Neurophysiology

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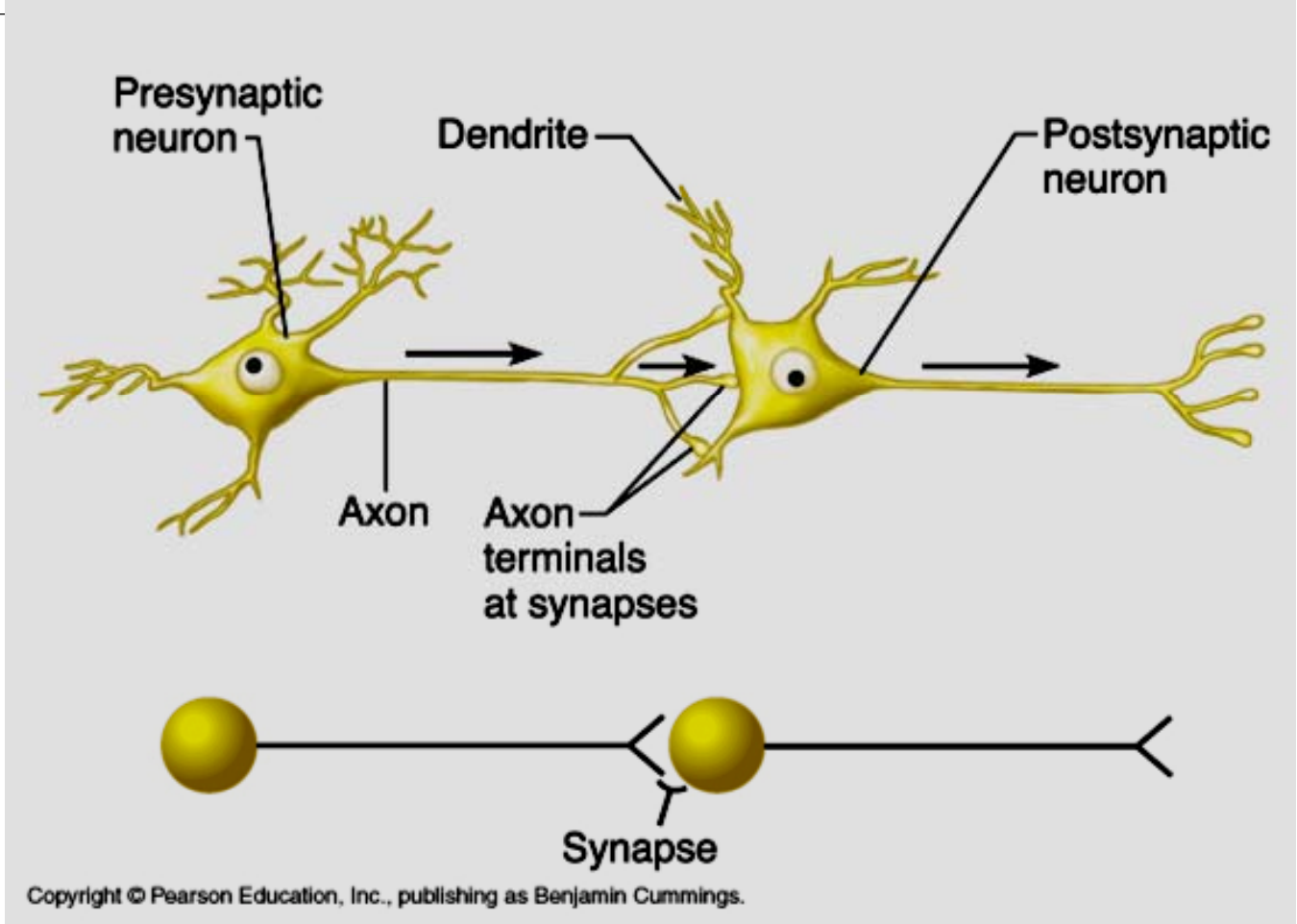
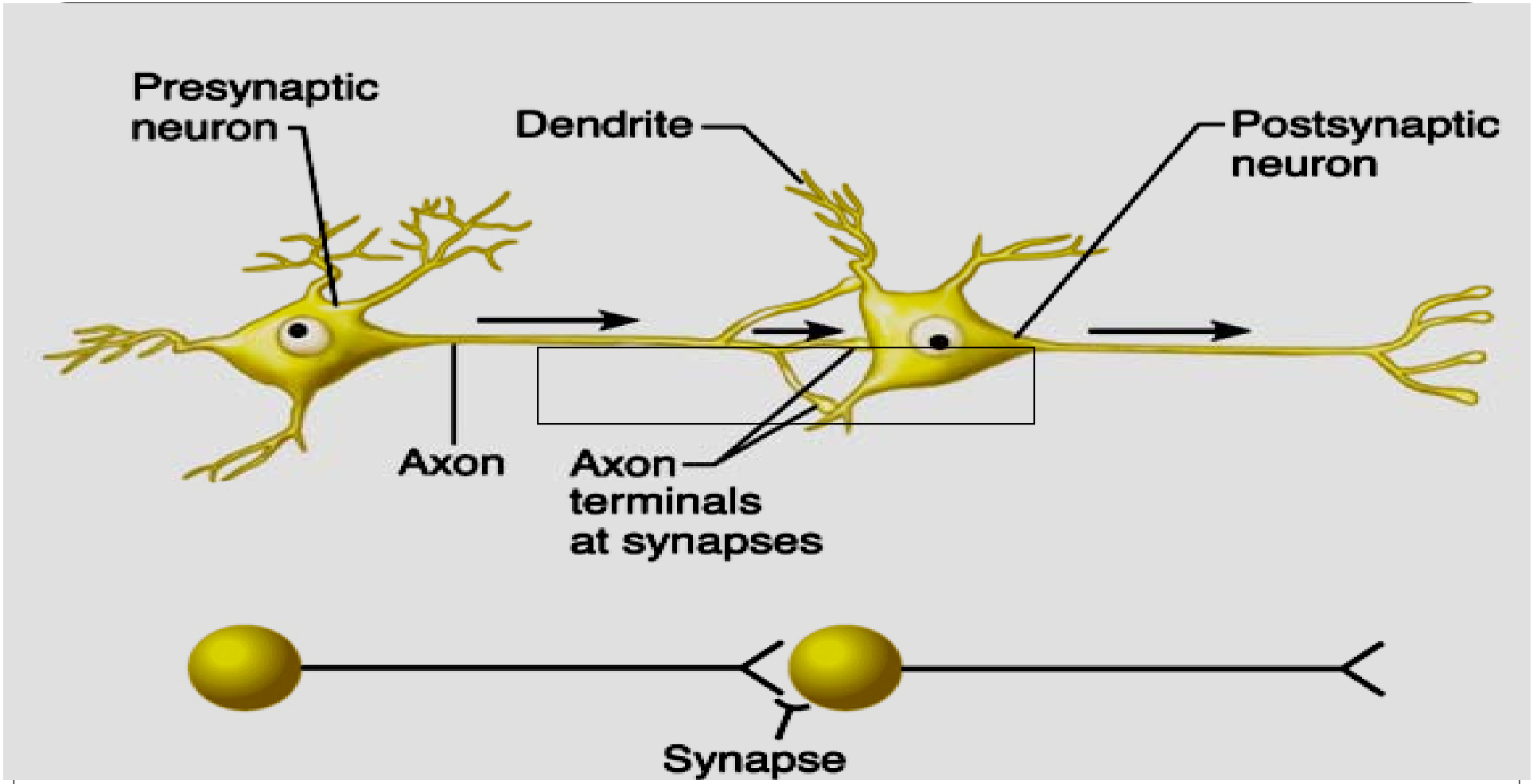
SYNAPSES

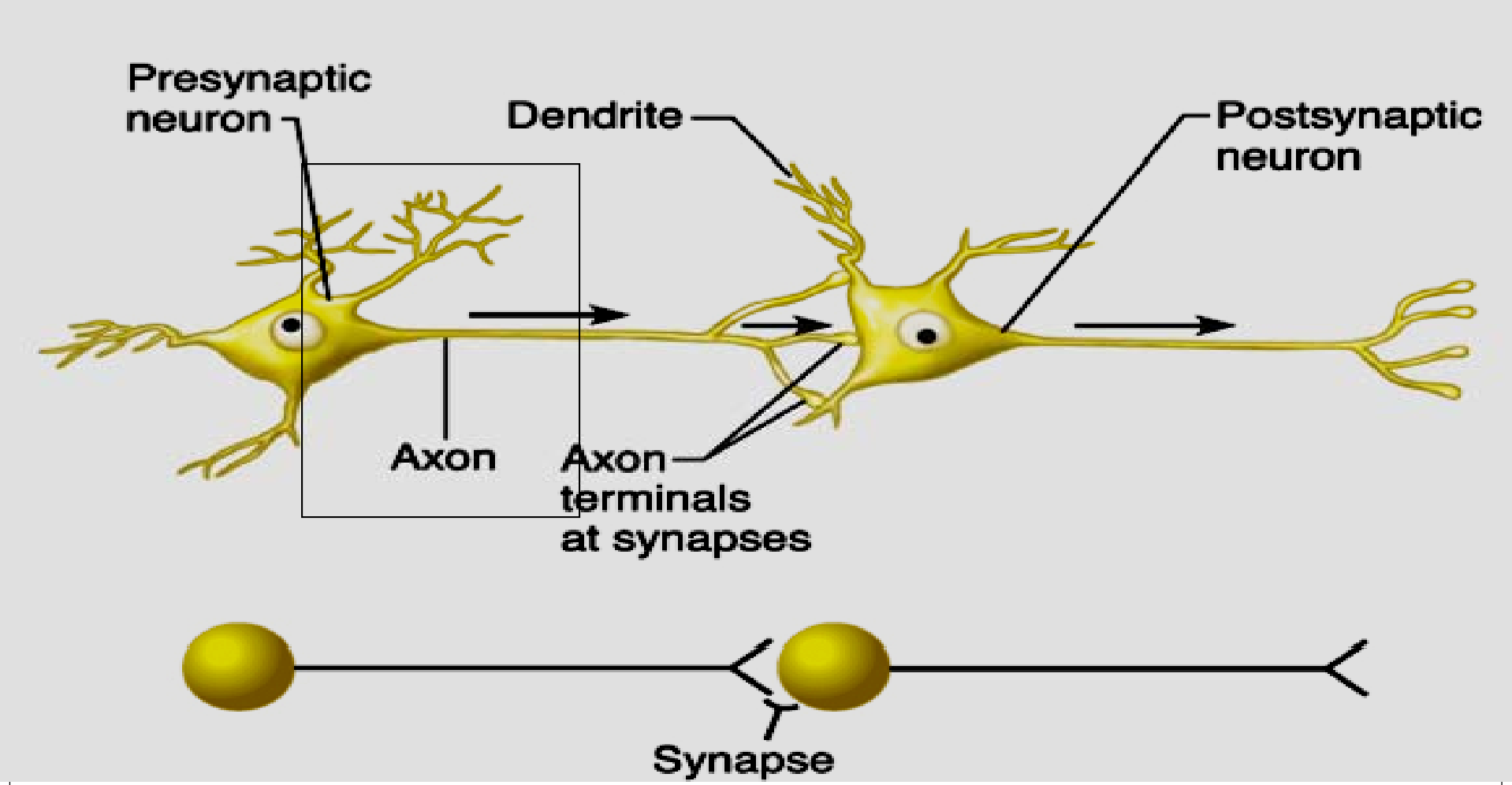
Synapses



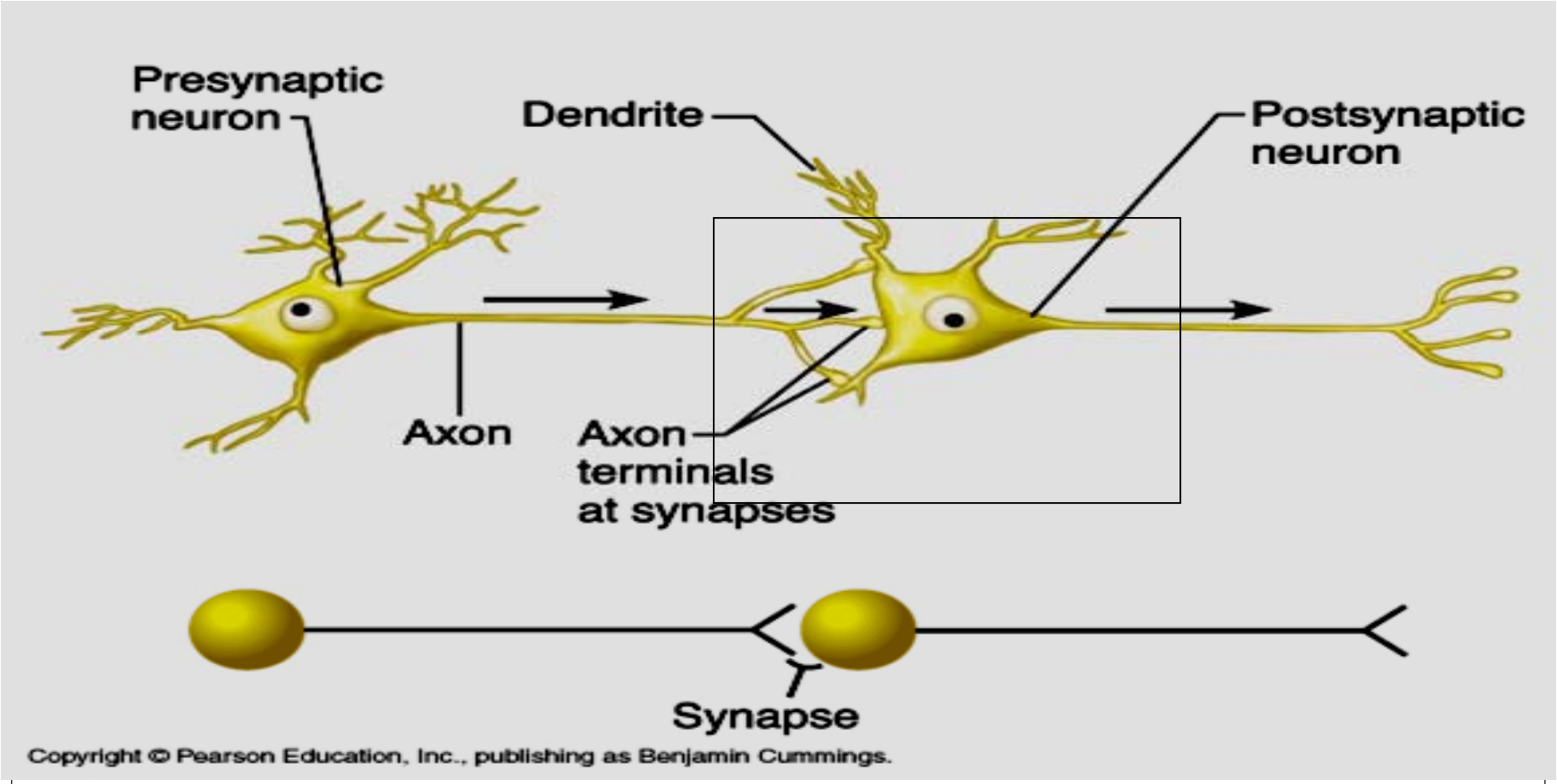
- The site at which neurons communicate is called a synapse,
- a cell junction that mediates the transfer of information from one neuron to the next



- Because signals pass across most synapses in one direction only, synapses determine the direction of information flow throughout the nervous system



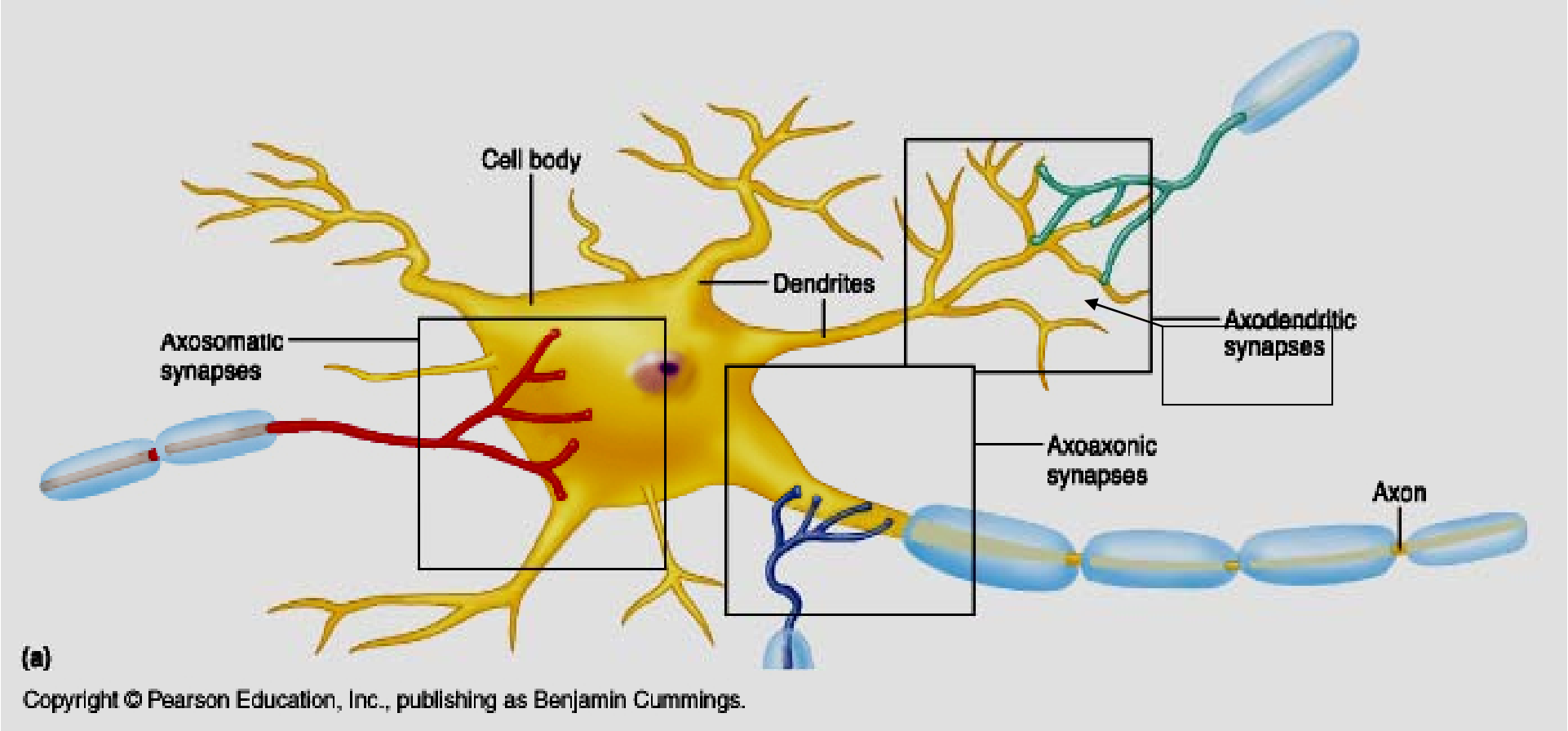
- The neuron the conducts impulses toward a synapse is called the presynaptic neuron



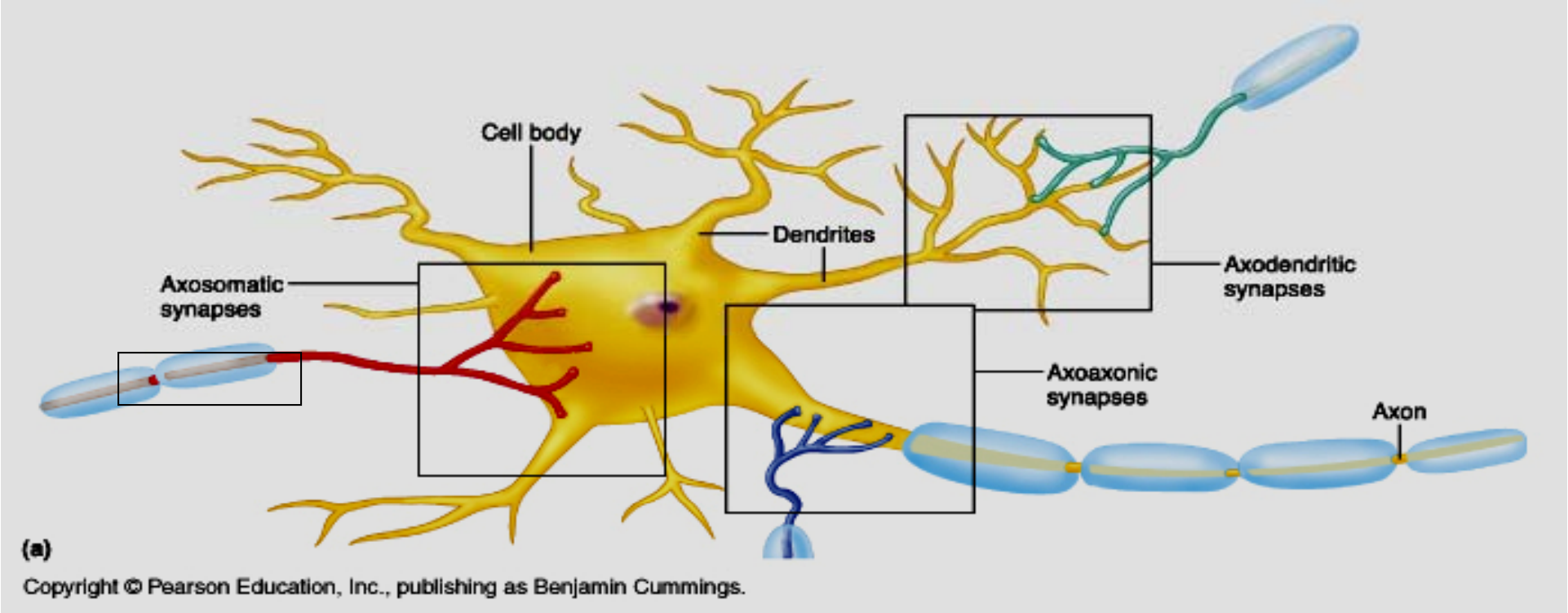
- The neuron that conducts impulses away from the synapse is called the postsynaptic neuron

