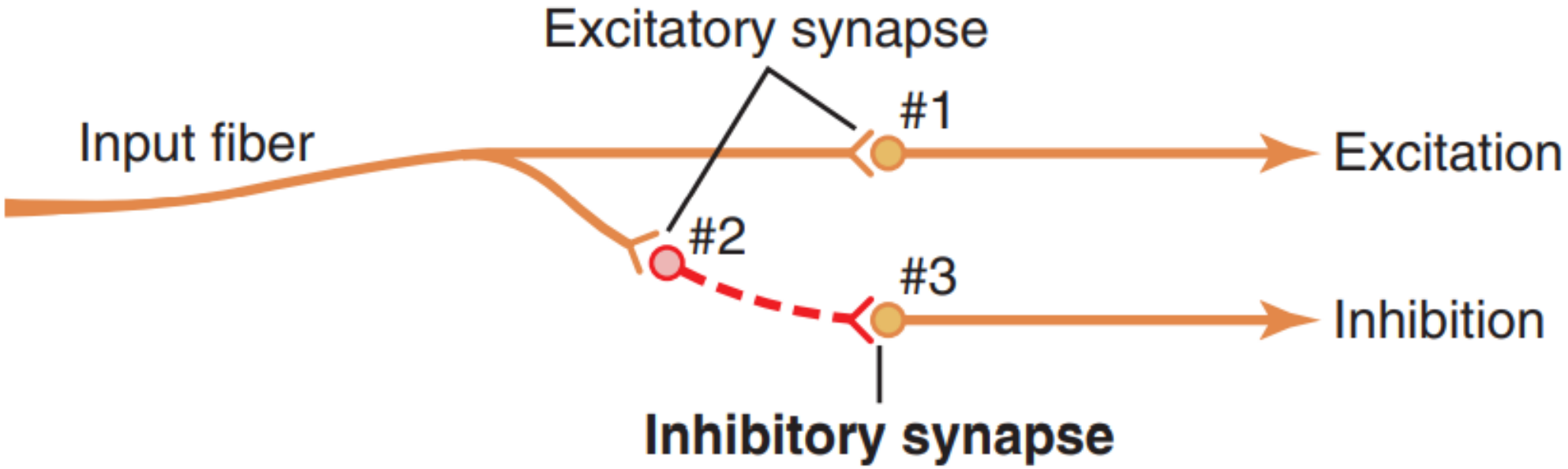

To brain
1 Stretching stimulates SENSORY RECEPTOR (muscle spindle)
2 SENSORY NEURON excited
5 EFFECTOR (same muscle) contracts and relieves the stretching
4 MOTOR NEURON excited
Spinal Nerve
3 Within INTEGRATING CENTER (spinal cord), sensory neuron activates motor neuron
Inhibitory interneuron
Antagonistic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