Synapses

- Most neurons function as presynaptic (information sending) and postsynaptic (information receiving neurons
- In essence they get information from some neurons and dispatch it to others



- Most synapses occur between the axon terminals of one neuron and the dendrites of another axons
- These are called axodendritic synapses



- Less common, and far less understood, are:
- synapses between two axons (axoaxonic),
- between two dendrites (dendrodendritic)
- between a dendrite and a cell body (dendosomatic)

Types of Synapses

§ ***Axodendritic – synapses between the axon of one neuron and the dendrite of another***

§ ***Axosomatic – synapses between the axon of one neuron and the soma of another***

§ ***Other types of synapses include:***
§ **Axoaxonic (axon to axon)**
§ **Dendrodendritic (dendrite to dendrite)**
§ **Dendrosomatic (dendrites to soma)**

2 FUNCTIONAL TYPE OF SYNAPSES

- **Electrical Synapses**
- § *Electrical synapses:*
- § **Are less common than chemical synapses**
- § **Correspond to gap junctions found in other cell types**
- § **Are important in the CNS in:**
  - § **Arousal from sleep**
  - § **Mental attention**
  - § **Emotions and memory**
  - § **Ion and water homeostasis**

Chemical Synapses

§ ***Specialized for the release and reception of neurotransmitters***

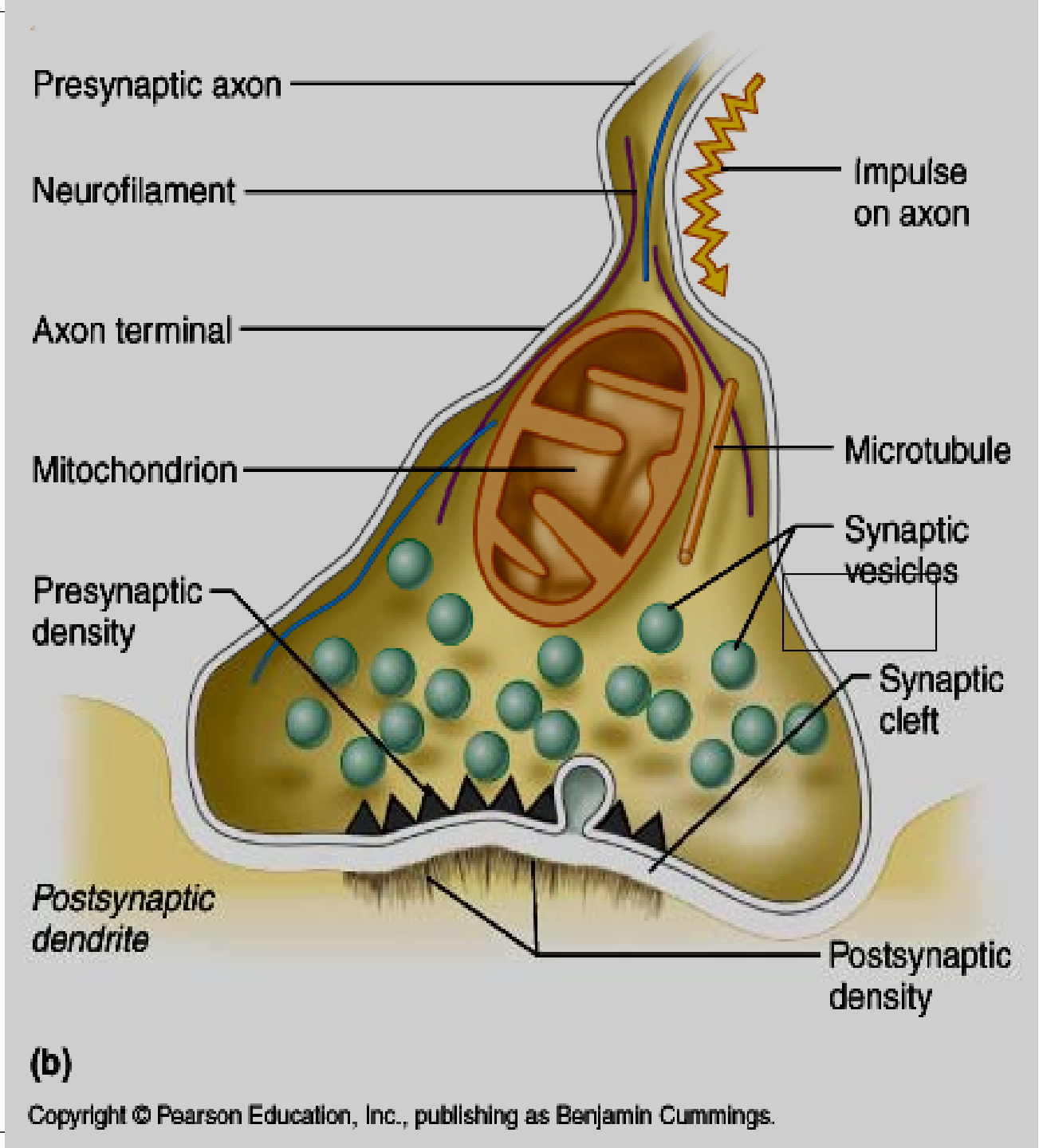
§ ***Typically composed of two parts:***

§ **Axonal terminal of the presynaptic neuron, which contains synaptic vesicles**

§ **Receptor region on the dendrite(s) or soma of the postsynaptic neuron**

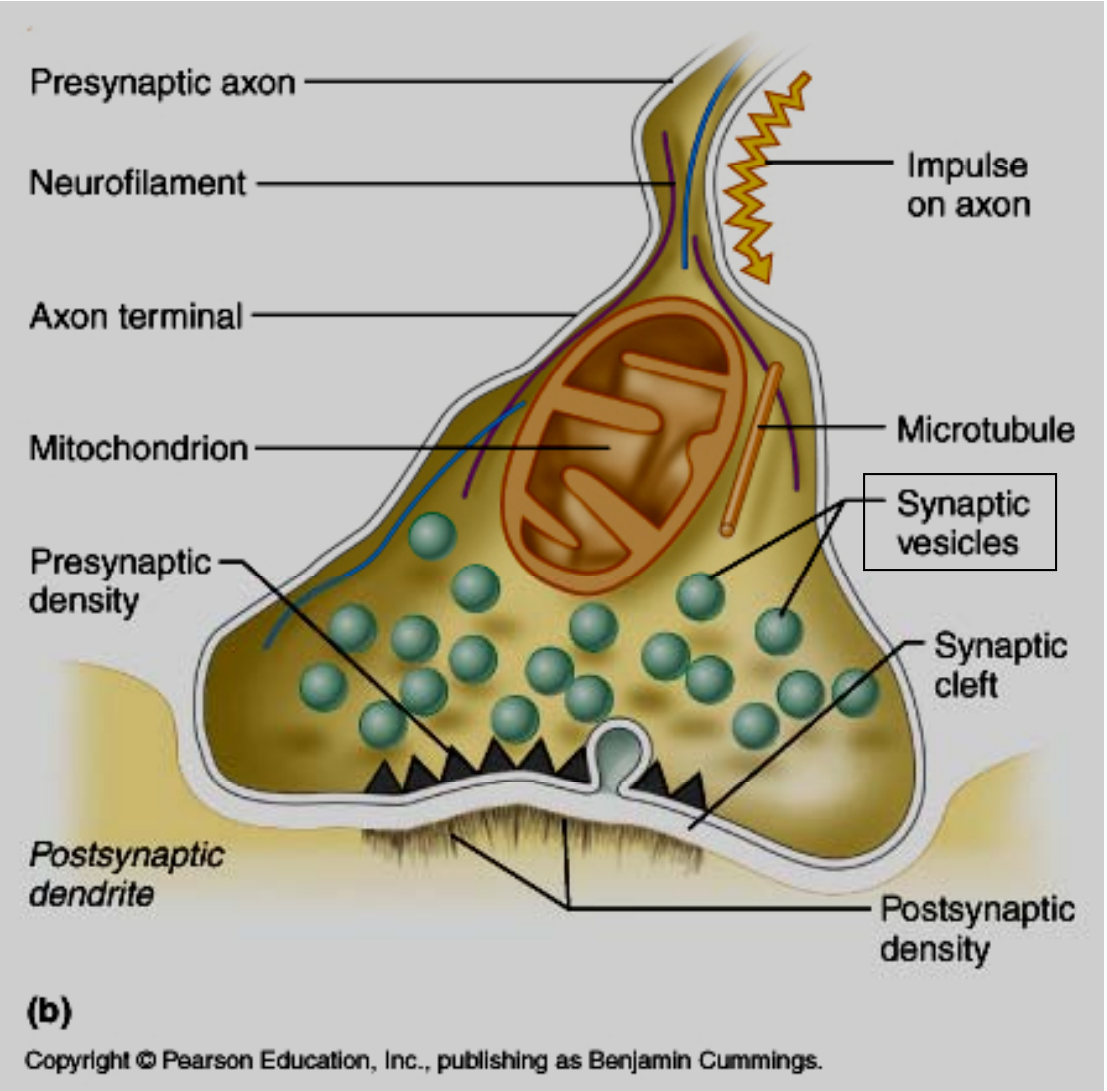
Synapses

- Structurally synapses are elaborate cell junctions
- At the typical axodendritic synapse the presynaptic axon terminal contain synaptic vesicles



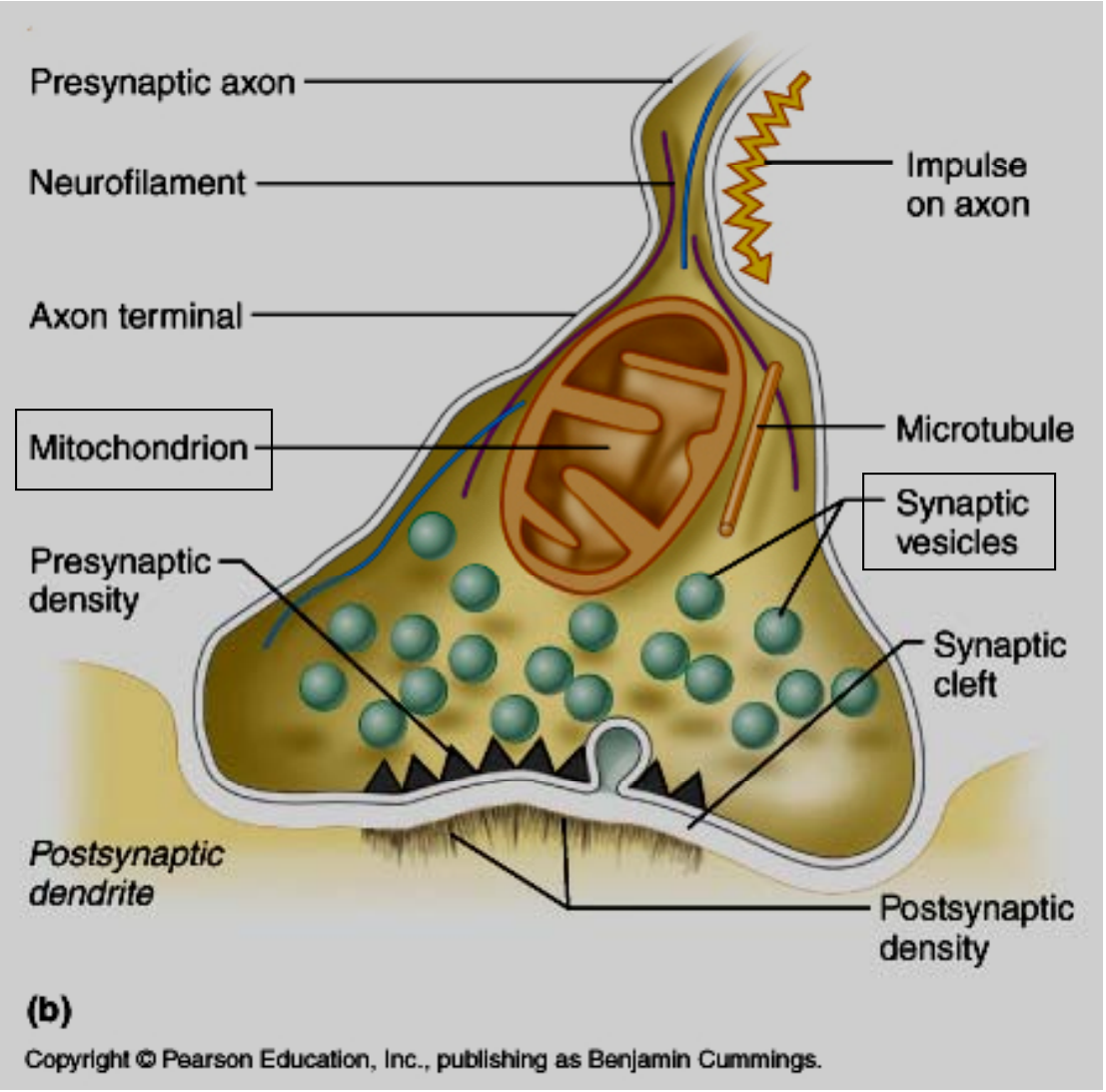
Synapses

- Synaptic vesicles are membrane bound sacs filled with molecular neurotransmitters
- These molecules transmit signals across the synapse



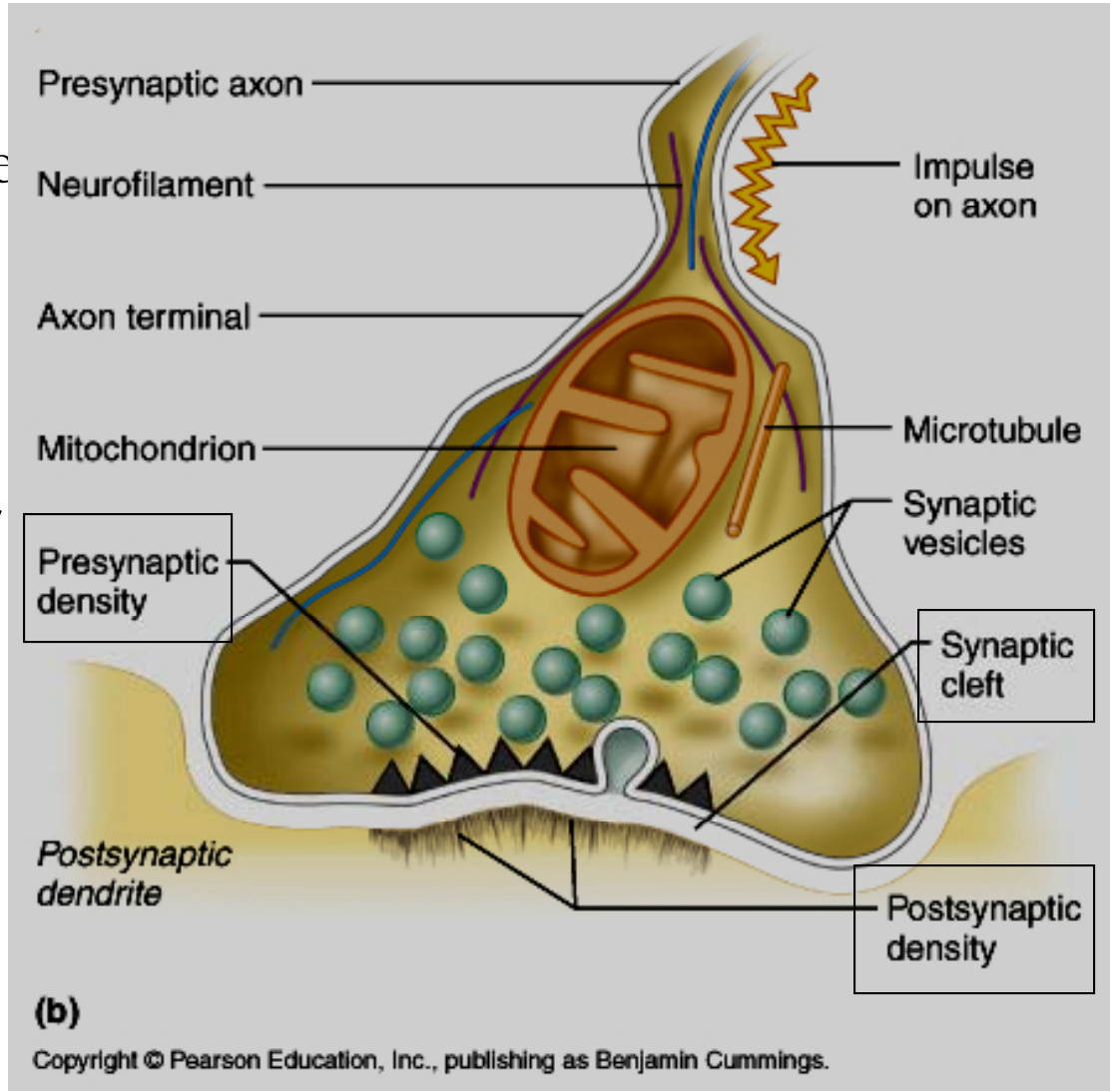
Synapses

- Mitochondria are abundant in the axon terminal as the secretion of neurotransmitters requires a great deal of energy



Synapses

- At the synapse, the plasma membranes of the two neurons are separated by a synaptic cleft
- On the under surfaces of the opposing cell membranes are dense materials; the pre- and post- synaptic densities



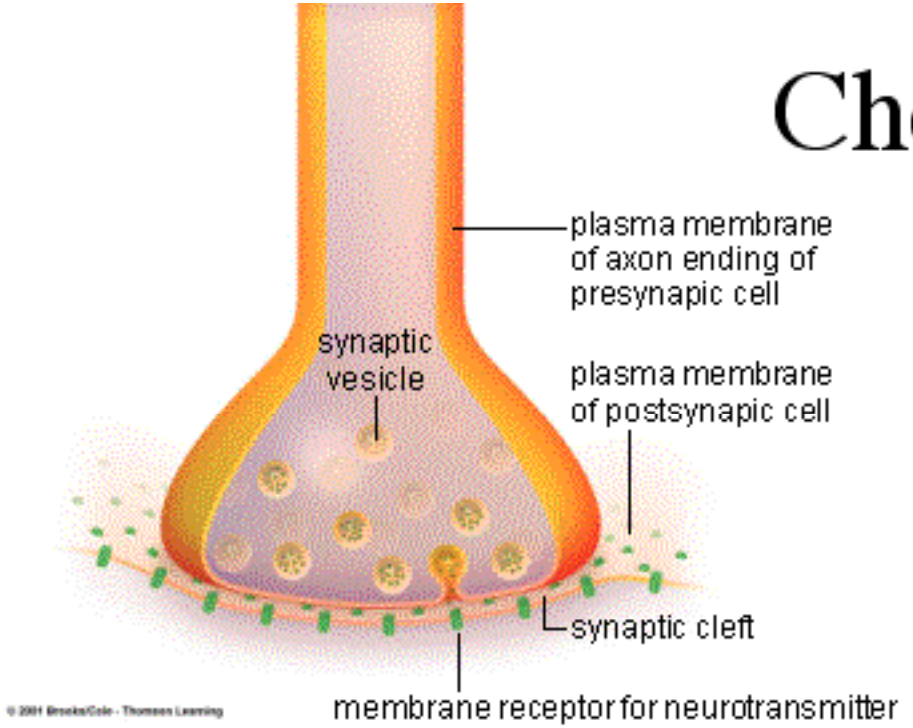
Synapses

- When an impulse travels along the axon of the presynaptic neuron, it signals the synaptic vesicles to fuse with the presynaptic membrane at the presynaptic density
- The released neurotransmitter molecules diffuse across the synaptic cleft and bind to the postsynaptic membrane at the post synaptic density