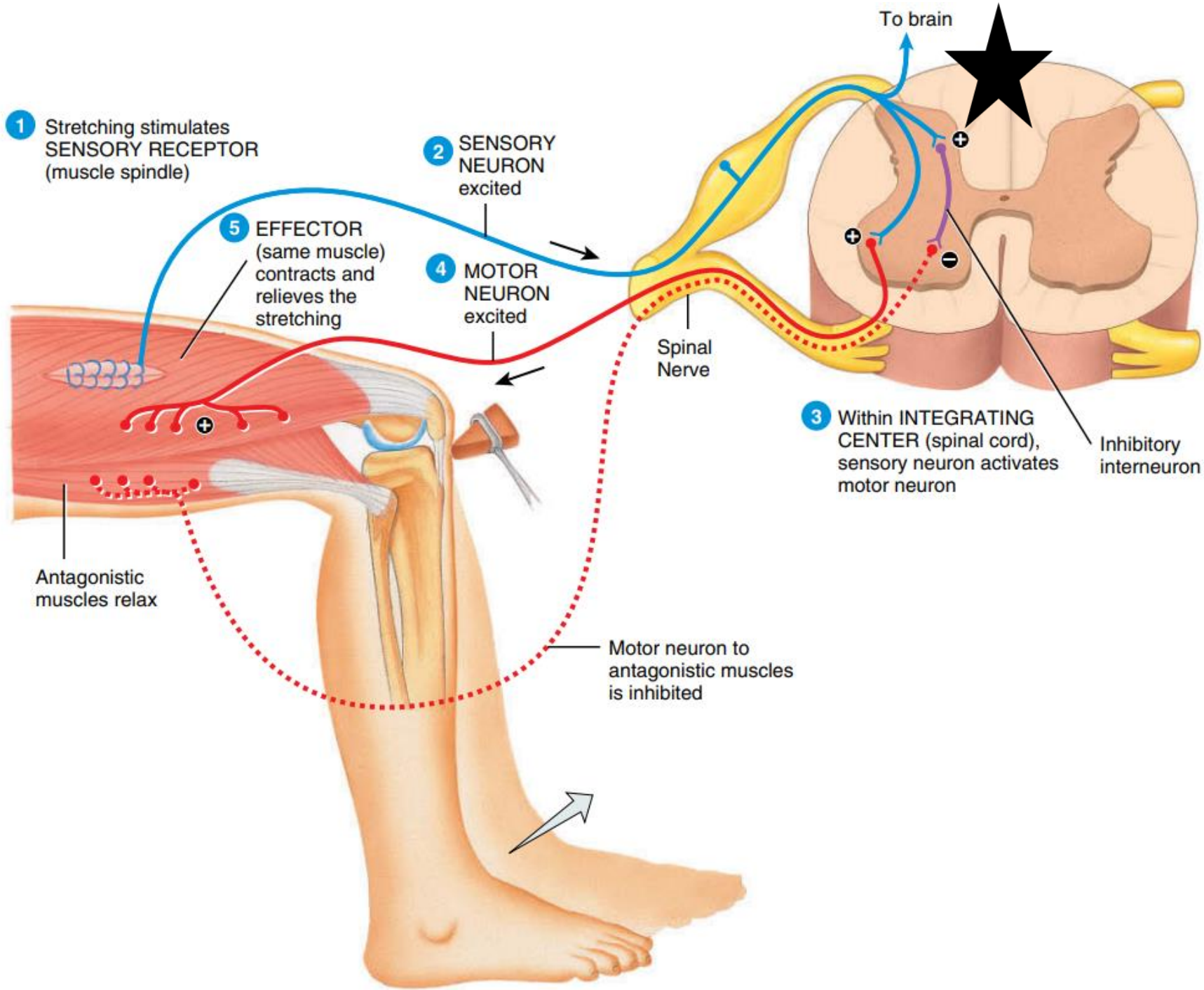
Reciprocal inhibition

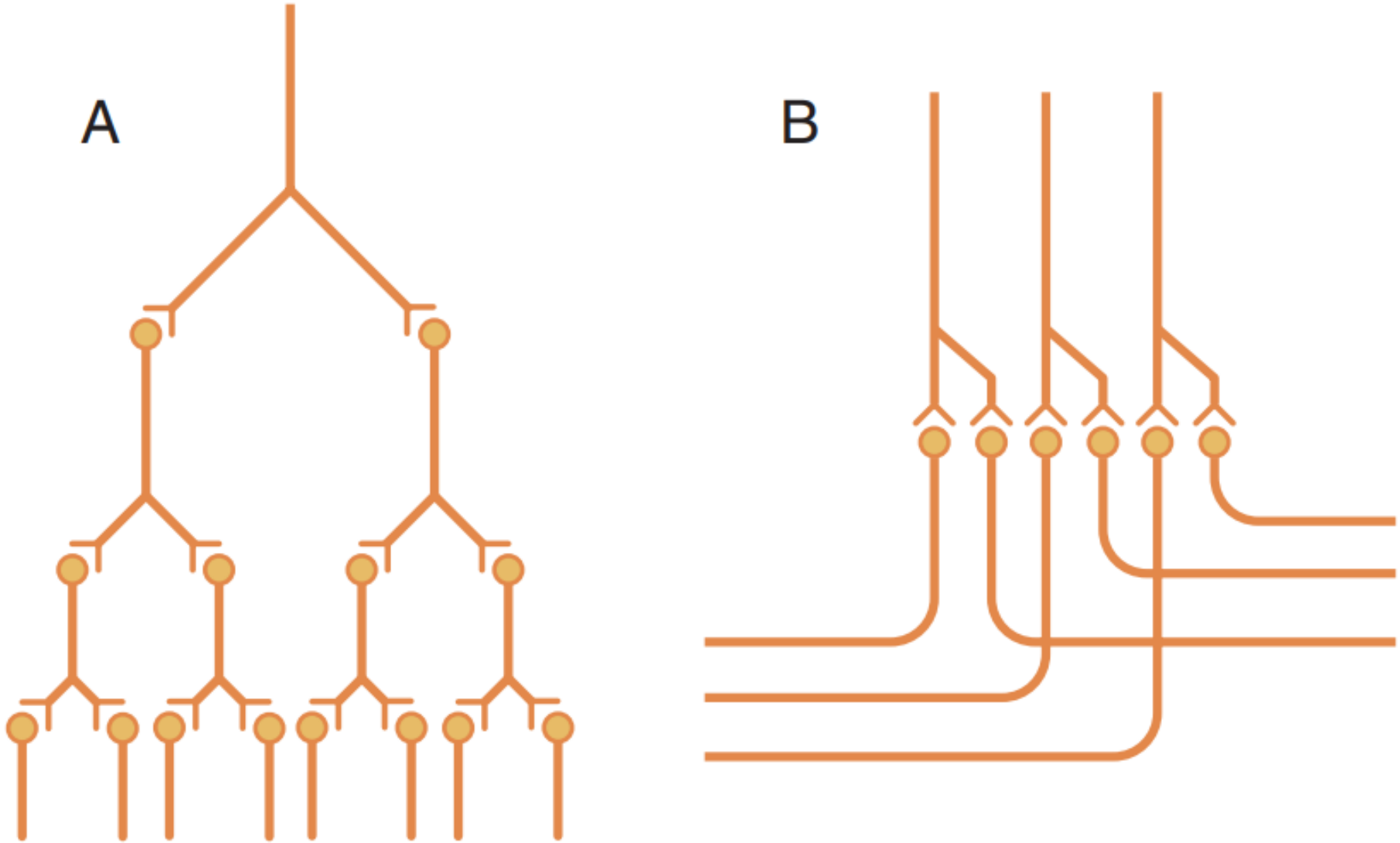
- Sometimes an incoming signal to a neuronal pool causes an output excitatory signal going in one direction and at the same time an inhibitory signal going elsewhere.

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

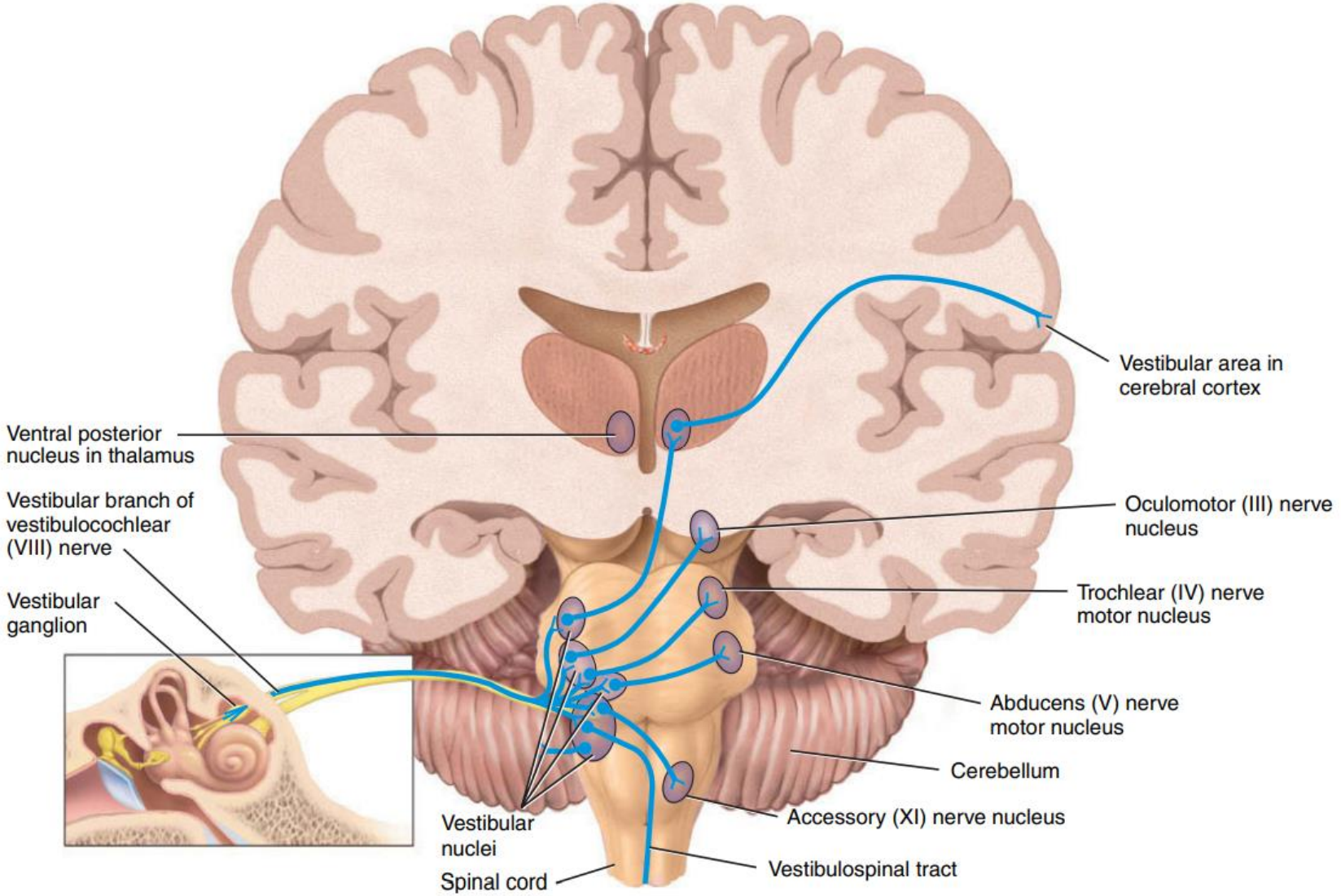
Reciprocal inhibition




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


A
B
Divergence in same tract
Divergence into multiple tracts

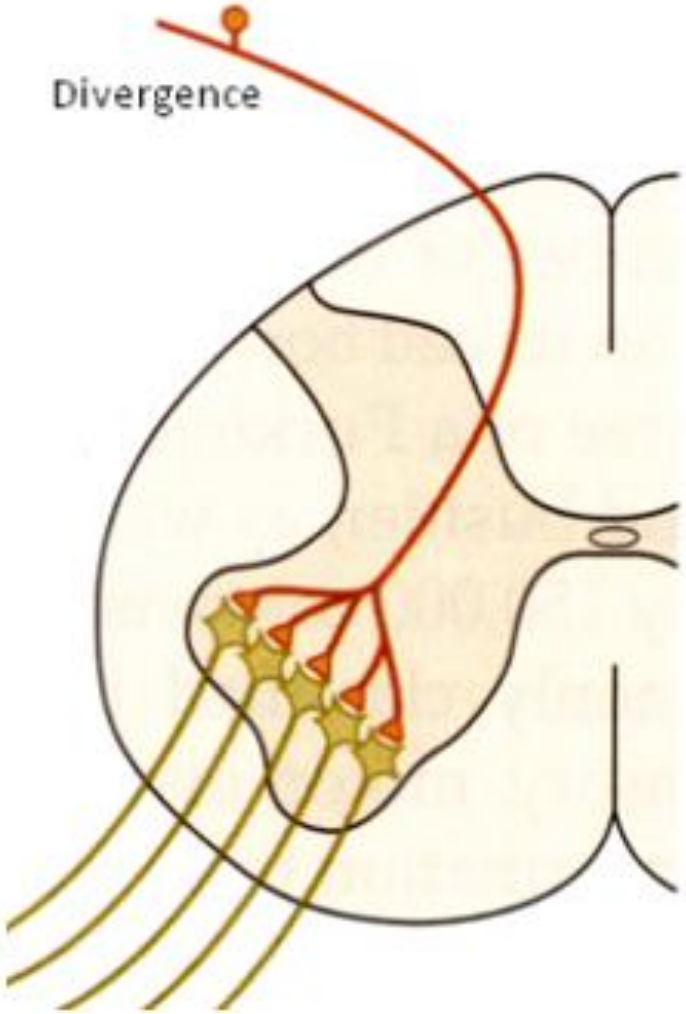
Divergence into multiple tracts

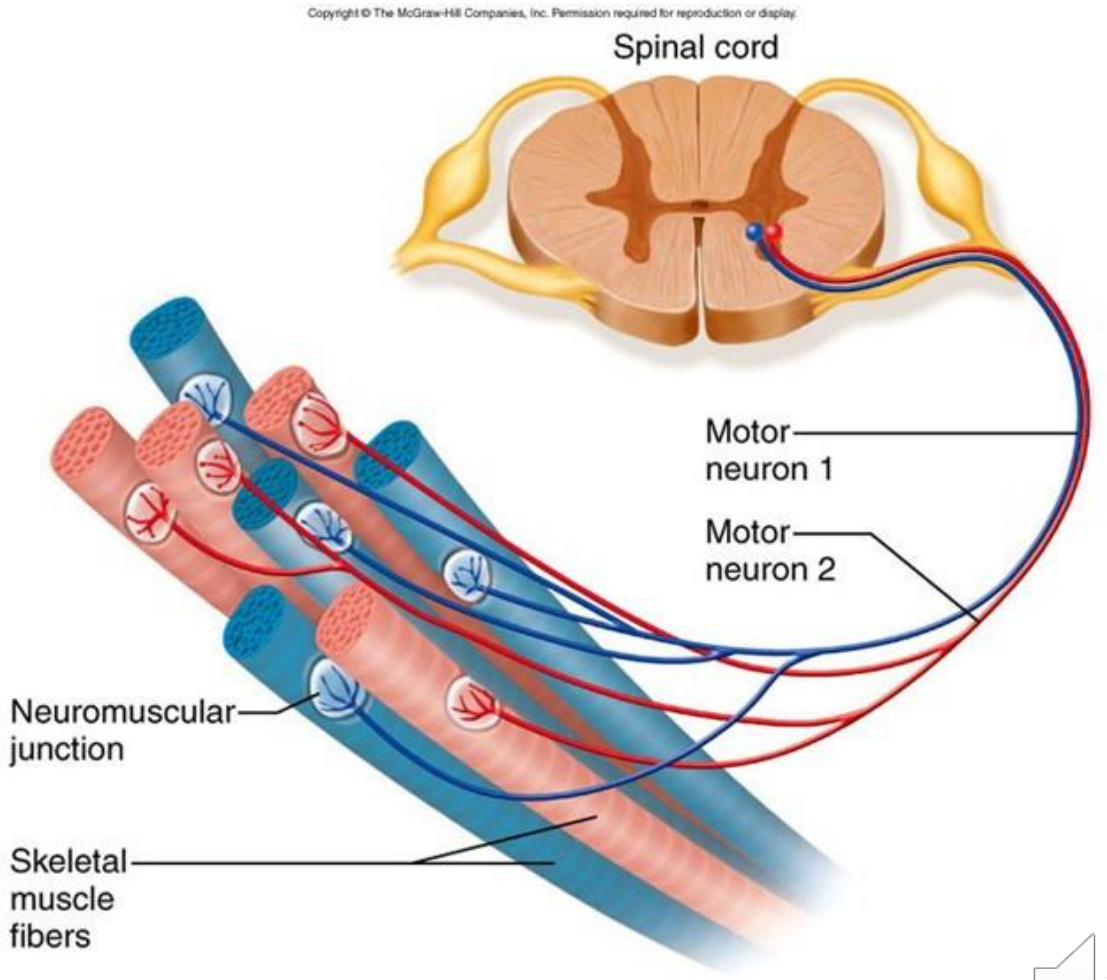


Amplifying divergence

- 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.