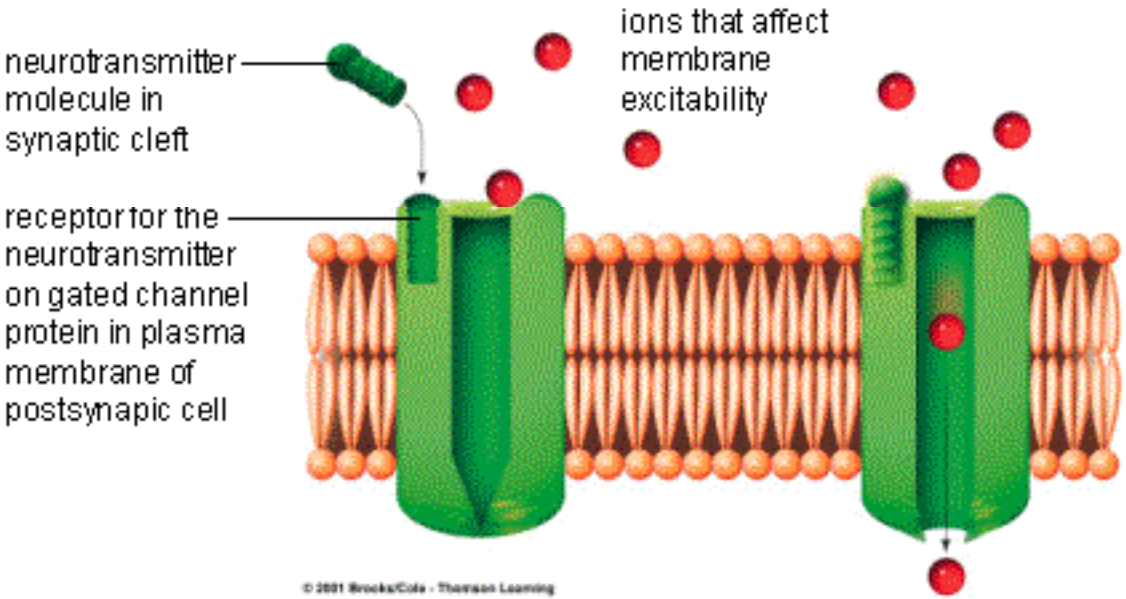
Synapse

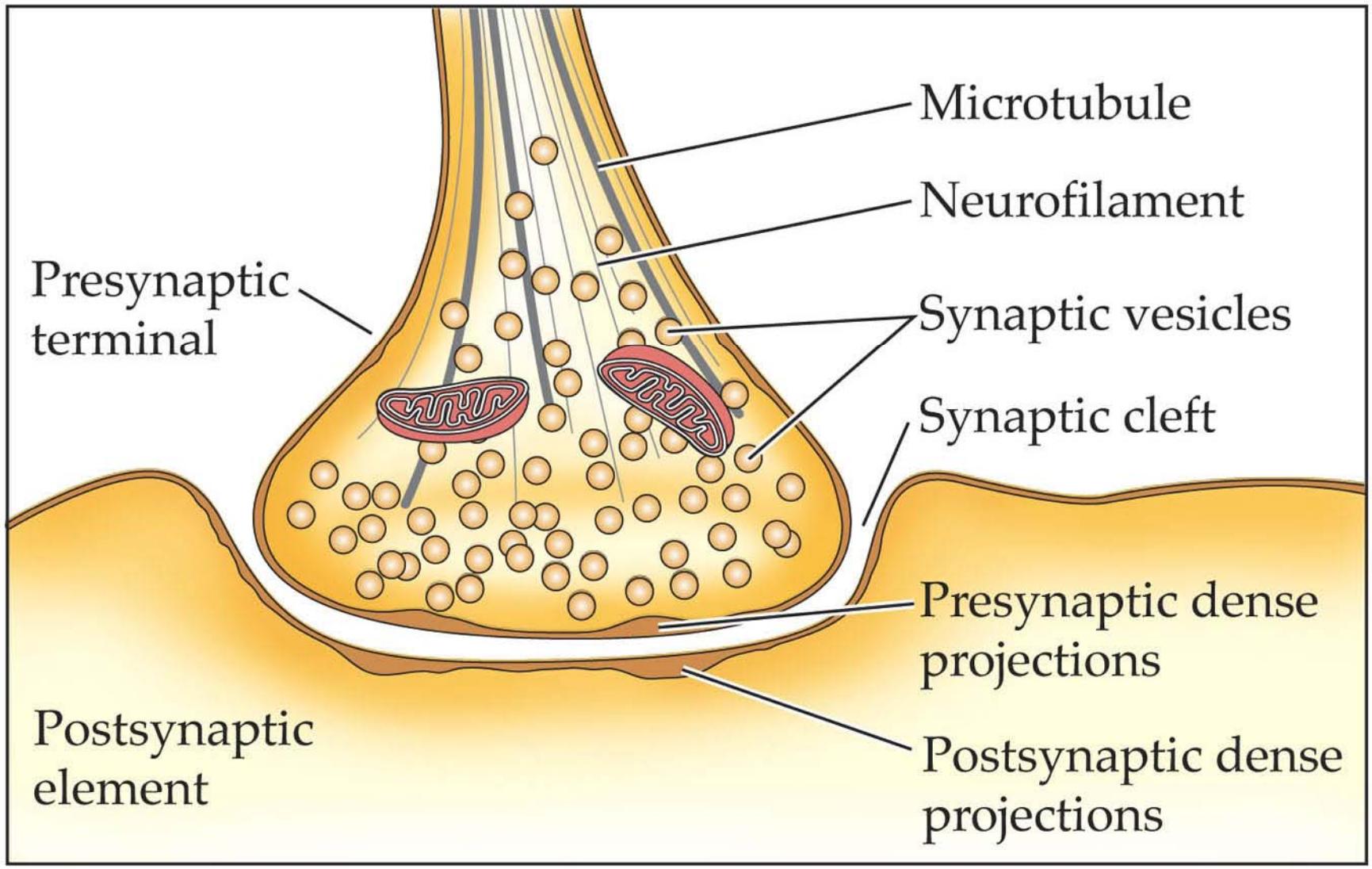
- The binding of the two membranes changes the membrane charge on the postsynaptic neuron, influencing the generation of a nerve impulse or action potential in that neuron

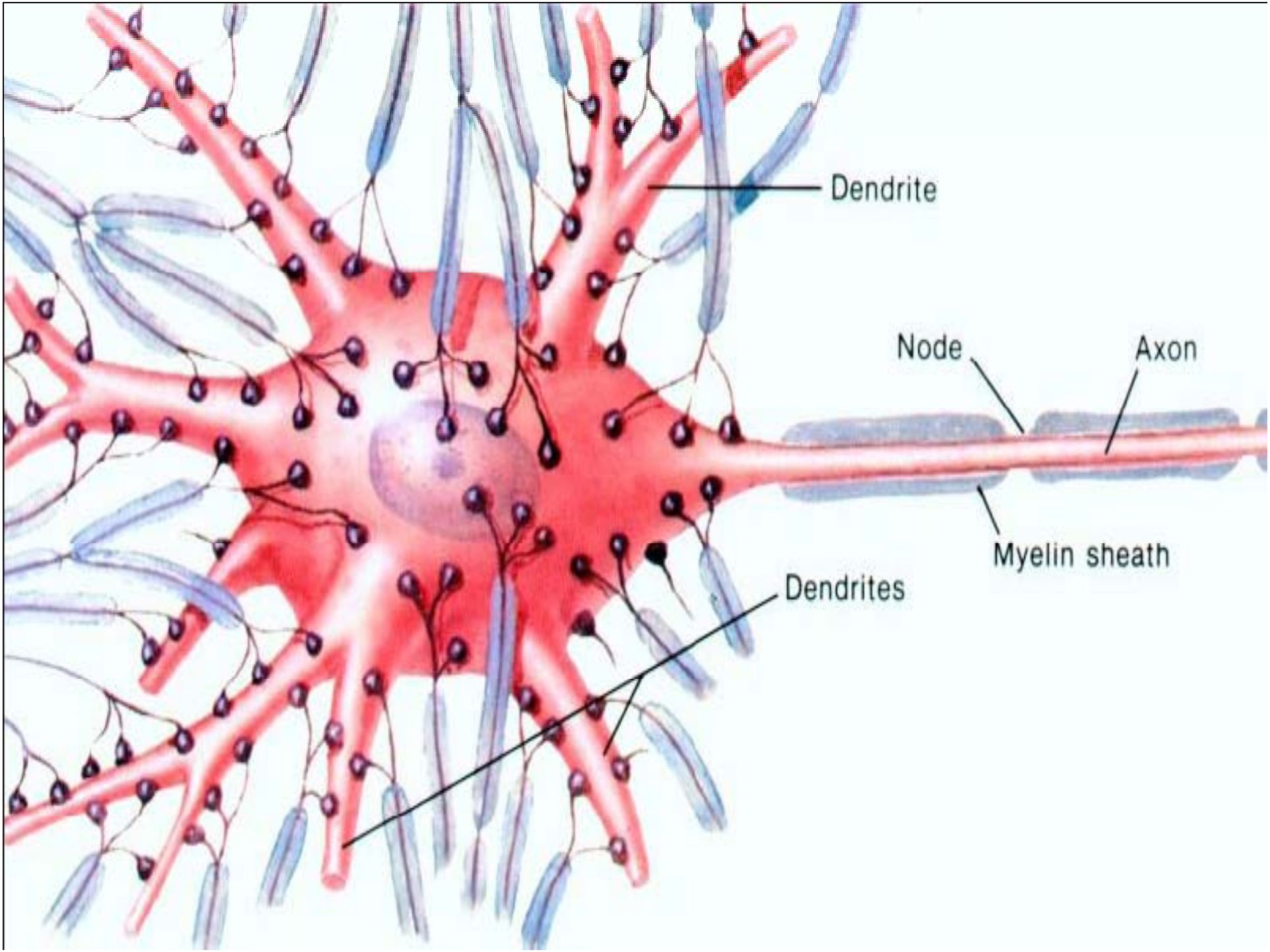
Chemical Synapse

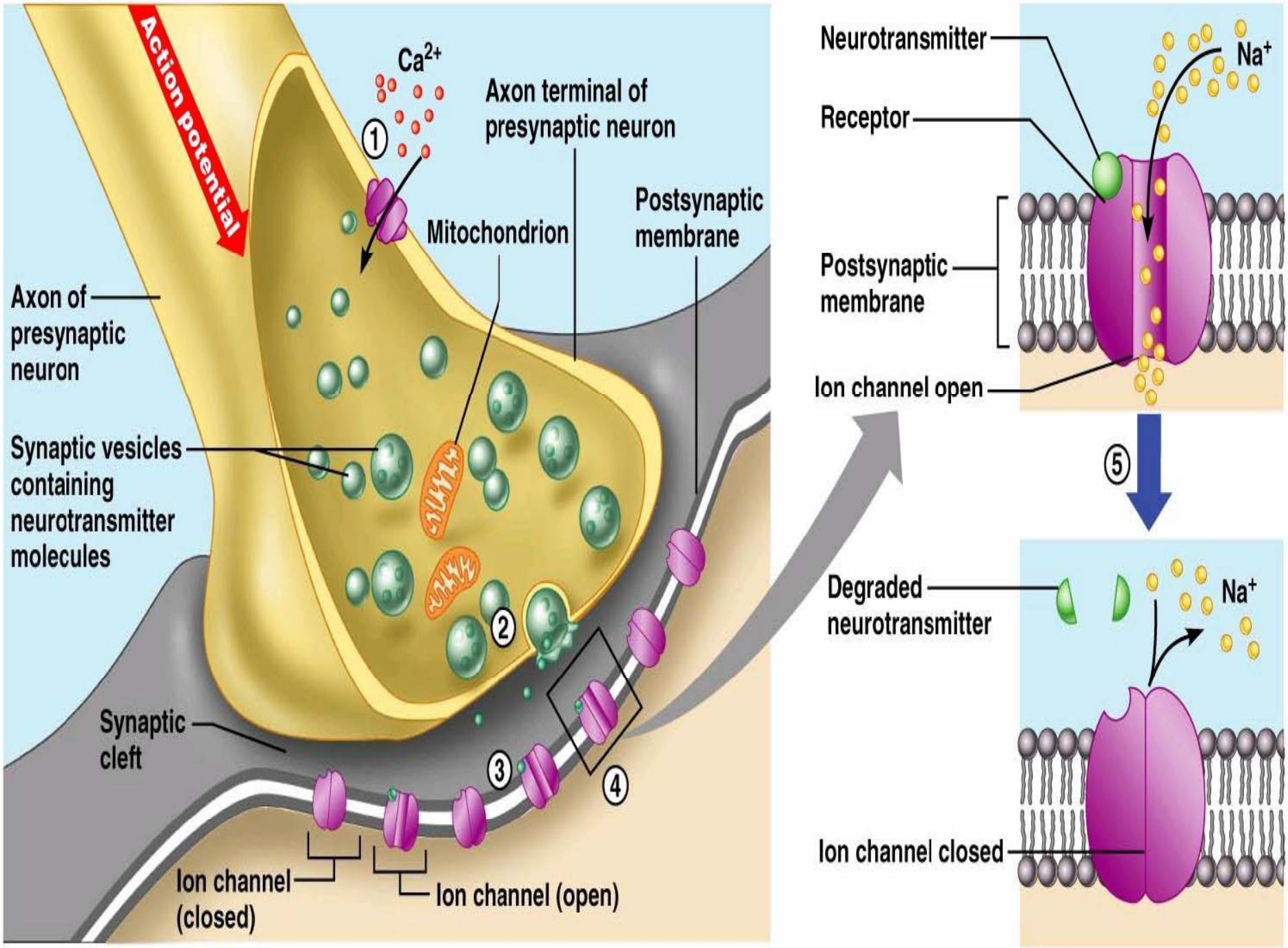


Gap between the terminal ending of an axon and the input zone of another cell






Dendrite
Node
Axon
Myelin sheath
Dendrites


Action potential
Ca^{2+}
Axon terminal of presynaptic neuron
Mitochondrion
Postsynaptic membrane
Axon of presynaptic neuron
Synaptic vesicles containing neurotransmitter molecules
Synaptic cleft
Ion channel (closed)
Ion channel (open)
1
2
3
4
Neurotransmitter
Receptor
Na^+
Postsynaptic membrane
Ion channel open
5
Degraded neurotransmitter
Na^+
Ion channel closed

Communication

- Begins with the stimulation of a neuron.
  - One neuron may be stimulated by another, by a *receptor* cell, or even by some physical event such as pressure.
- Once stimulated, a neuron will communicate information about the causative event.
  - Such neurons are sensory neurons and they provide info about both the internal and external environments.
  - Sensory neurons (a.k.a. afferent neurons) will send info to neurons in the brain and spinal cord. There, association neurons (a.k.a. interneurons) will integrate the information and then perhaps send commands to motor neurons (efferent neurons) which synapse with muscles or glands.

Neurotransmitters

Neurotransmitters

· Acetylcholine (AcH)
· Dopamine (DA)
· Histamine
· Norepinephrine (NE)
· Epinephrine
· Serotonin (5HT)

Peptides

· GammaAminobutyric Acid (GABA)
· Glutamate
· Aspartate
· Glycine

Neuropeptides

· Insulin
· Betaendorphin
· Neuropeptide Y
· Calcitonin

Types of NT

1.Acetylcholine (ACh)
    1. this NT has 2 types of receptors
      A. nicotinic receptors:
        a. agonist: is nicotine
        b. antagonist: is curare

      B. muscarinic receptors:
        a. agonist: is muscarine
        b. antagonist: in atropine (deadly nightshade

2. deactivated by acetylcholinesterase (AChE) & choline is reused

3. physostigmine: inhibits AChE (agonist) but is reversible.

4. botulinum toxin prevents the release of ACH from the terminal button (antagonist)

5. black widow spider venom causes ACH terminals to release ACH (agonist)

Monoamines

All monoamines work thru metabotropic receptors

Monoamine oxidase (MAO) & catechol-O-methyltransferase (COMT) deactivate these.

1. The drug reserpine prevents the storage of the monoamines

types of monoamines:

I. Indolamines:

1. Serotonin (5-HT)
   A. produced in the raphe nuclei in the midline of the pons & medulla
2. B. the drug parachlorophenylalanine (PCPA) blocks tryptophan hydroxylase & prevents the
   synthesis of 5-HT (an antagonist)
   C. iproniazid block MAO (agonists)

II. Catecholamines:
The amino acid tyrosine is the precursor
NT is released thru axononal varicosities: swellings on the axon
1. Norepinephrine (NE) noradrenalin
 A. in the CNS this is produced in the locus ceruleus (nucleus in midbrain) &
 is distributed though out the CNS

2. Epinephrine (E) adrenaline
 A. works at the same receptors as NE
 B. stimulates the sympathetic nervous system
 C. ephedrine: alpha & beta receptor agonist
 D. propranolol: beta receptor blocker has antihypertensive effects
3 Dopamine (DA)
 A. produced in substantia nigra & ventral tegmental area (midbrain) & sent to
 the cortex, limbic system, hypothalamus, & basal ganglia
 B. implicated in movement disorders e.g., in Parkinson's disease (L-DOPA)
 C. cocaine and amphetamine work by preventing reuptake
 D. apomorphine: stimulates only autoreceptors (an antagonist)

CRITERIA

- NT found in axon terminals
- NT released by action potentials
- Synthesis identified
- External application mimic normal Response
- Pharmacology same for normal and externally applied NT ~