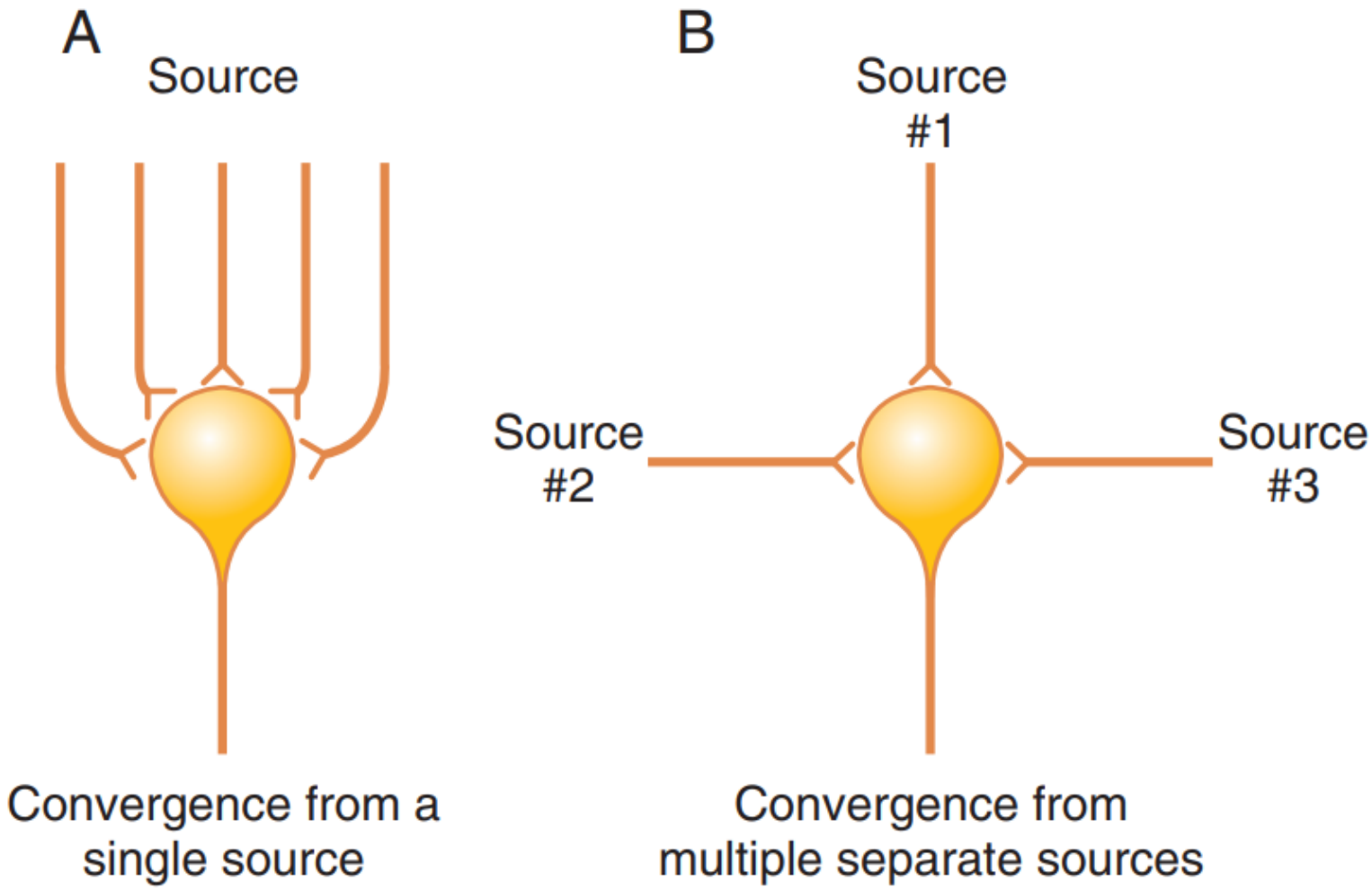
Amplifying divergence



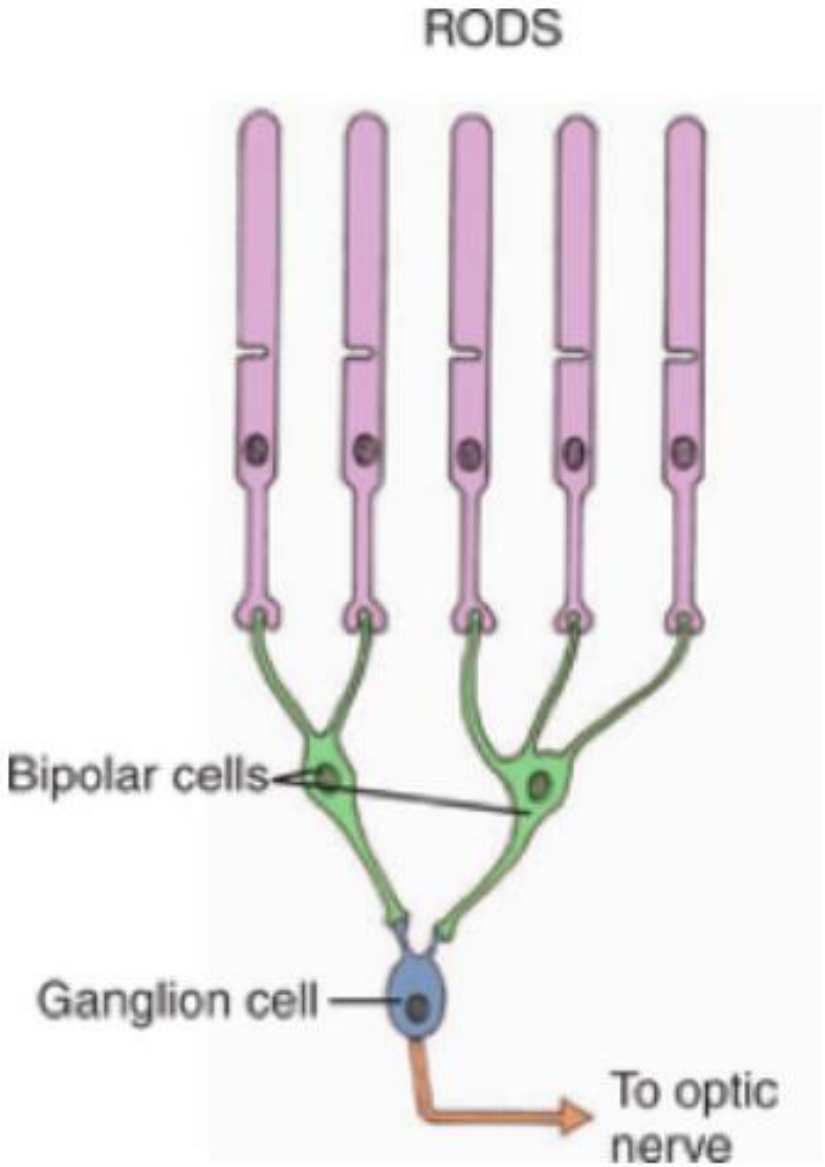


Convergence

- 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

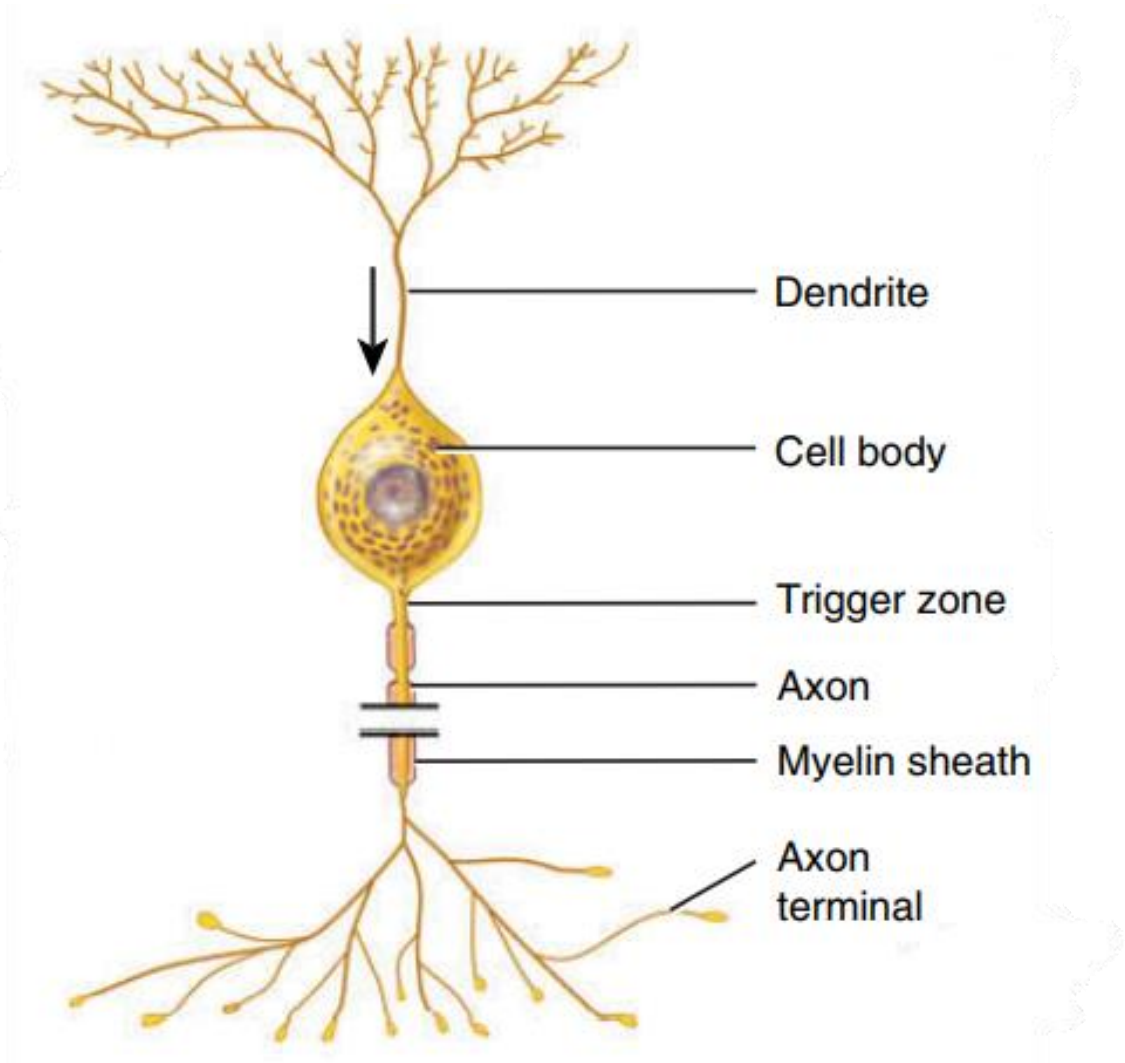

A
Source
B
Source
#1
Source
#2
Source
#3
Convergence from a
single source
Convergence from
multiple separate sources

Convergence in photoreceptors (Rods)



http://veteriankey.com/retina/

Bipolar neurons

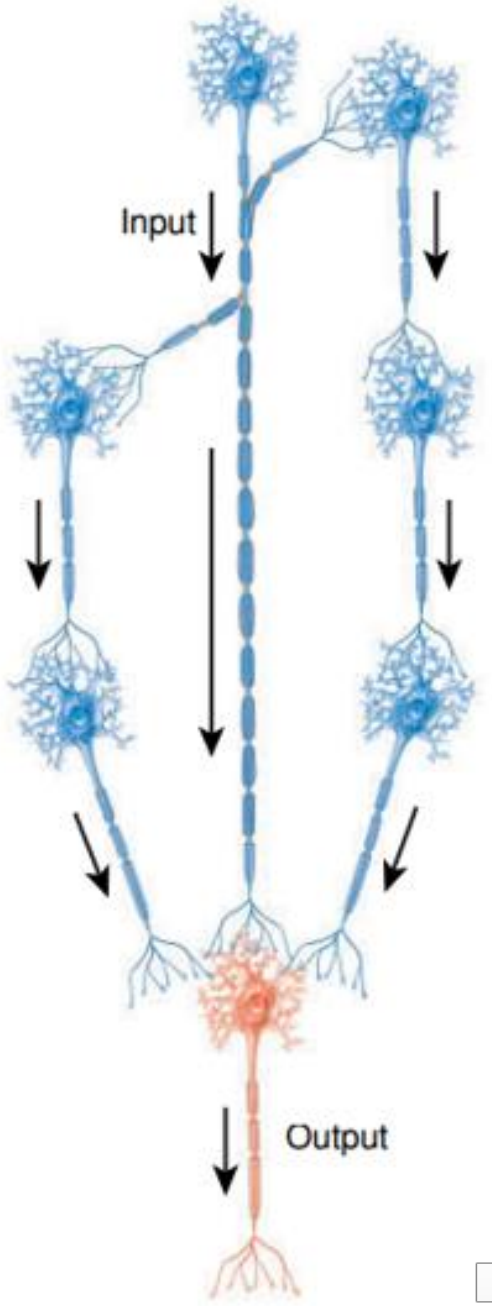


Afterdischarge

- A signal entering a pool causes a prolonged output discharge.
- **Synaptic afterdischarge**: as in some neuropeptides.