Lock & Key Model

- NT binds to receptor

  NT = key

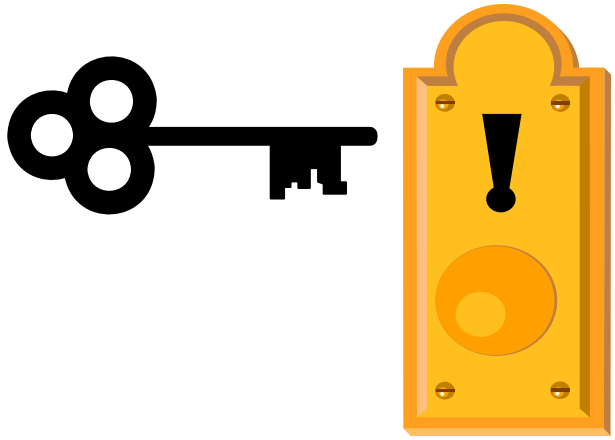
  Receptor = lock

- Receptor changes shape

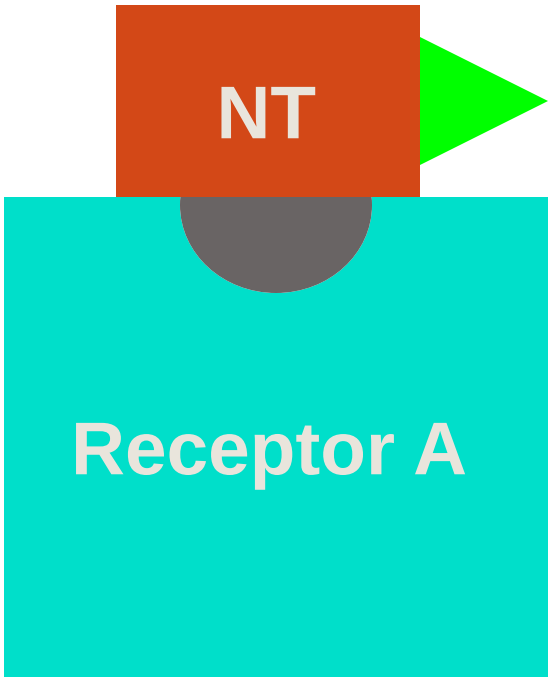
  determines if EPSP or IPSP

  receptor subtypes

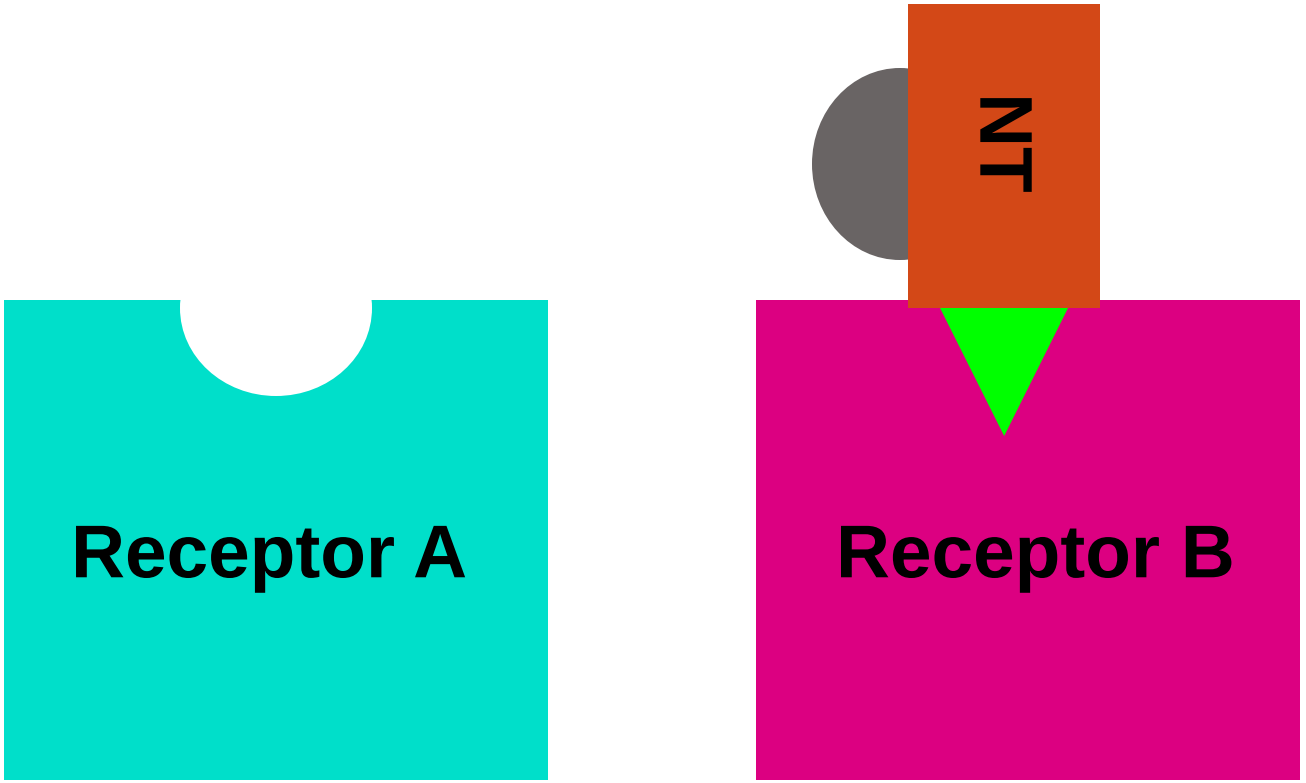
- NOT NT ~



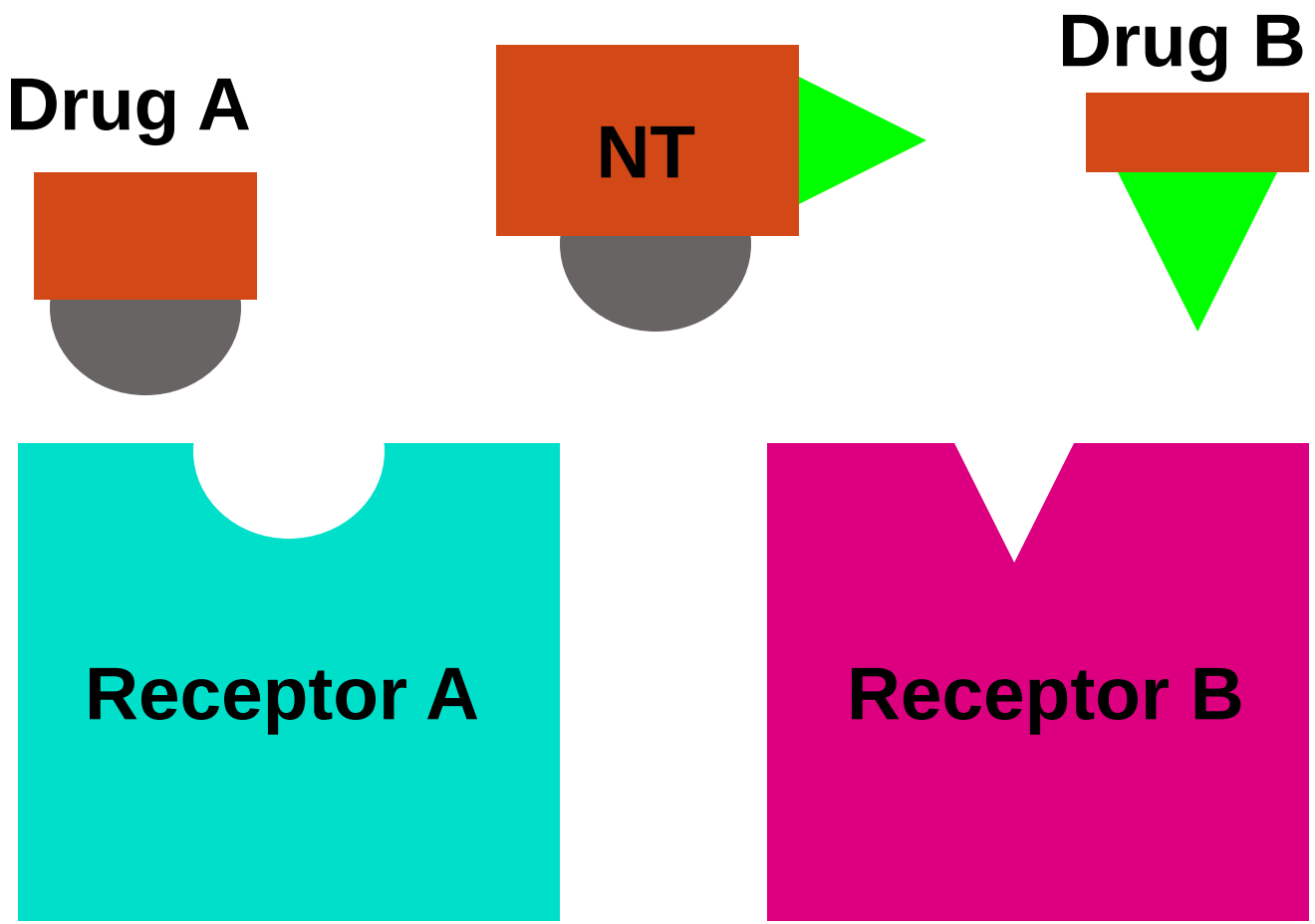
- ligand binds to receptor
- activation: + or - ~



- Same NT can bind to different -R
- different part of NT ~



Specificity of drugs



Acetylcholine - ACh

- Most abundant NT in Peripheral N.S.
  - also found in Central N.S.
- Precursor = choline

  nutrient
- Degraded by acetylcholinesterase-
  - AChE

    Membrane bound - pre- & postsynaptic
- Nicotinic receptor - ionotropic
- Muscarinic receptor - metabotropic ~

Ach - Distrubution

- Peripheral N.S.
- Excites somatic muscle
- Autonomic NS
  - Ganglia
  - Parasympathetic NS
  - Neuroeffector junction
- Central N.S. - widespread
  - Hippocampus
  - Hypothalamus ~

Cholinergic Agonists

- Direct
  - Muscarine
  - Nicotine
  - small doses
- Indirect
  - AChE Inhibitors ~

AChE inhibitors

- Physostigmine
- Organophosphates - irreversible
  - DFP
  - Soman & Sarin
  - Malathion*
- Agonist or Antagonist?

  indirect agonist ~

Cholinergic Antagonists

- Direct

  Nicotinic - Curare

  Muscarinic - Atropine

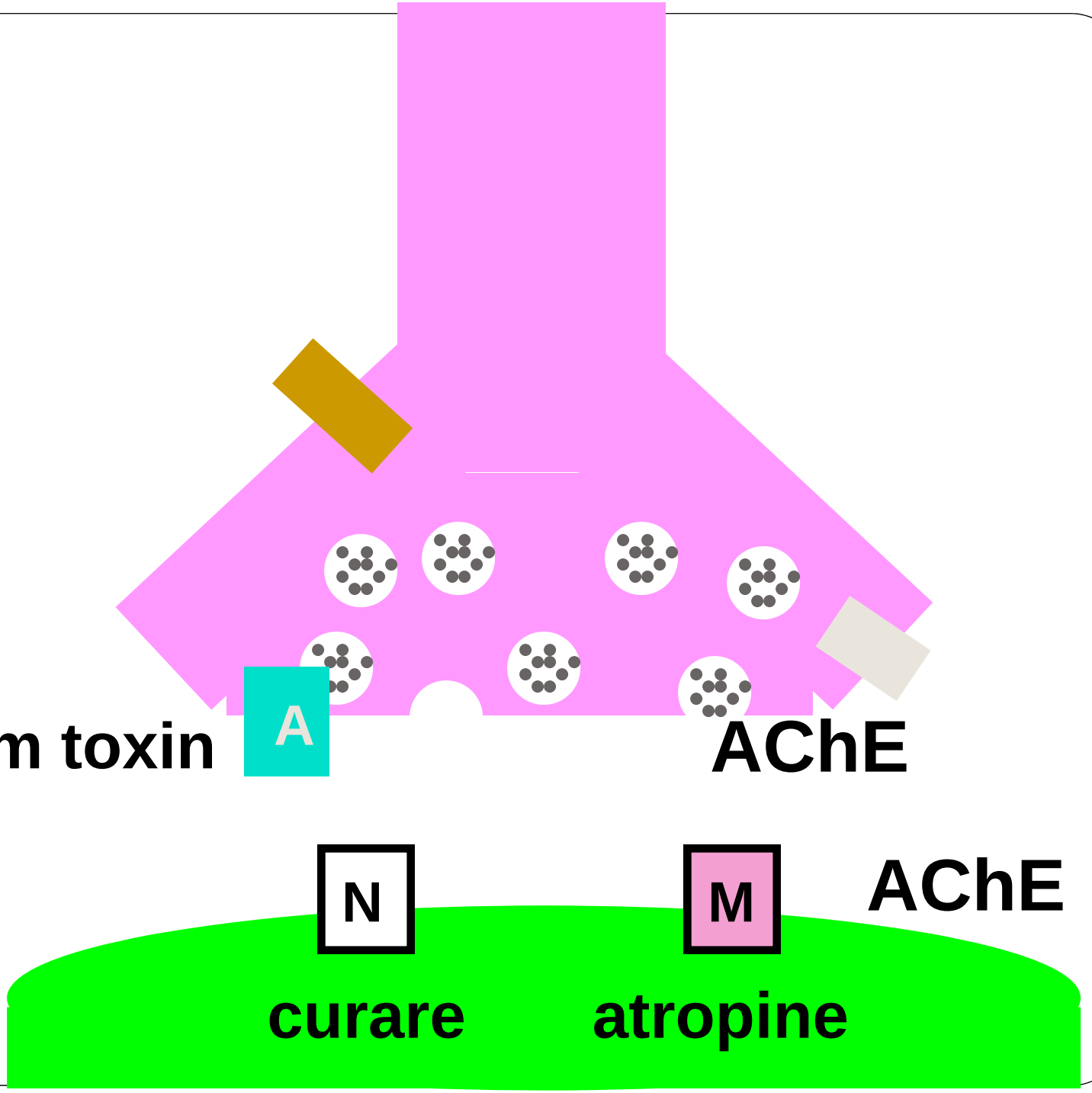
  Scopolamine

- Indirect

  Botulinum Toxin

  Black Widow Spider Venom ~

ACh



Monamines

- Amino acid precursors
  - single amine group
- 2 groups

  Catecholamines - catechol ring

  Indolamine - indole ring
- Affected by many of same drugs ~

Monoamines

- Catecholamines

  Dopamine - DA
  - Dopaminergic

  Norepinephrine - NE
  - Noradrenergic

  Epinephrine - E
  - Adrenergic ~

- Indolamines

  _Serotonin - 5-HT
  - Serotonergic

Monoamines

- Terminated by…

  reuptake

  monoamine oxidase - MAO

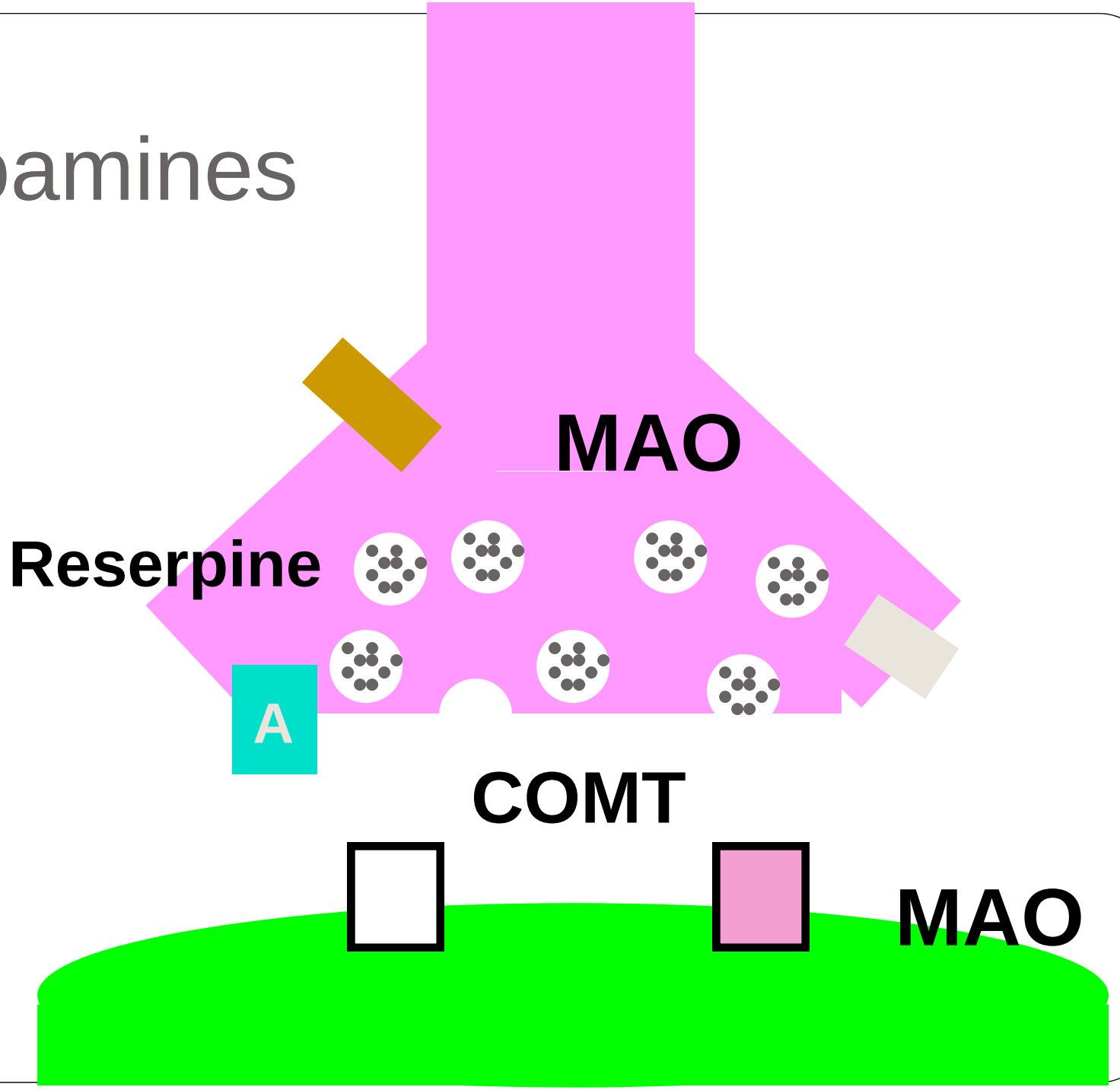
  catechol-O-methyltranferase - COMT

  also in liver

- Reserpine ---> leaky vesicles

  depletes monoamines ~

Monoamines



Indirect Monoamine Agonists

- MAOIs

  Iproniazid

- Reuptake blockers
  - Tricyclic antidepressants
    - Imipramine
    - Desipramine

  Cocaine & Amphetamine ~

Dopamine

- Only in central nervous system

  mostly inhibitory systems
- Reward
- Schizophrenia
- Movement
  - Nigrostriatal Pathway
- At least 5 DA-R types: D_1, D_2, etc. ~

Dopaminergic Drugs

- Agonist
  - L-dopa
- Antagonists
  - Chlorpromazine
    - D_1
  - Haloperidol
    - D_2 ~

Norepinephrine

- Peripheral N.S.
  - Sympathetic neuroeffector junction
  - Adrenal glands
- Central N.S.
  - Hypothalamus
  - Locus coeruleus
- Alpha & Beta receptor subtypes
  - NE_{α} & NE_{β} ~

Noradrenergic Drugs

- Agonists
  - Mescaline
  - Ephedrine
- Antagonist
  - Propranalol -
  - beta receptors ~

Serotonin

- NOT a catecholamine
- Peripheral

  98% in blood & smooth muscle
- Central N.S.

  Raphe nucleus

  Hypothalamus
- R subtypes: $5HT_1$ & $5HT_2$ ~

Sertonergic Drugs

- Agonists
  - SSRIs
    - Selective Serotonin Reuptake Inhibitors
  - Buspirone
  - MDMA
    - Ecstacy ~

Gamma-aminobutyric acid

- GABA - GABAergic
- Major NT in brain inhibitory system
- Receptor subtypes

  $GABA_A$ - controls Cl- channel

  $GABA_B$ - controls K+ channel
- Precursor = glutamate ~

Neuropeptide

- Substance P - pain signaling
- Endorphins - analgesia, euphoria ~

Endorphins

- Opioids

  Dynorphin

  - met-enkephalin
  - leu-enkephalin
  - Beta-endorphin

Endorphins (cont.)

- Agonists
  - morphine
  - heroin
  - codeine
- Antagonists
  - naloxone
  - naltrexone ~

Other NTs

- Excitatory amino acids
  - Glutamate & Aspartate
- Histamine
  - Inflammatory Response
- Nitric Oxide - It's a gas
- Anandamide

MODE OF ACTION

Postsynaptic Potentials

§ ***Neurotransmitter receptors mediate changes in membrane potential according to:***

- § The amount of neurotransmitter released
- § The amount of time the neurotransmitter is bound to receptors

§ ***The two types of postsynaptic potentials are:***

- § EPSP – excitatory postsynaptic potentials
- § IPSP – inhibitory postsynaptic potentials order

- § Spatial summation – postsynaptic neuron is stimulated by a large number of terminals at the same time
- § IPSPs can also summate with EPSPs, canceling each other out

Excitatory Postsynaptic Potentials(EPSP)

§ ***EPSPs are graded potentials that can initiate an action potential in an axon***

§ Use only chemically gated channels

§ Na + and K + flow in opposite directions at the same time

§ ***Postsynaptic membranes do not generate action potentials***

Inhibitory Synapses and IPSPs

§ ***Neurotransmitter binding to a receptor at inhibitory synapses:***

§ Causes the membrane to become more permeable to potassium and chloride ions

§ Leaves the charge on the inner surface negative

§ Reduces the postsynaptic neuron's ability to produce an action potential

Summation

§ A single EPSP cannot induce an action potential

§ EPSPs must summate temporally or spatially to induce an action potential

§ Temporal summation – presynaptic neurons transmit impulses in rapidfire order

§ Spatial summation – postsynaptic neuron is stimulated by a large number of terminals at the same time

§ IPSPs can also summate with EPSPs, canceling each other out

The main membrane processes involved in neural activities are:

1. **resting potential: the transmembrane potential of a resting cell**

2. **graded potential: a temporary localized change in the resting potential, caused by a stimulus**

3. **action potential: an electrical impulse (produced by the graded potential) that propagates along the surface of an axon to a synapse.**

4. **synaptic activity: the release of neurotransmitters at the presynaptic membrane, which produce graded potentials in a postsynaptic membrane.**

5. **information processing: the response (integration of stimuli) of a postsynaptic cell.**

The 3 main requirements for a transmembrane potential are:

1. **A concentration gradient of ions (Na+, K+) across the cell membrane**

2. **The membrane be selectively permeable through membrane channels**

3. **Passive and active transport mechanisms maintain a difference in charge across the membrane (*resting potential* = -70 mV)**

***Passive* forces acting across the membrane are**

- **chemical**
- **electrical.**

ELECTRICAL SYNAPSES

Action potential is transmitted from one cell to another by the direct flow of current.

- Conduction can occur in both directions, and there is essentially no synaptic delay.
- Cells with electrical synapses are joined by gap junctions.

1. **Chemical gradients:**
-concentration gradients of ions (Na+, K+) across the membrane

2. **Electrical gradients:**
- the charges of positive and negative ions are separated across the membrane, resulting in a *potential difference*.

- positive and negative charges attract one another
- if charges are not separated, they will move to eliminate potential difference, resulting in an electrical current

- how much current a membrane can restrict is called its resistance

Electrochemical gradient:

1. the sum of chemical and electrical forces acting on an ion (Na+, K+) across a cell membrane is the electrochemical gradient for that ion.

2. chemical gradient of potassium tends to move potassium out of the cell, but the electrical gradient of the cell membrane opposes this movement

3. the transmembrane potential at which there is no net movement of a particular ion across the cell membrane is the *equilibrium potential* for that ion (K+ = -90 mV, Na+ = +66 mV).

4. the electrochemical gradient is a form of *potential energy*

***Active* forces maintain the cell membrane's *resting potential* (-70 mV).**

The cell actively pumps out sodium ions (Na+), and pumps in potassium ions (K+).

The sodium-potassium exchange pump (the carrier protein *sodium-potassium ATPase*), powered by ATP, exchanges 3 Na+ for each 2 K+, balancing the passive forces of diffusion.

Relative Refractory Period

- Could an AP be generated during the undershoot?
  - Yes! But it would take an initial stimulus that is much, much stronger than usual.
    - *WHY?*
  - This situation is known as the relative refractory period.

Imagine, if you will, a toilet.

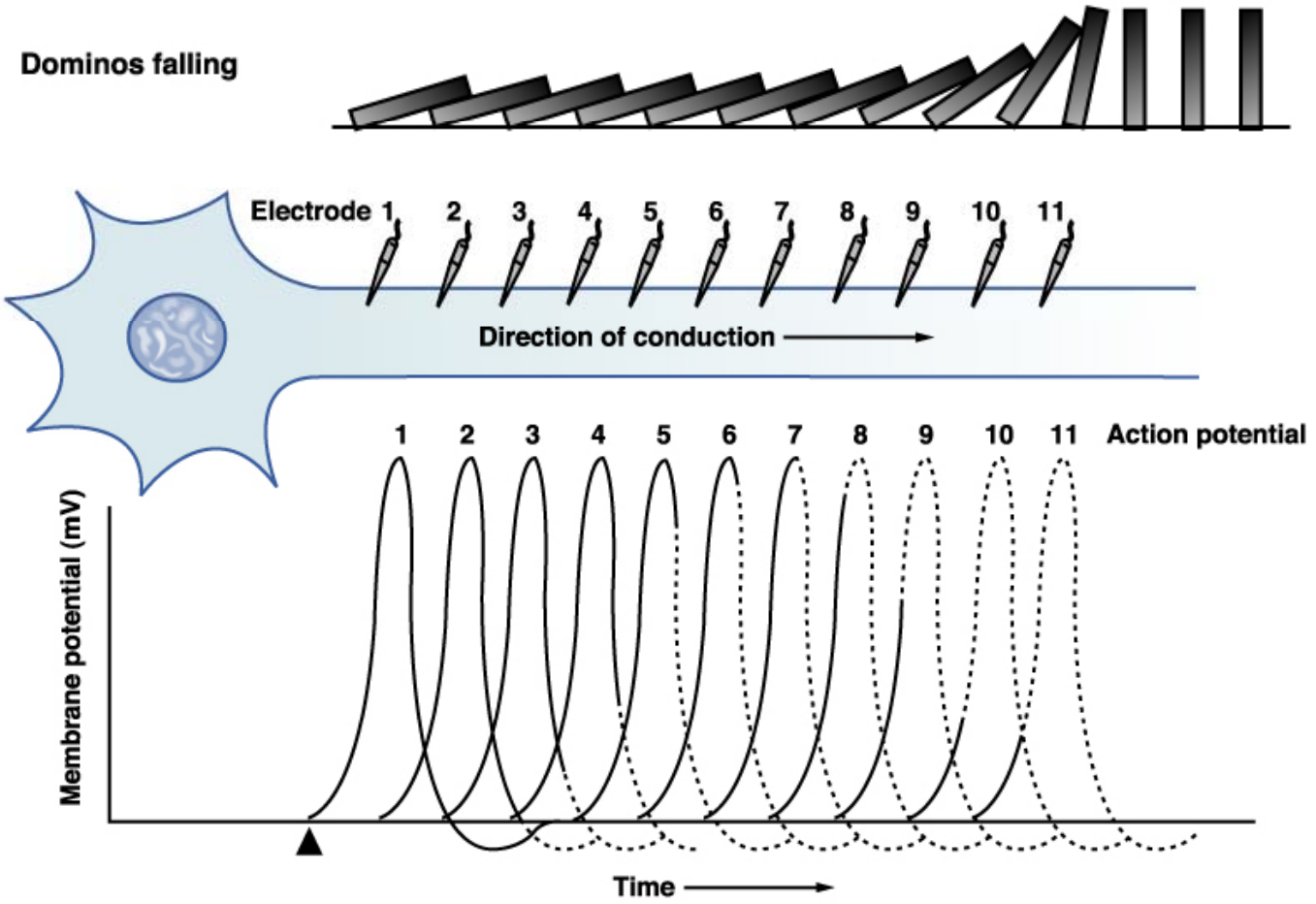
When you pull the handle, water floods the bowl. This event takes a couple of seconds and you cannot stop it in the middle. Once the bowl empties, the flush is complete. Now the upper tank is empty. If you try pulling the handle at this point, nothing happens (*absolute refractory*). Wait for the upper tank to begin refilling. You can now flush again, but the intensity of the flushes increases as the upper tank refills *(relative refractory)*

Action Potential Conduction

- If an AP is generated at the axon hillock, it will travel all the way down to the synaptic knob.
- The manner in which it travels depends on whether the neuron is myelinated or unmyelinated.
- Unmyelinated neurons undergo the *continuous conduction* of an AP whereas myelinated neurons undergo *saltatory conduction* of an AP.

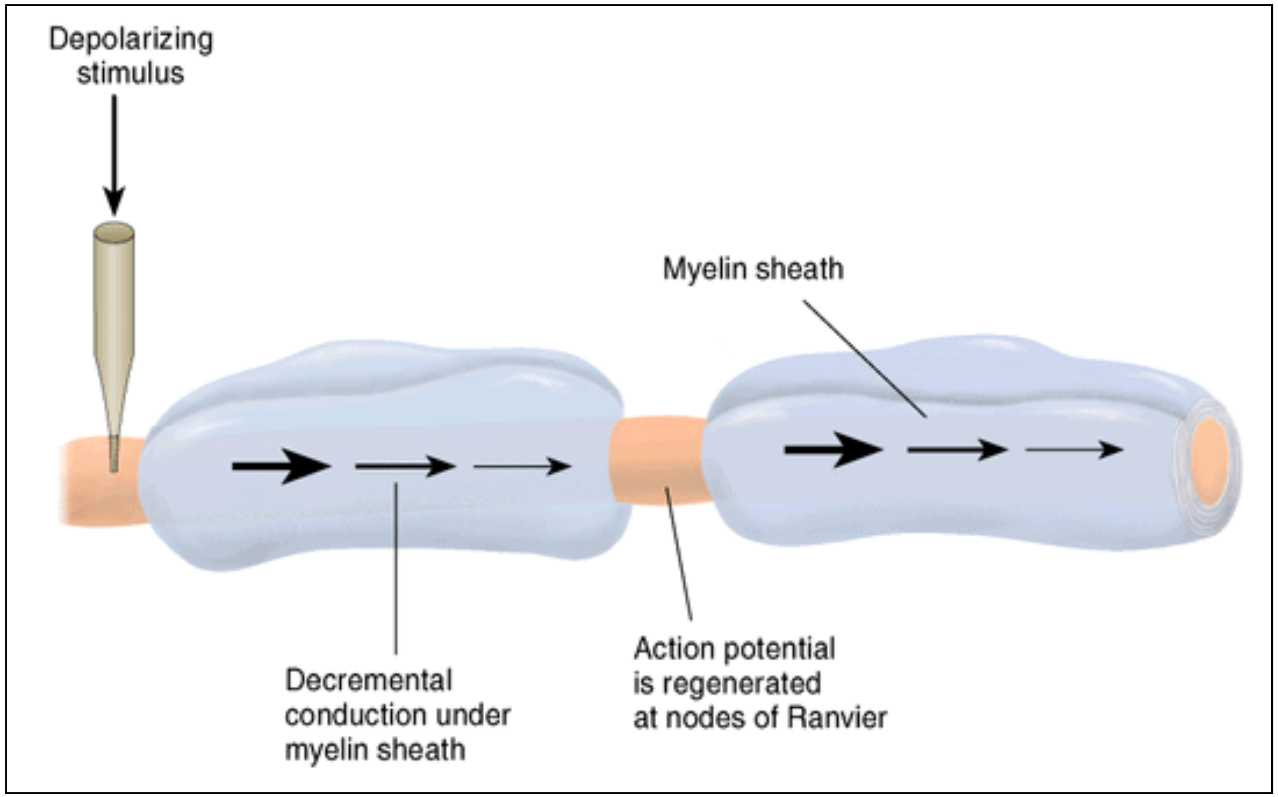
Continuous Conduction

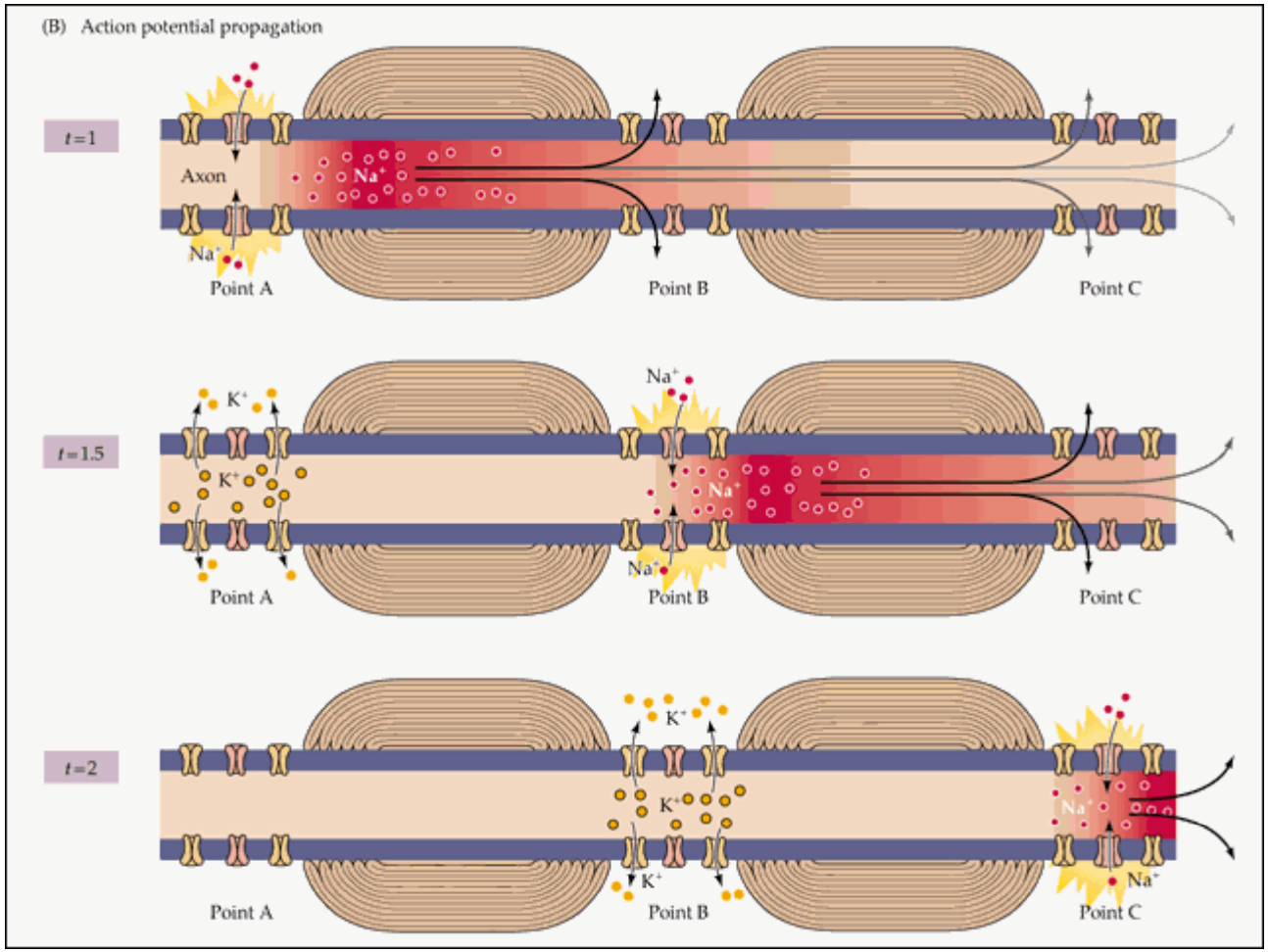
- Occurs in unmyelinated axons.
- In this situation, the wave of de- and repolarization simply travels from one patch of membrane to the next adjacent patch.
- APs moved along the of a muscle
- Analogous to falling.



Saltatory Conduction

- Occurs in myelinated axons.
- *Saltare* is a Latin word meaning "to leap."
- Recall that the myelin sheath is not completed. There exist myelin free regions along the axon, the nodes of Ranvier.




(B) Action potential propagation
t=1
Axon
Na+
Na+
Point A
Point B
Point C
t=1.5
K+
K+
Na+
Na+
Point A
Point B
Point C
t=2
K+
K+
K+
Na+
Na+
Point A
Point B
Point C

Rates of AP Conduction

1. Which do you think has a faster rate of AP conduction – myelinated or unmyelinated axons?
2. Which do you think would conduct an AP faster – an axon with a large diameter or an axon with a small diameter?

The answer to #1 is a myelinated axon. If you can't see why, then answer this question: could you move 100ft faster if you walked heel to toe or if you bounded in a way that there were 3ft in between your feet with each step?

The answer to #2 is an axon with a large diameter. If you can't see why, then answer this question: could you move faster if you walked through a hallway that was 6ft wide or if you walked through a hallway that was 1ft wide?

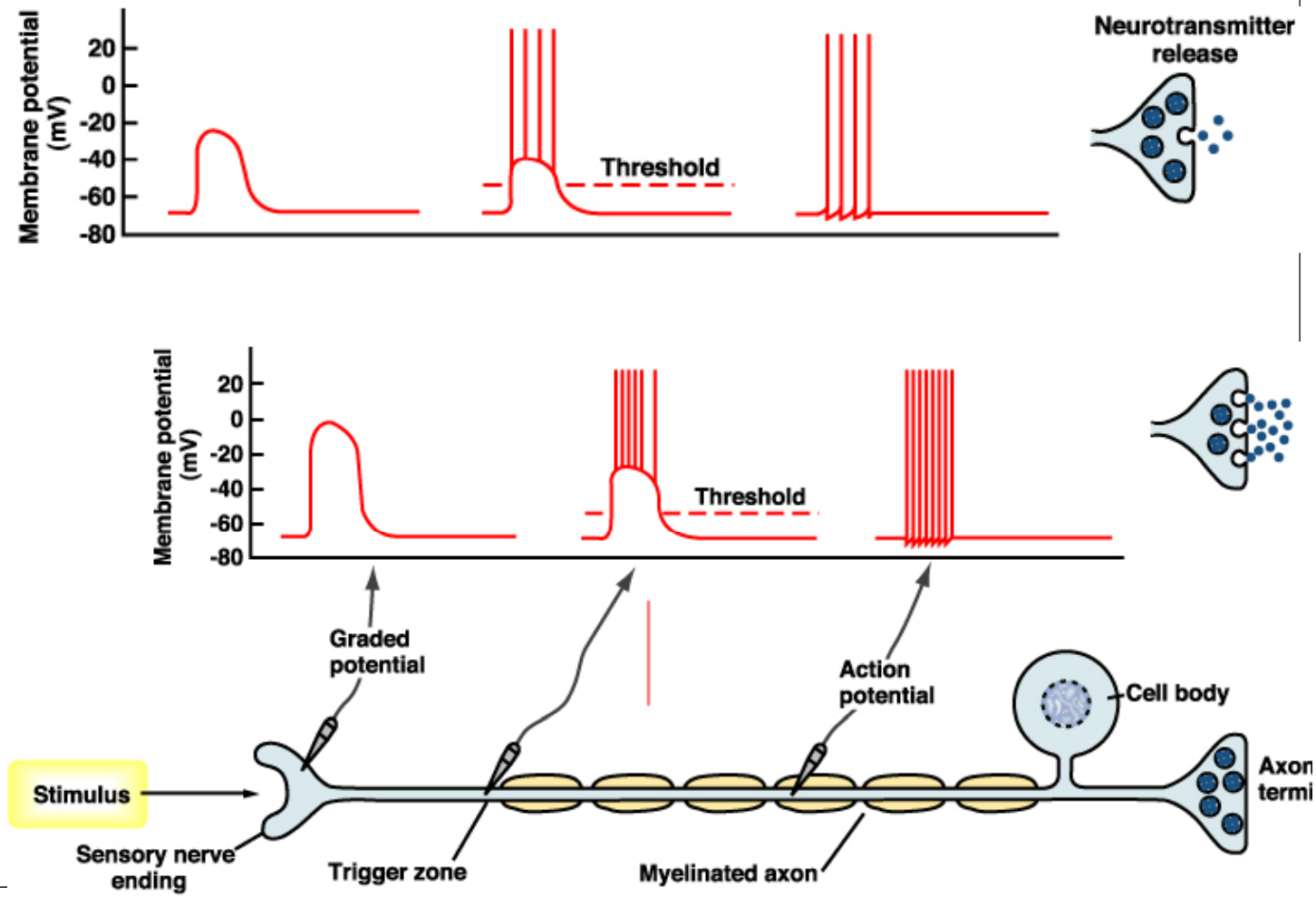
Types of Nerve Fibers

1. Group A
   - Axons of the somatic sensory neurons and motor neurons serving the skin, skeletal muscles, and joints.
   - Large diameters and thick myelin sheaths.
     - How does this influence their AP conduction?
2. Group B
   - Type B are lightly myelinated and of intermediate diameter.
3. Group C
   - Type C are unmyelinated and have the smallest diameter.
   - Autonomic nervous system fibers serving the visceral organs, visceral sensory fibers, and small somatic sensory fibers are Type B and Type C fibers.

Now we know how signals get from one end of an axon to the other, but how exactly do APs send information?

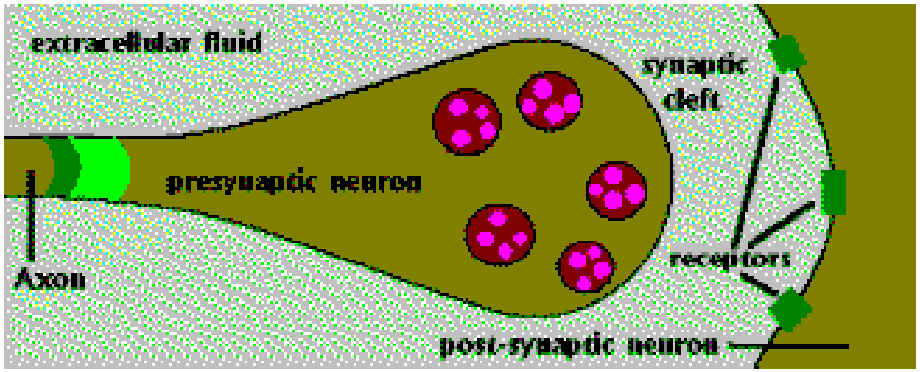
- Info can't be encoded in AP size, since they're "all or none."

In the diagram on the right, notice the effect that the size of the graded potential has on the frequency of AP's and on the quantity of NT released. The weak stimulus resulted in a small amt of NT release compared to the strong stimulus.



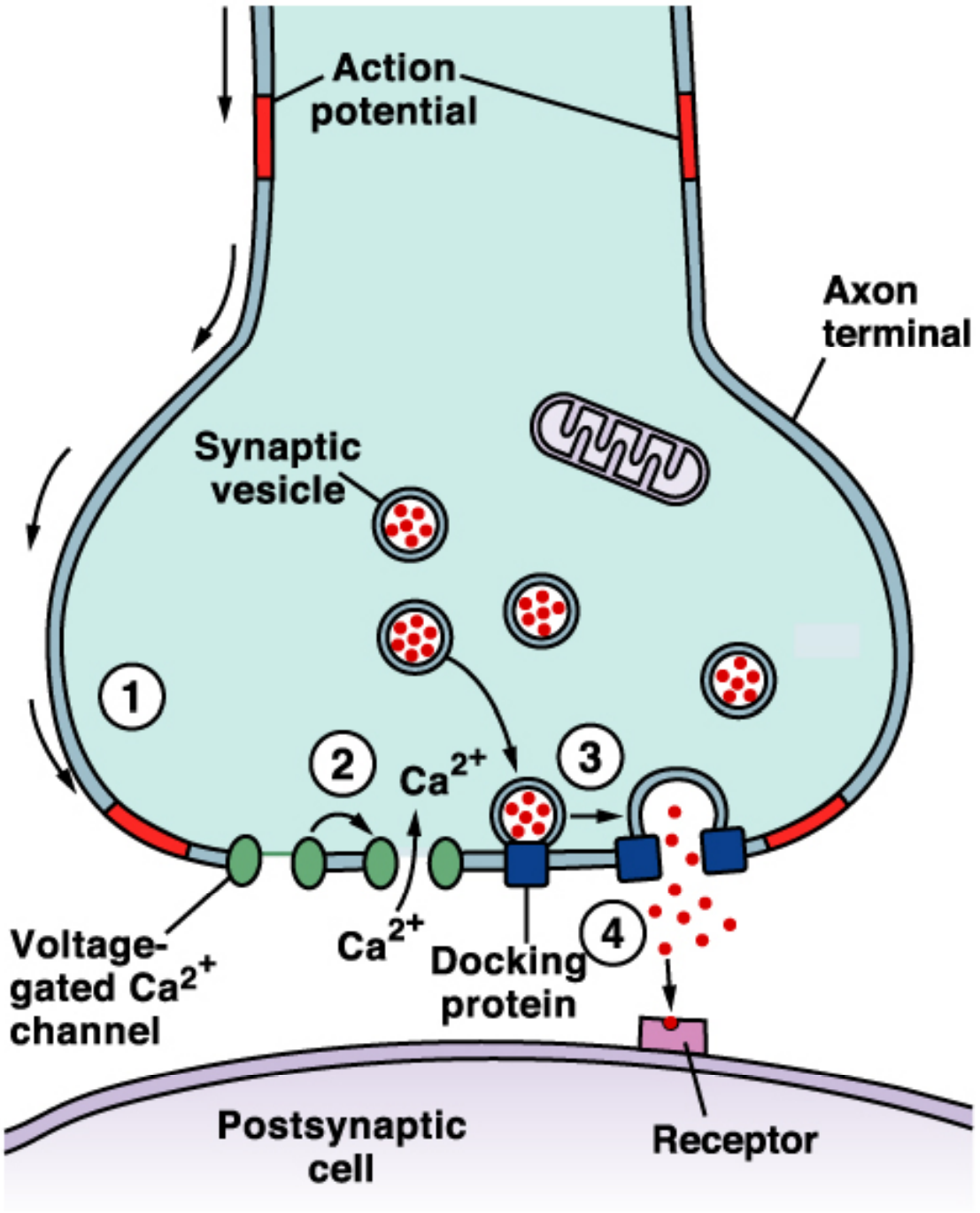
Chemical Signals

- One neuron will transmit info to another neuron or to a muscle or gland cell by releasing chemicals called neurotransmitters.
- The site of this chemical interplay is known as the synapse.
  - An axon terminal (synaptic knob) will abut another cell, a neuron, muscle fiber, or gland cell.
  - This is the site of transduction – the conversion of an electrical signal into a chemical signal.