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

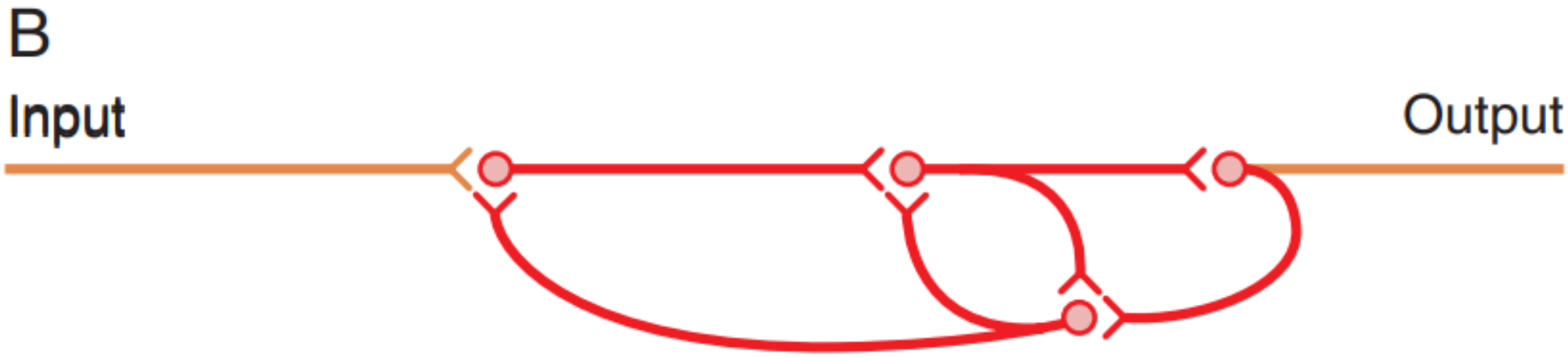
- One of the most important circuits in the nervous system.
- Caused by positive feedback within the neuronal circuit that feeds back to re-excite the input of the same circuit.
- Consequently, once stimulated, the circuit may discharge repetitively for a long time.

Reverberatory circuits

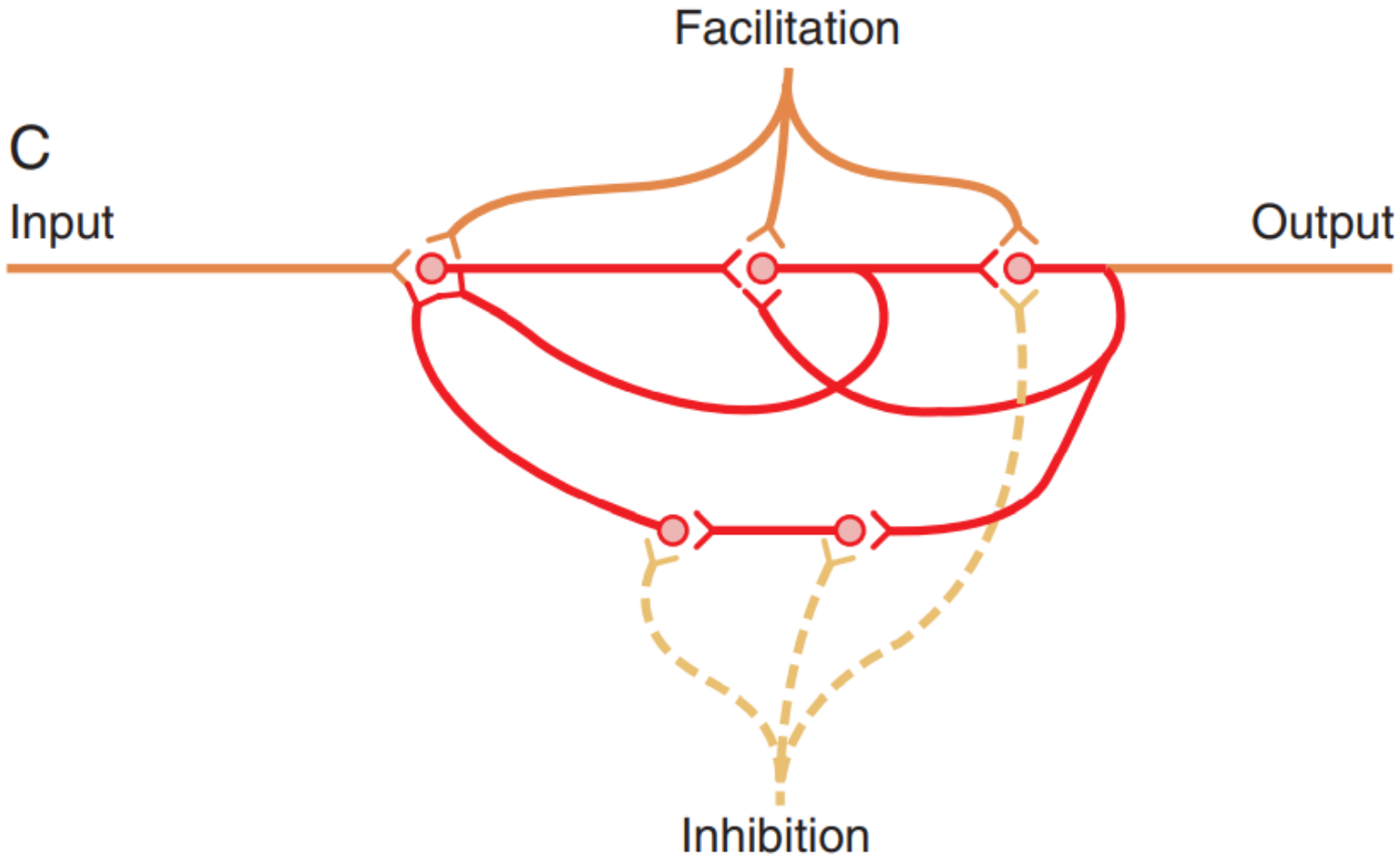
The output neuron sends a collateral nerve fiber back to its own dendrites or soma to restimulate itself.