Synaptic Transmission

- An AP reaches the axon terminal of the presynaptic cell and causes V-gated Ca^{2+} channels to open.
- Ca^{2+} rushes in, binds to regulatory proteins & initiates NT exocytosis.
- NTs diffuse across the synaptic cleft and then bind to receptors on the postsynaptic membrane and initiate some sort of response on the postsynaptic cell.



Effects of the Neurotransmitter

- Different neurons can contain different NTs.
- Different postsynaptic cells may contain different receptors.
  - Thus, the effects of an NT can vary.
- Some NTs cause cation channels to open, which results in a graded depolarization.
- Some NTs cause anion channels to open, which results in a graded hyperpolarization.

MODE OF ACTION

Postsynaptic Potentials

§ ***Neurotransmitter receptors mediate changes in membrane potential according to:***

- § The amount of neurotransmitter released
- § The amount of time the neurotransmitter is bound to receptors

§ ***The two types of postsynaptic potentials are:***

- § EPSP – excitatory postsynaptic potentials
- § IPSP – inhibitory postsynaptic potentials order

- § Spatial summation – postsynaptic neuron is stimulated by a large number of terminals at the same time
- § IPSPs can also summate with EPSPs, canceling each other out

Excitatory Postsynaptic Potentials(EPSP)

§ ***EPSPs are graded potentials that can initiate an action potential in an axon***

§ Use only chemically gated channels

§ Na + and K + flow in opposite directions at the same time

§ ***Postsynaptic membranes do not generate action potentials***

Inhibitory Synapses and IPSPs

§ ***Neurotransmitter binding to a receptor at inhibitory synapses:***

§ Causes the membrane to become more permeable to potassium and chloride ions

§ Leaves the charge on the inner surface negative

§ Reduces the postsynaptic neuron's ability to produce an action potential

Summation

§ A single EPSP cannot induce an action potential

§ EPSPs must summate temporally or spatially to induce an action potential

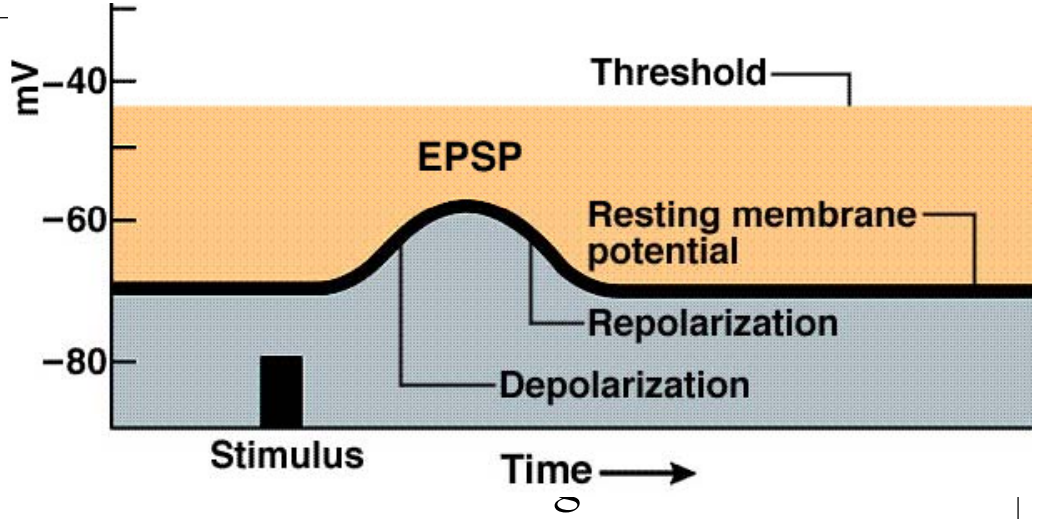
§ Temporal summation – presynaptic neurons transmit impulses in rapidfire order

§ Spatial summation – postsynaptic neuron is stimulated by a large number of terminals at the same time

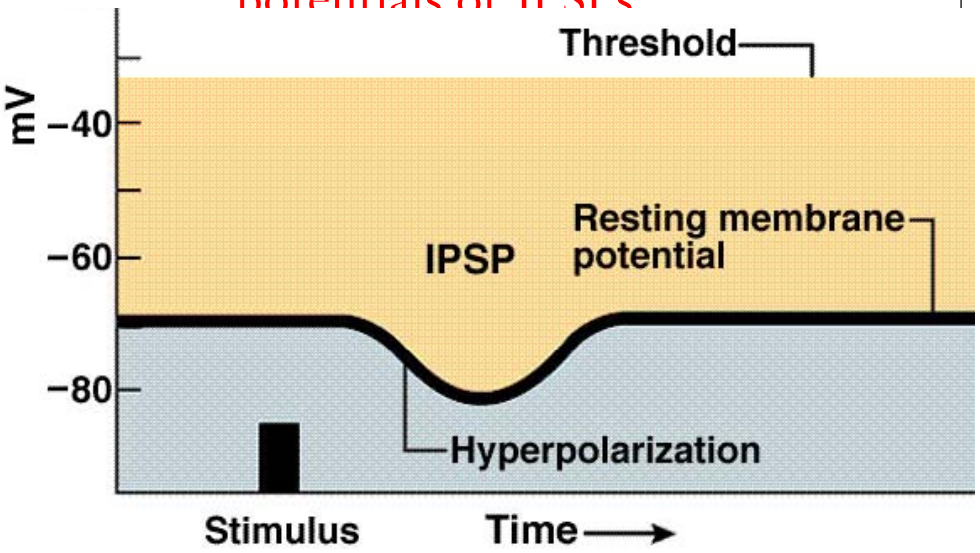
§ IPSPs can also summate with EPSPs, canceling each other out

EPSPs & IPSPs

- Typically, a single synaptic
  create a
  strong enough to migrate
  hillock and



  - However, a graded depolarization will bring the neuronal V_M closer to threshold. Thus, it's often referred to as an excitatory postsynaptic potential or EPSP.
  - Graded hyperpolarizations bring the neuronal V_M farther away from threshold and thus are referred to as inhibitory postsynaptic potentials or IPSPs



Characteristics of EPSPs

Transient depolarizations

- Excitatory because Em moves closer to threshold
- Increase in conductance to Na^+ and K^+
- Na^+ influx causes depolarization.
- EPSPs at synapses between neurons are similar to the EPPs at neuromuscular junctions.

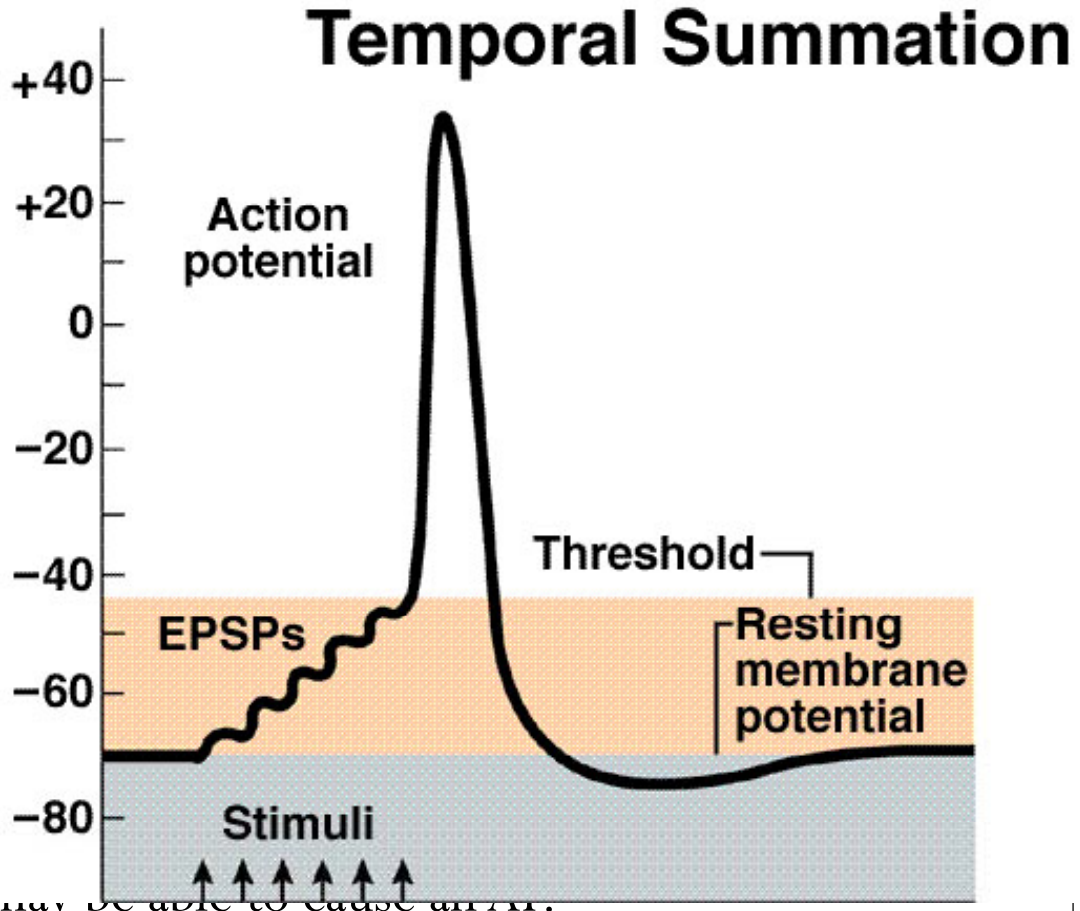
Characteristics of IPSPs

Transient hyperpolarizations

- Inhibitory because Em moves farther away from its threshold
- Increased conductance to Cl^-
- Cl^- influx causes hyperpolarization
- Also can be produced by increased K^+ conductance and an accelerated K^+ efflux

Summation

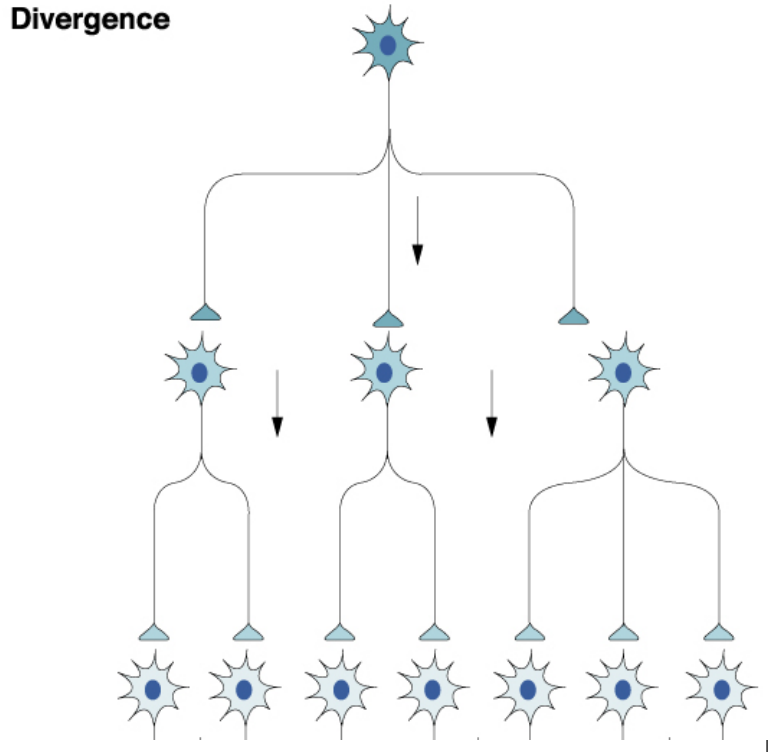
- One EPSP is usually enough
- However, EPSPs may summed.
- Temporal summation
  - The same presynaptic stimulates the multiple times in a brief perio combination of all the EPSPs

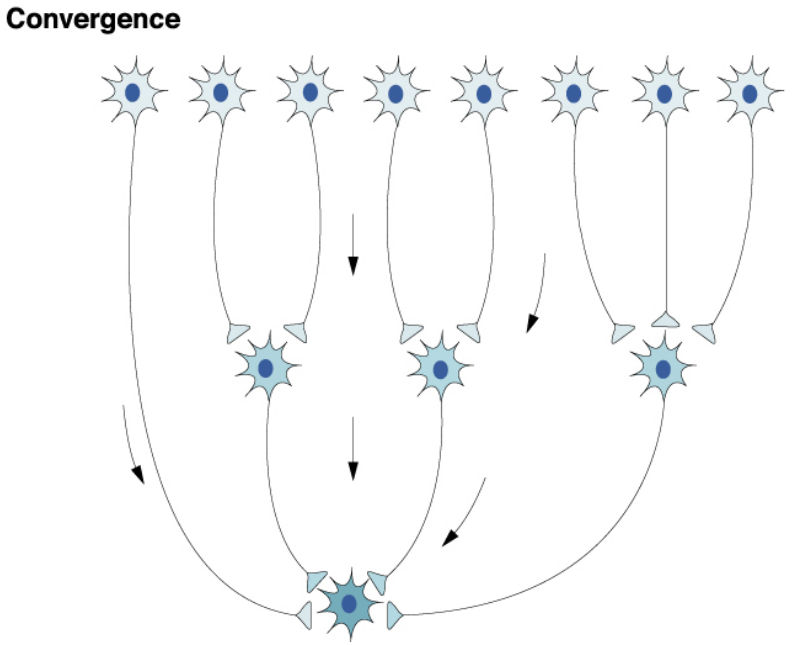


- Spatial summation
  - Multiple neurons all stimulate a postsynaptic neuron resulting in a combination of EPSPs which may yield an AP

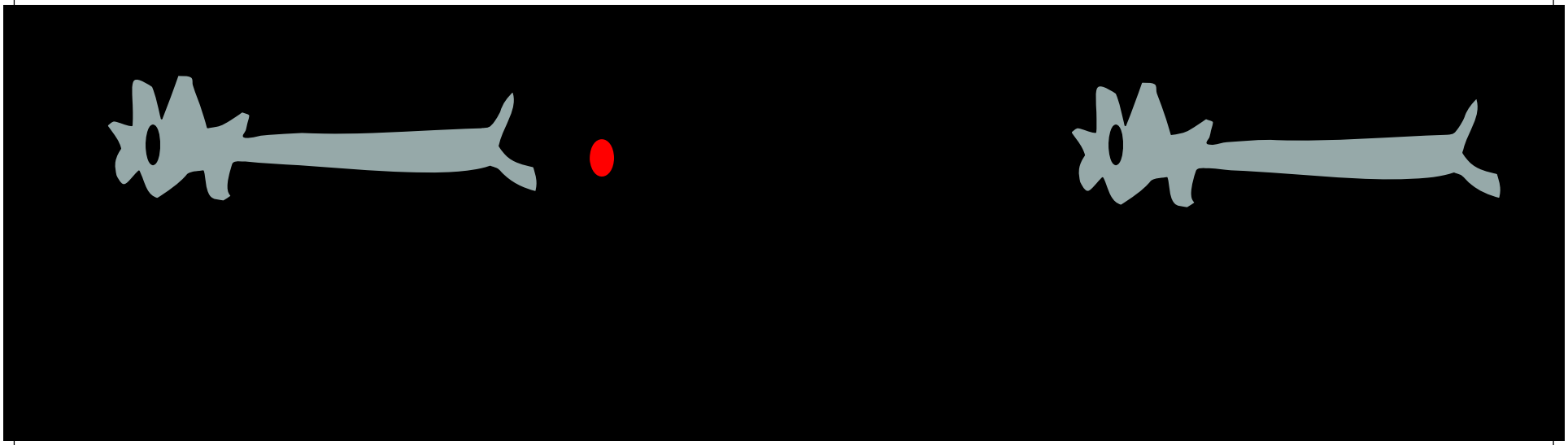
Communication btwn neurons is not typically a one-to-one event.

- Sometimes a single neuron branches and its collaterals synapse on multiple target neurons. This is known as divergence.
- A single postsynaptic neuron may have synapses with as many as 10,000 postsynaptic neurons. This is convergence.
- *Can you think of an advantage to having convergent and divergent circuits?*