Reverberatory circuits

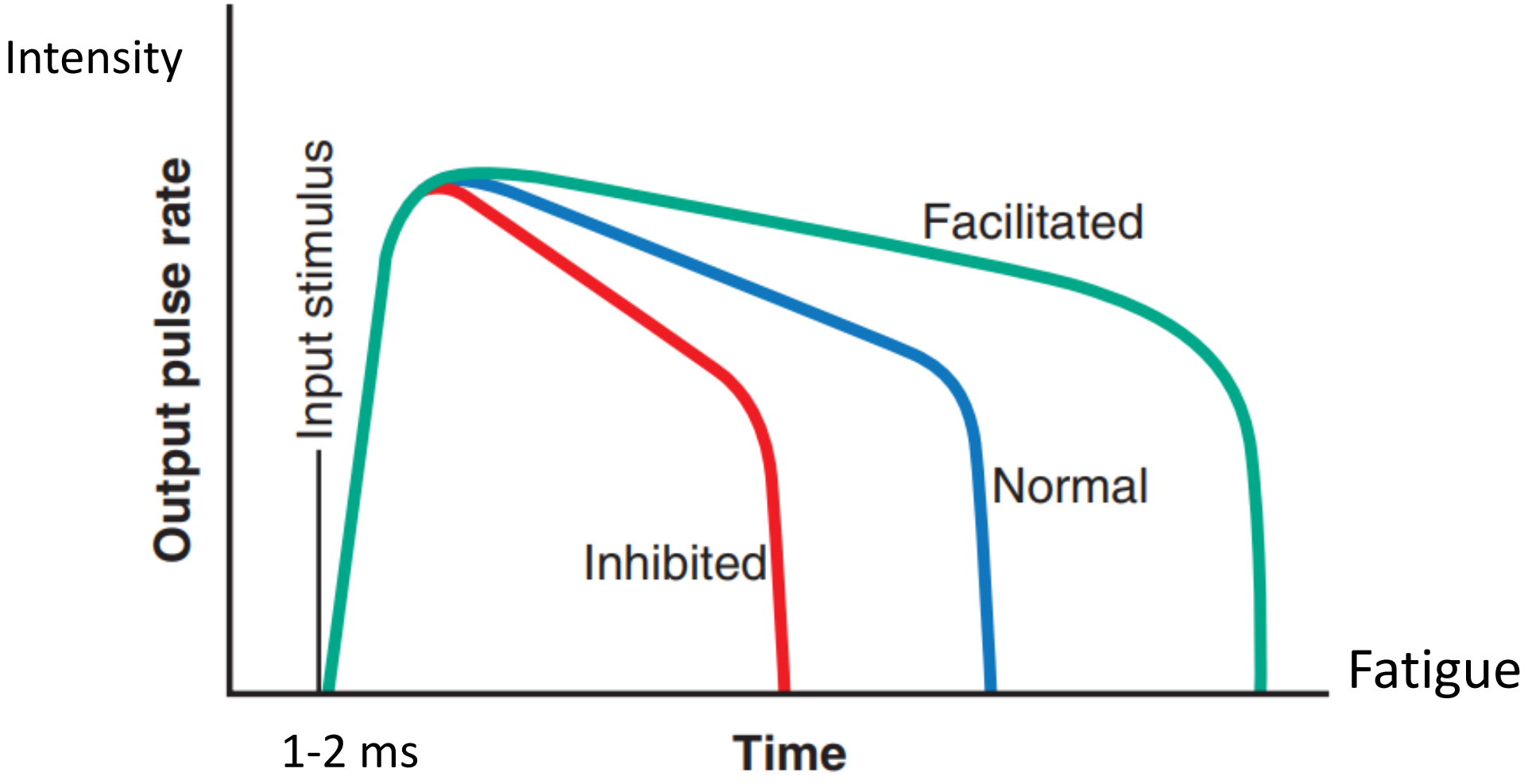
A few additional neurons in the feedback circuit, which causes a longer delay between initial discharge and the feedback signal.



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



Reverberatory circles



Reverberatory circles

- The cause of the sudden cessation of reverberation is fatigue of synaptic junctions in the circuit.

- Fatigue beyond a certain critical level lowers the stimulation of the next neuron in the circuit below threshold level so that the circuit feedback is suddenly broken.

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

Continuous signal output

- **Continuous Discharge Caused by Intrinsic Neuronal Excitability.** Neurons, like other excitable tissues, discharge repetitively if their level of excitatory membrane potential rises above a certain threshold level.

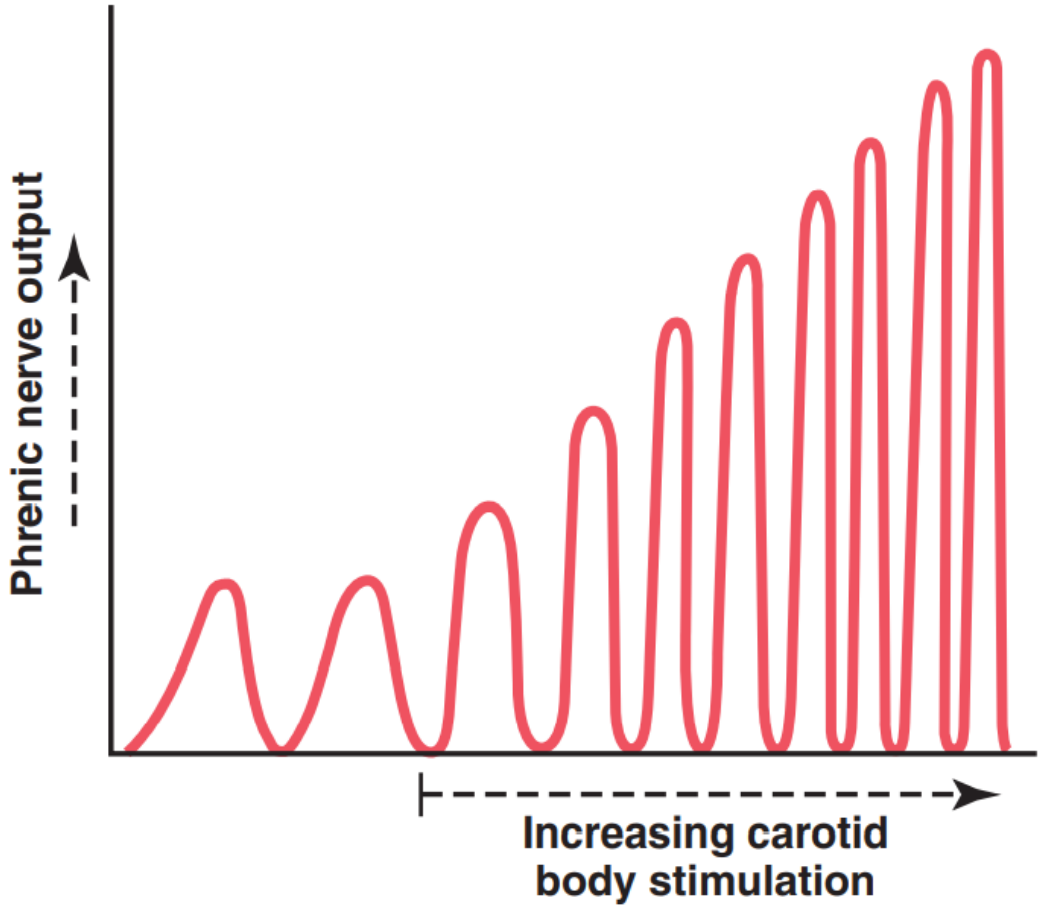
- The membrane potentials of many neurons even normally are high enough to cause them to emit impulses continually.

- The rates at which these cells emit impulses can be increased by excitatory signals or decreased by inhibitory signals.

Continuous signal output

- **A reverberating** circuit that does not fatigue enough to stop reverberation is a source of continuous impulses.

- Excitatory impulses entering the reverberating pool can increase the output signal, whereas inhibition can decrease or even extinguish the signal.



The rhythmical output of summated nerve impulses from the respiratory center, showing that progressively increasing stimulation of the carotid body increases both the intensity and the frequency of the phrenic nerve signal to the diaphragm to increase respiration.

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).

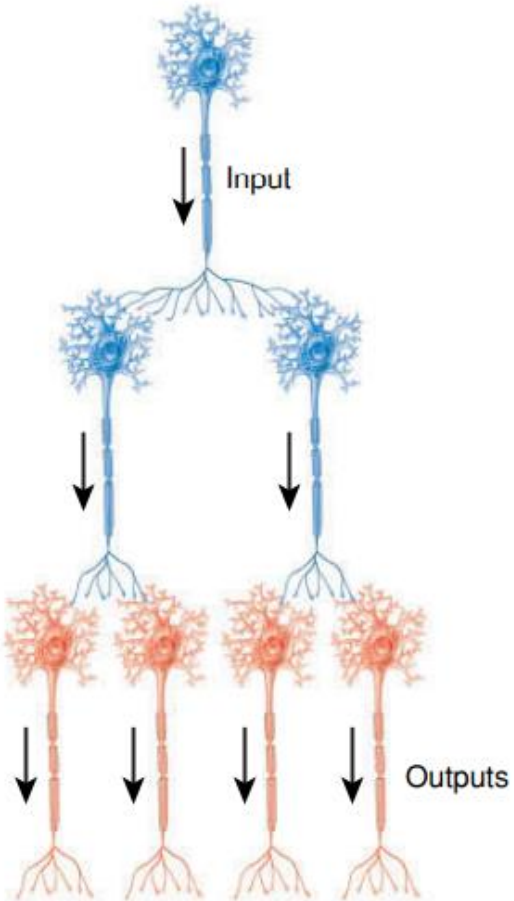
Stability of neuronal circuits

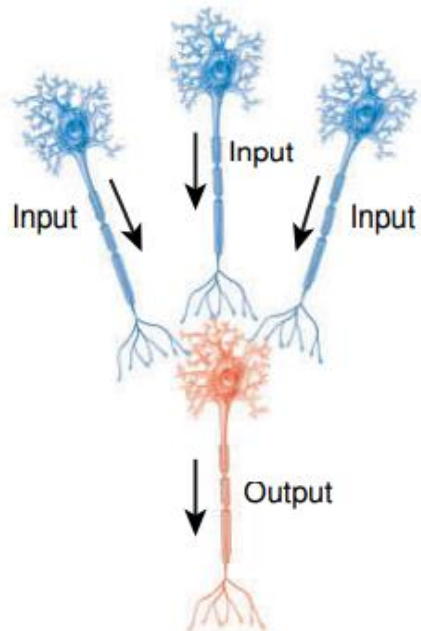
INHIBITORY CIRCUITS

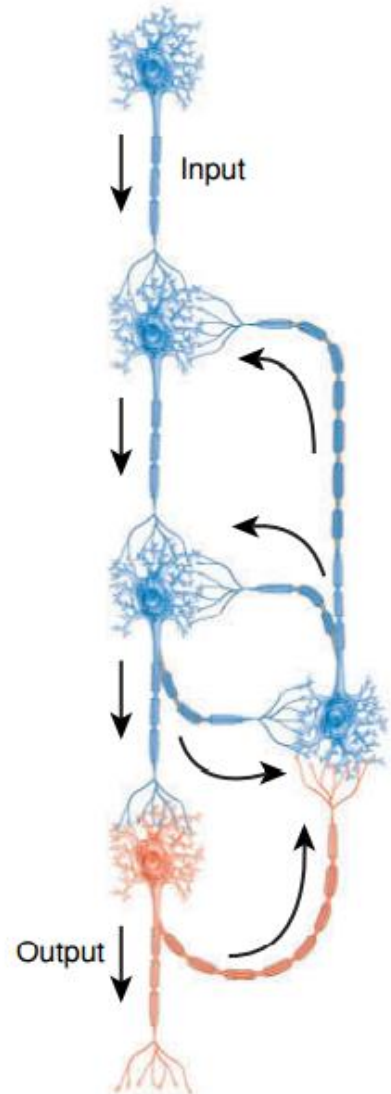
(2) some neuronal pools that exert gross inhibitory control over widespread areas of the brain (for instance, many of the basal ganglia exert inhibitory influences throughout the muscle control system).

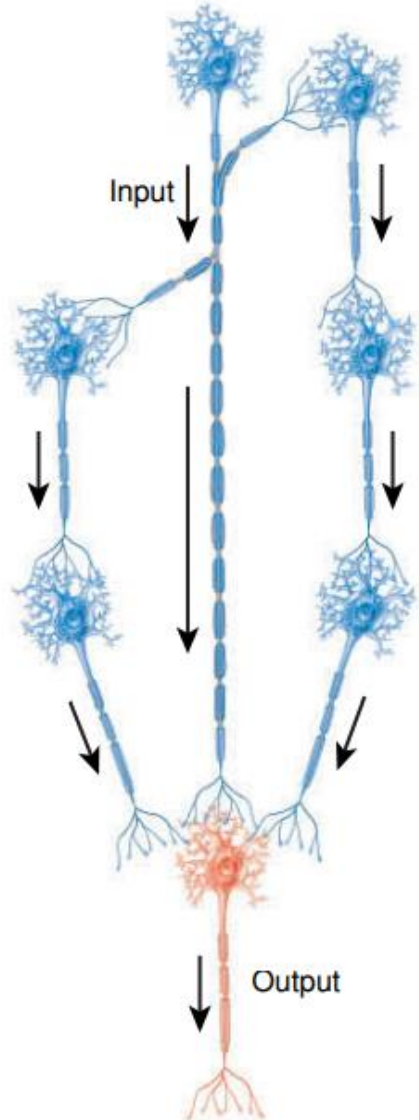
Stability of neuronal circuits

- The long-term sensitivities of synapses can be changed tremendously by up-regulating the number of receptor proteins at the synaptic sites when there is underactivity and down-regulating the receptors when there is overactivity.


Input
Outputs


Input
Input
Input
Output


Input
Output


Input
Output

Questions? Feedback?

Thank you