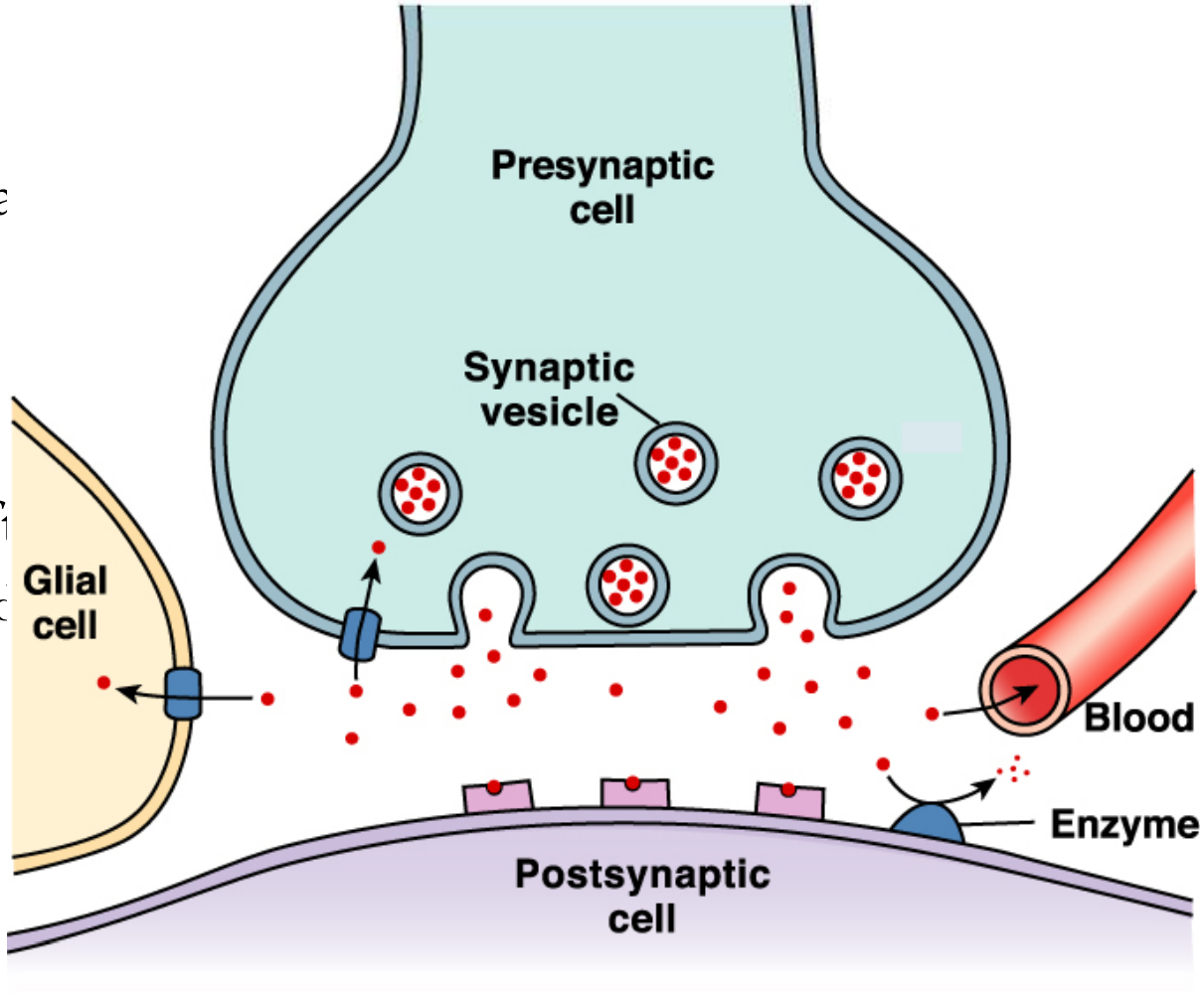


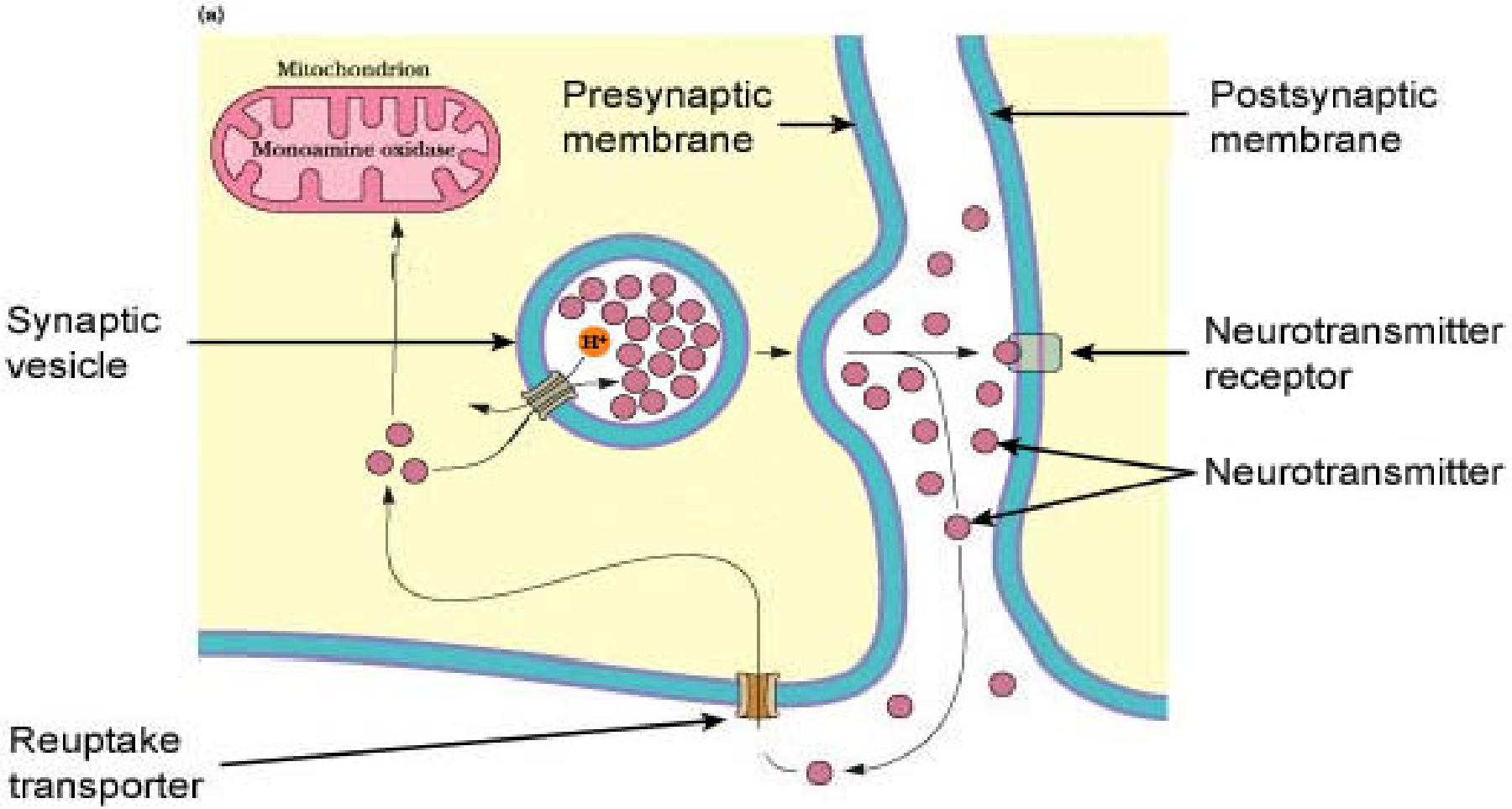
- Neurons may also form reverberating circuits.
  - A chain of neurons where many give off collaterals that go back and synapse on previous neurons.
    - What might be a benefit of this arrangement?



Neurotransmitter Removal

- Why did we want remove ACh neuro- muscula
- How was ACh the NMJ?
- NTs are removed synaptic clef
  - Enzymatic
  - Diffusion
  - Reuptake





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Phases of the Action Potential

- 1 – resting state
- 2 – depolarization phase
- 3 – repolarization phase
- 4 – hyperpolarization

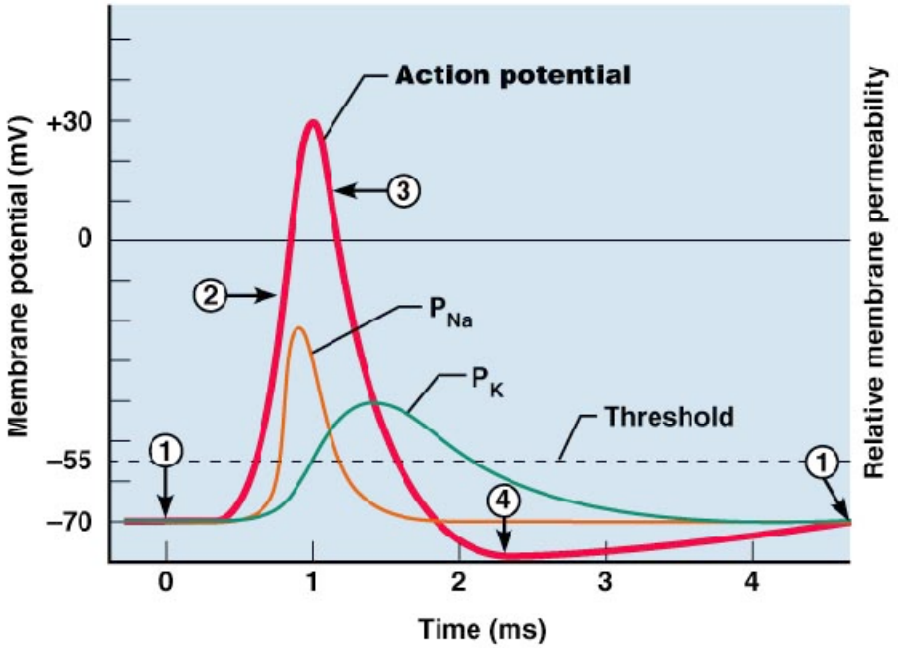

Figure 11.12

Absolute and Relative Refractory

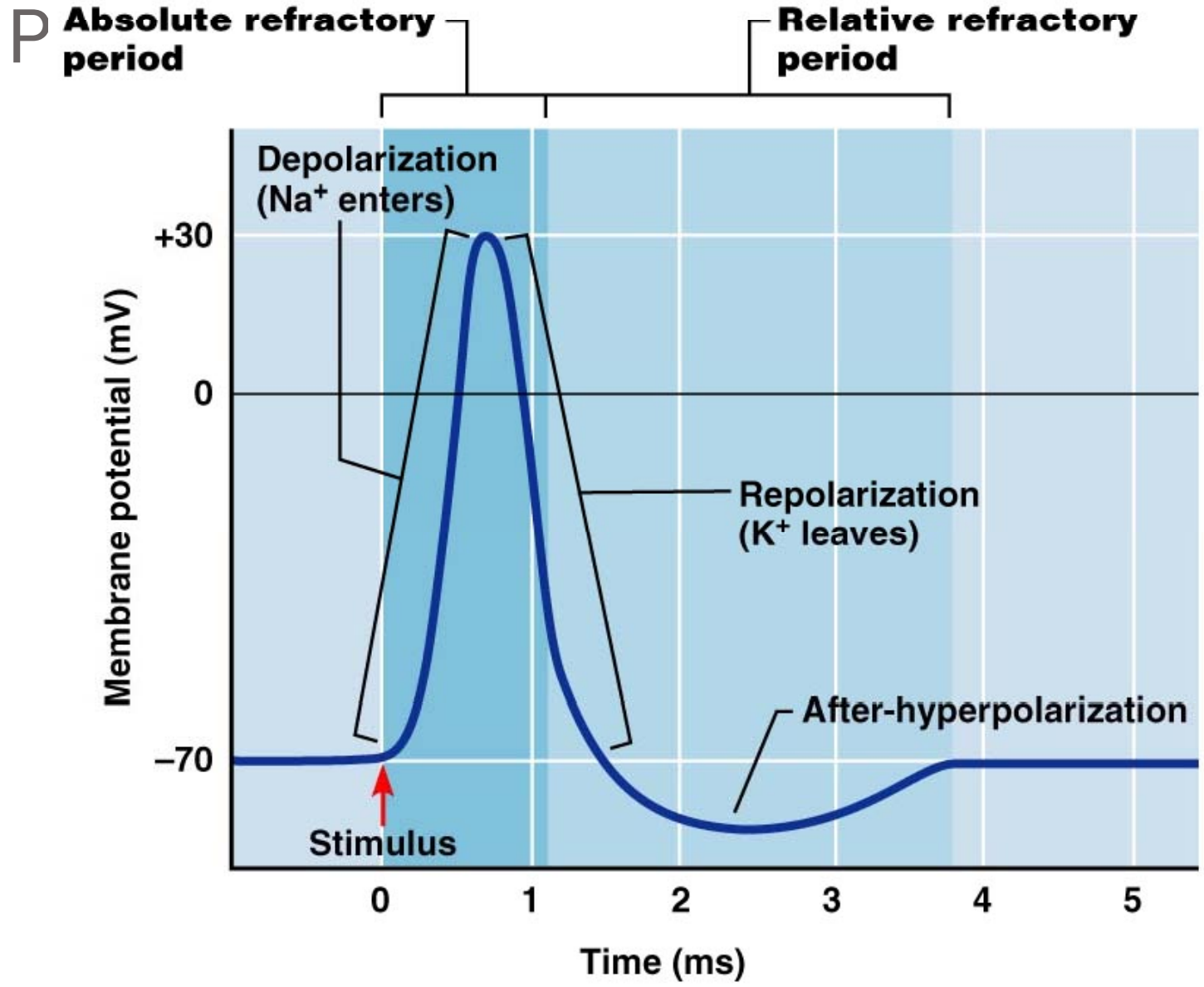

Figure 11.15

Axonal Conduction

- Depolarization
  - Threshold
  - Axon Hillock
  - Na ions rush in resulting in:
  - Action potential;
    - All or none phenomenon, high frequency
    - Afterpotentials; hyperpolarizing, depolarizing; slow frequency
    - Changes in membrane permeabilities
    - Propagation

- Refractory period

Postsynaptic Potentials

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Synaptic Transmission

Post-synaptic potentials (PSP's);

- Excitatory
- Inhibitory
- Interaction

Summation/Integration

- **temporal**
- **spatial**
- **decremental conduction** on dendrites and soma

axon hillock is critical area at which threshold must be reached

After release of neurotransmitter,

reuptake

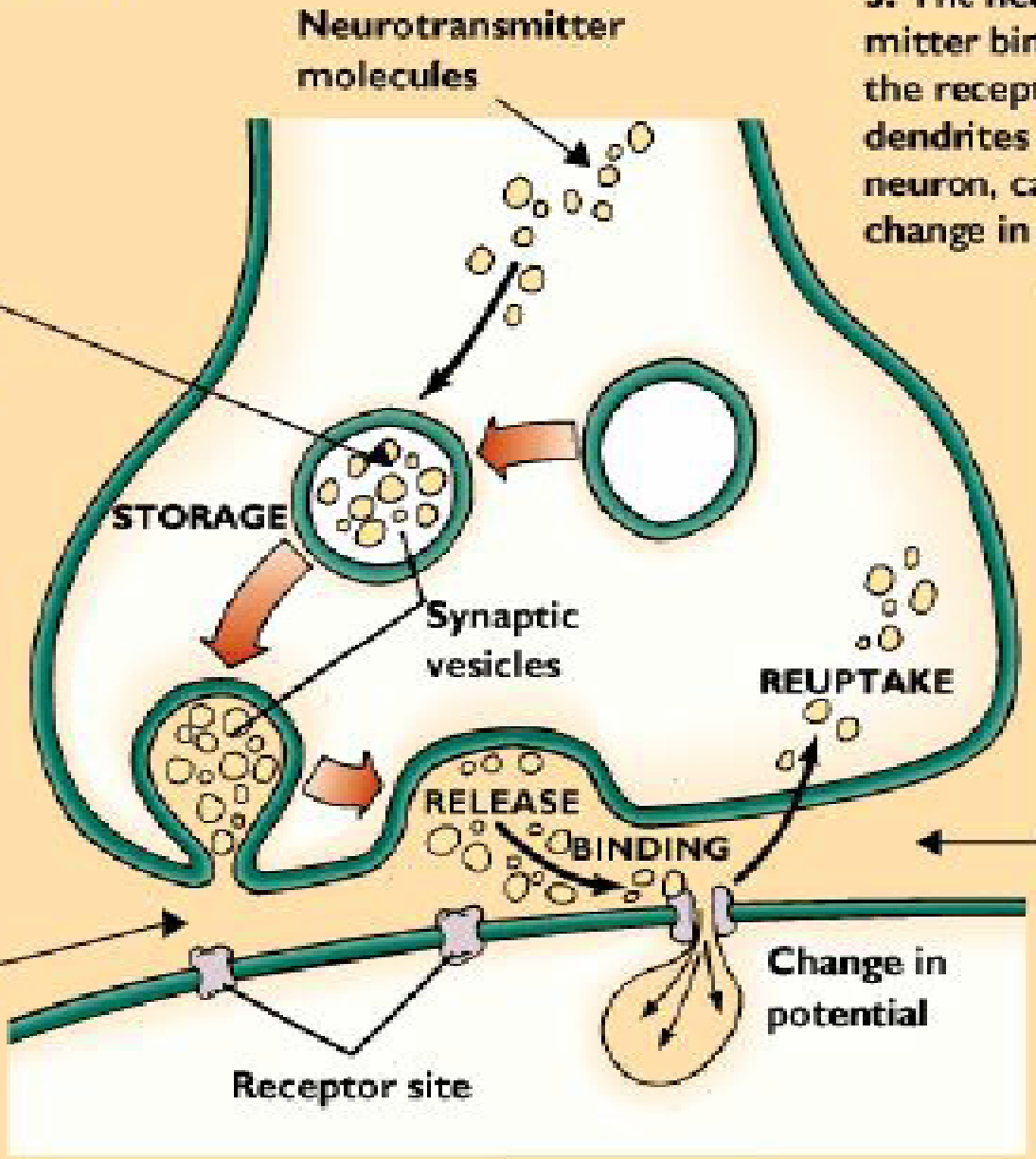
degradation

Functional Synaptic Units

Synaptic Transmission

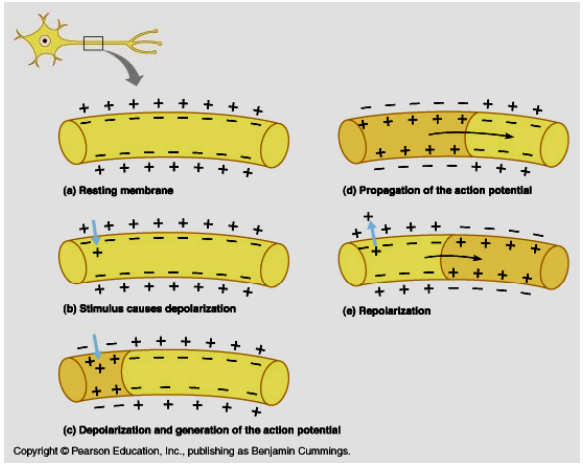
1. Within the axons of the neuron are neurotransmitters, which are held in storage-like vesicles until they are released when the neuron is stimulated.

2. The small space between the axon terminal and the dendrite of the next axon is called the synapse. An action potential stimulates the release of neuro-transmitters across the synapse.



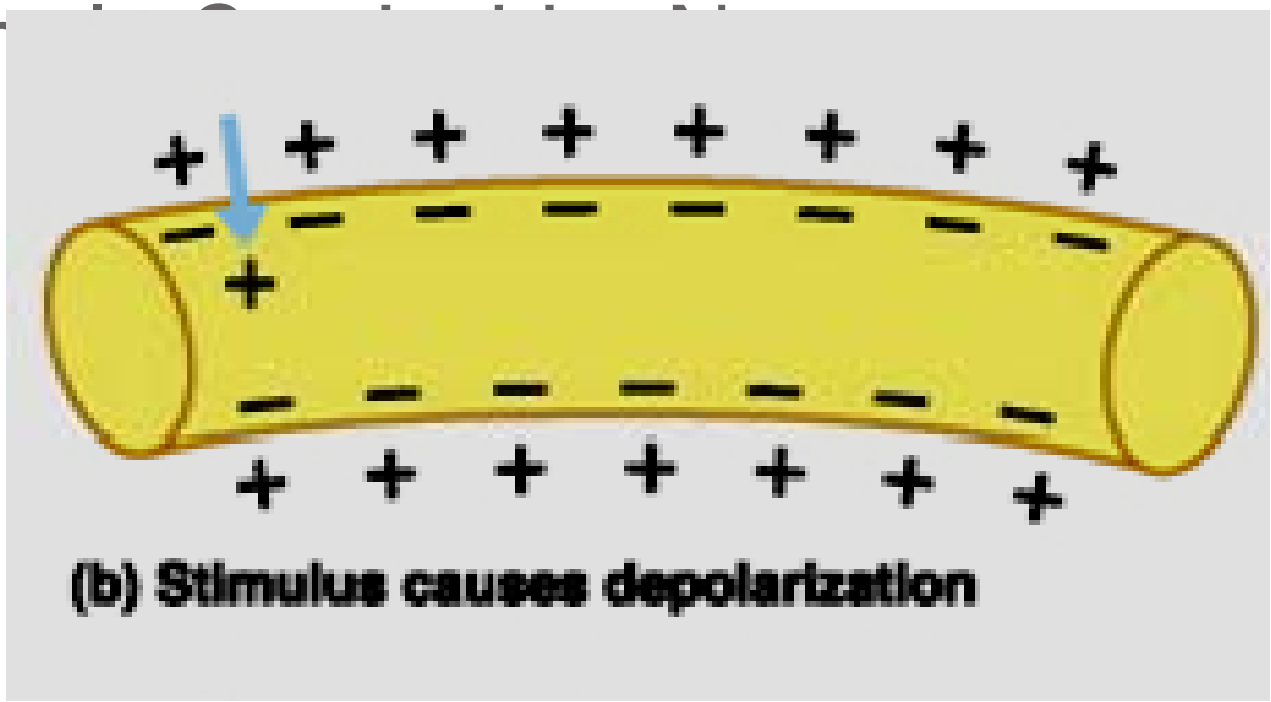
3. The neurotrans-mitter binds itself to the receptor sites on dendrites of the next neuron, causing a change in potential.

Signals Carried by Neurons



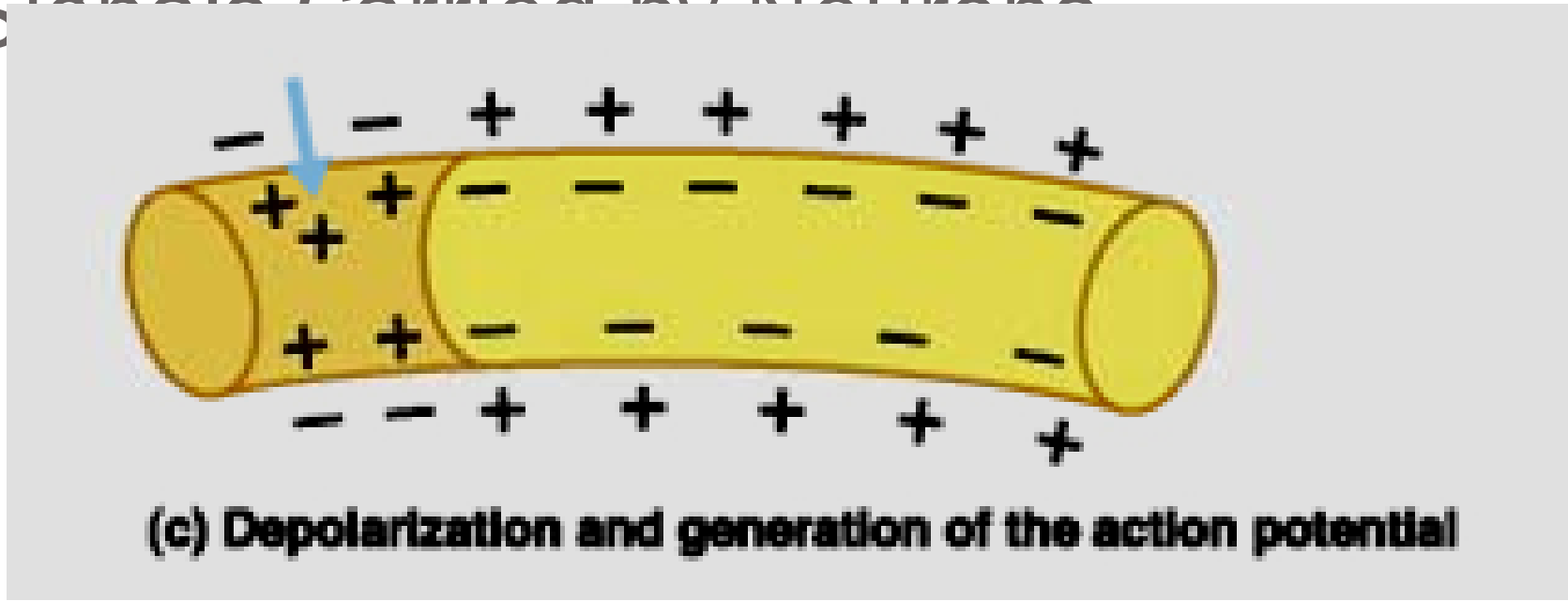
- In a resting (unstimulated) neuron, the membrane is polarized which means that the inner cytoplasmic side is negatively charged with respect to its outer, extracellular side

Sign



- When a neuron is stimulated the permeability of the plasma membrane changes at the site of the stimulus, allowing positive ions to rush in.
- As a result, the inner face of the membrane becomes less negative or depolarized

Signals Carried by Neurons

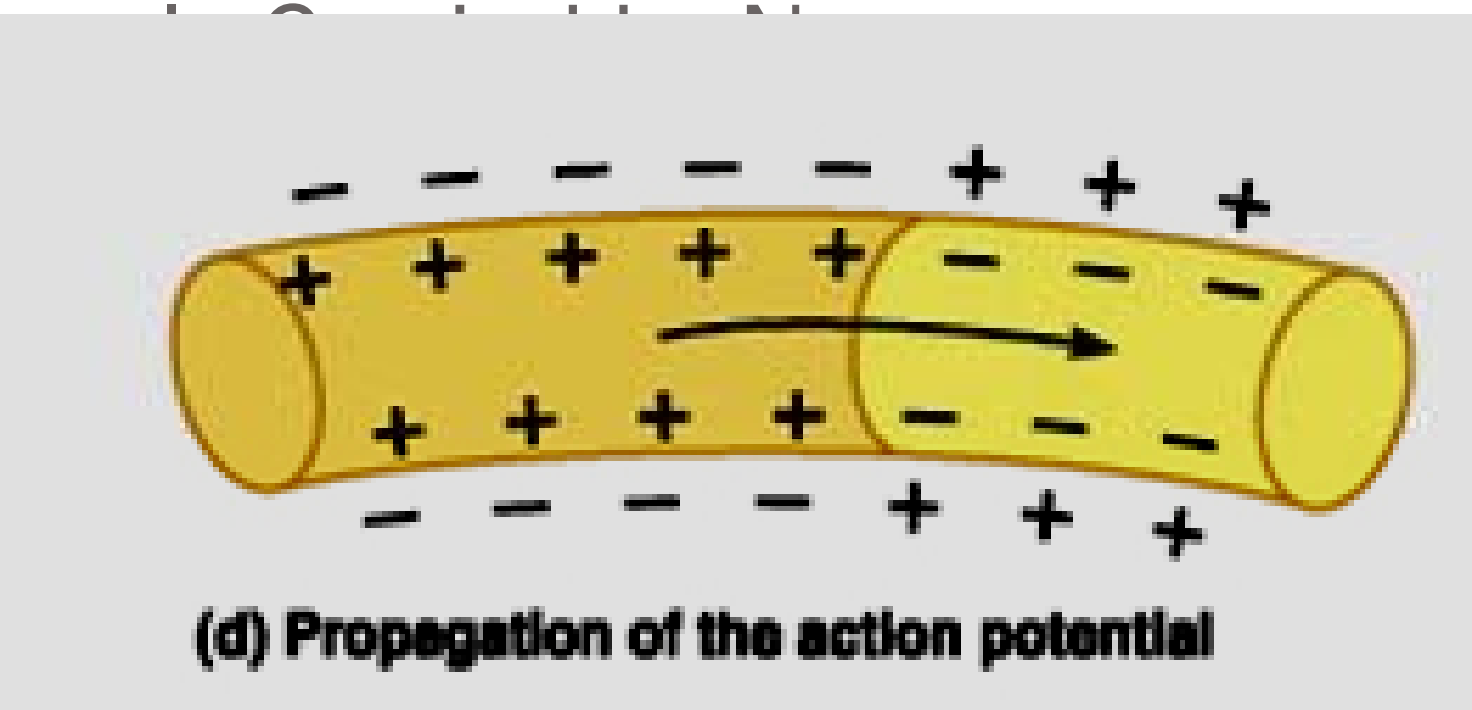


- Any part of the neuron depolarizes if stimulated, but at the axon alone this can result in the triggering of a nerve impulse or action potential

Signals Carried by Neurons

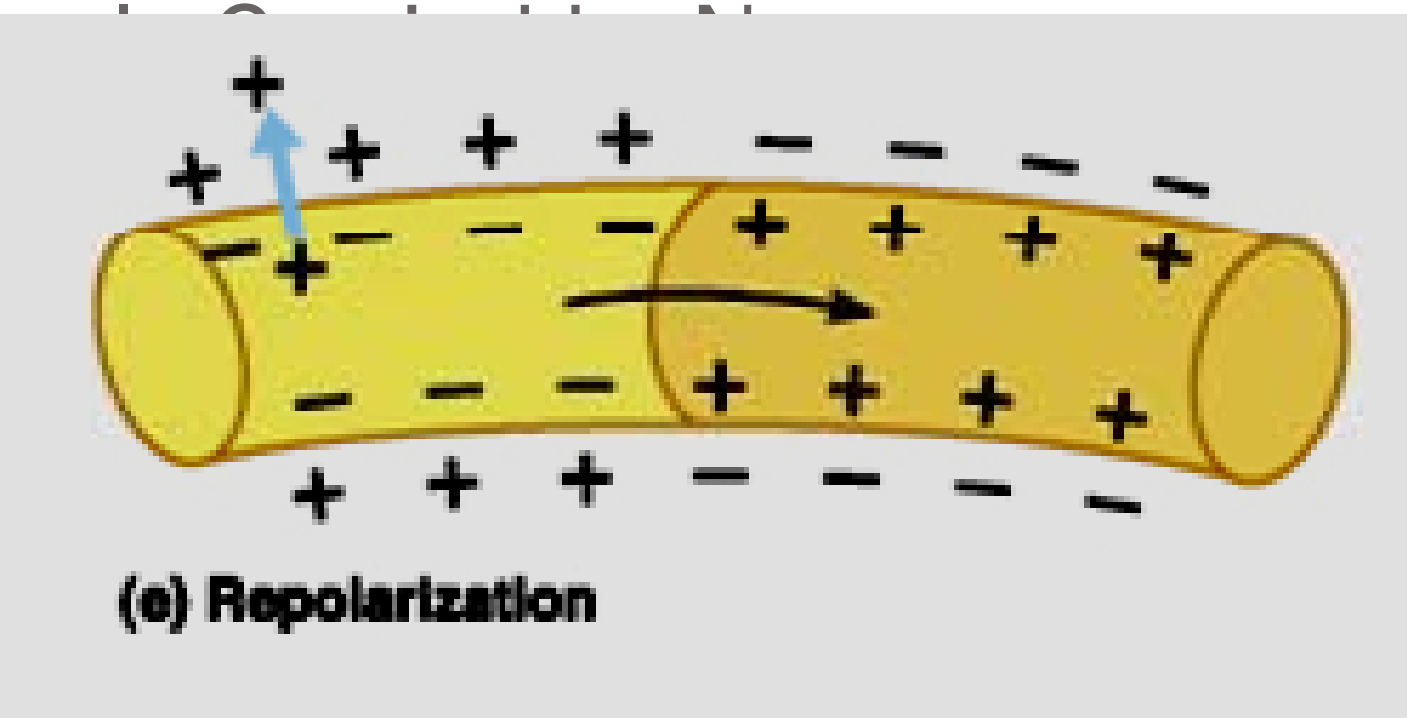
- When a nerve impulse or action potential develops the membrane is not only depolarized , but its polarity is completely reversed so it becomes negative externally and positive internally

Si



- Once begun, the nerve impulse travels rapidly down the entire length of the axon without decreasing in strength

Sig



- After the impulse has passed the membrane repolarizes itself

Graded Potential

- In humans, natural stimuli are not applied directly to axons, but to dendrites and the cell body which constitute the receptive zone of the neuron
- When the membrane of this receptive zone is stimulated it does not undergo a polarity reversal
- Instead it undergoes a local depolarization in which the inner surface of the membrane merely becomes less negative

Graded Potential

- This local depolarization is called a graded potential which spreads from the receptive zone to the axon hillock (trigger zone) decreasing in strength as it travels
- If this depolarizing signal is strong enough when it reaches the initial segment of the axon, it acts as the trigger that initiates an action potential in the axon
- Signals from the receptive zone determine if the axon will fire an impulse

Synaptic Potential

- Most neurons in the body do not receive stimuli directly from the environment but are stimulated only by signals received at synapses from other neurons
- Synaptic input influences impulse generation through either excitatory or inhibitory synapses

Synaptic Potential

- In excitatory synapses, neurotransmitters released by presynaptic neurons alter the permeability of the postsysnaptic membrane to certain ions, this depolarizes the postsynapatic membrane and drives the postsynaptic neuron toward impulse generation

Synaptic Potential

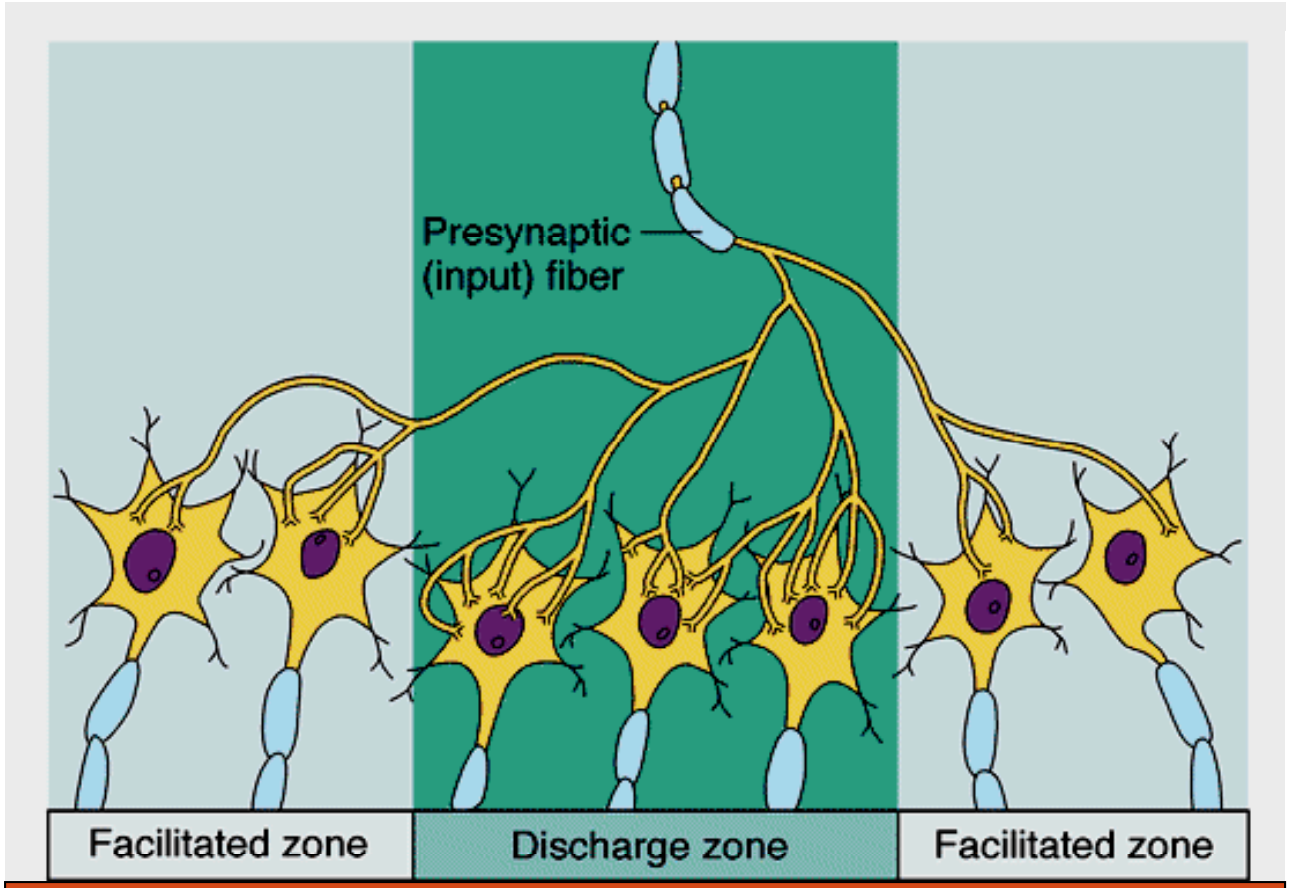
- Inhibitory synapses cause the external surface of the postsynaptic membrane to become even more positive, thereby reducing the ability of the postsynaptic neuron to generate an action potential
- Thousands of excitatory and inhibitory synapses act on every neuron, competing to determine whether or not that neuron will generate an impulse

Neural Integration

- The organization of the nervous system is hierarchical
- The parts of the system must be integrated into a smoothly functioning whole
- Neuronal pools represent some of the basic patterns of communication with other parts of the nervous system

Neuronal Pools

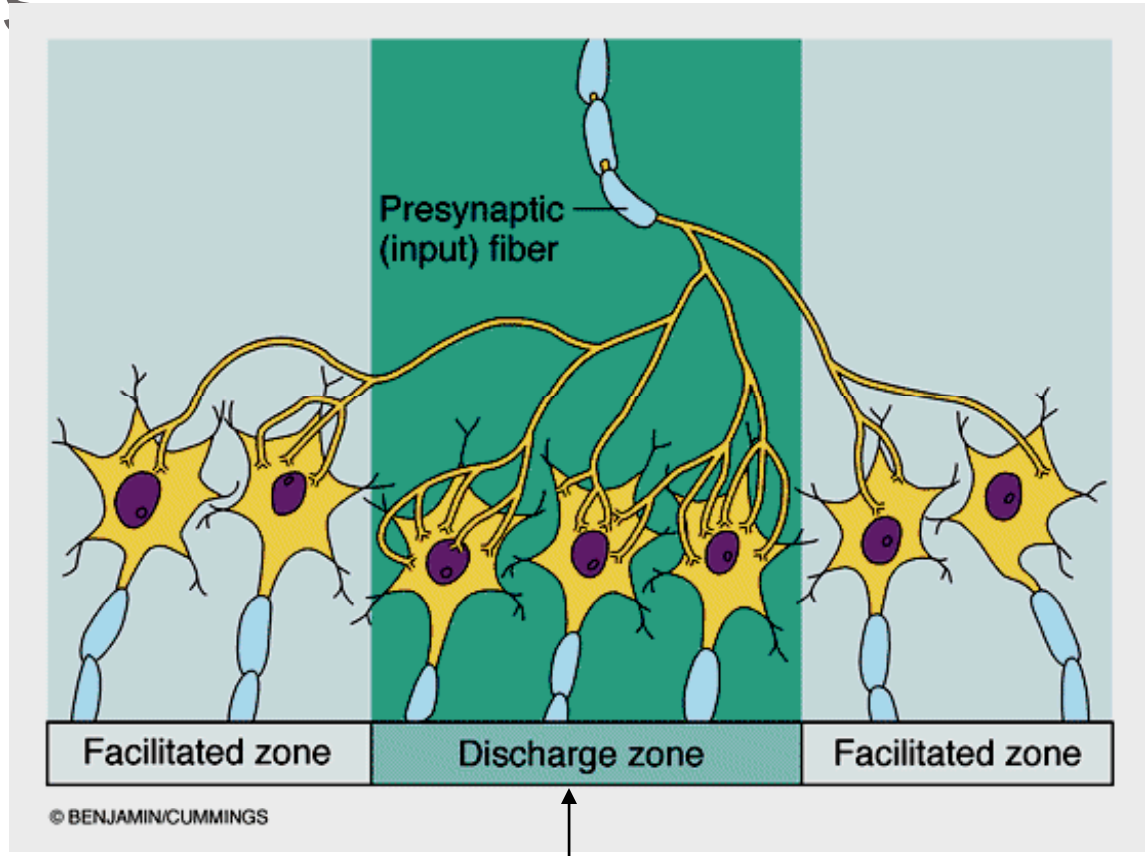
- Neuronal pools are functional groups of neurons that process and integrate incoming information from other sources and transmit it forward



One incoming presynaptic fiber synapses with Several different neurons in the pool. When Incoming fiber is excited it will excite some Postsynaptic neurons and facilitate others.

Neuronal Pools

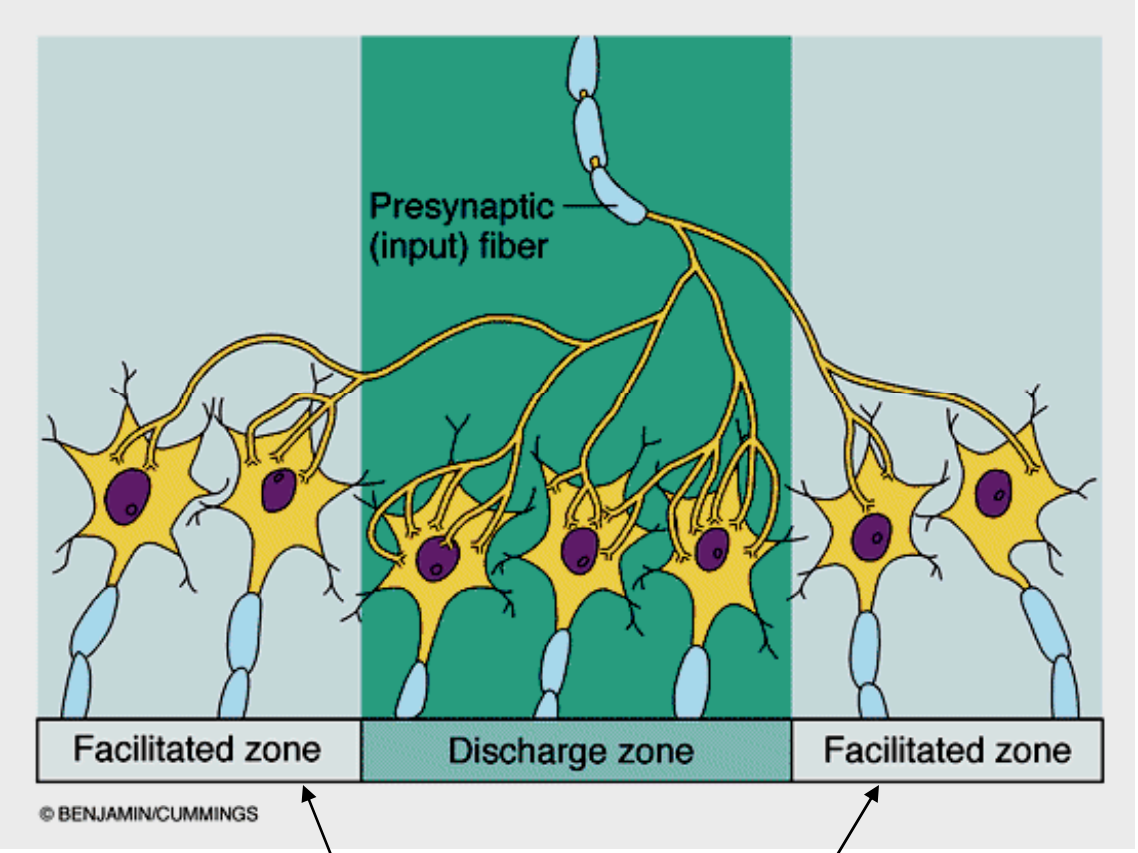
- Neurons most likely to generate impulses are those most closely associated with the incoming fiber because they receive the bulk of the synaptic contacts
- These neurons are in the discharge zone



Discharge Zone

Neuronal Pools

- Neurons farther away from the center are not excited to threshold by the incoming fiber, but are facilitated and can easily brought to threshold by stimuli from another source
- The periphery of the pool is the facilitated zone



Facilitated zone

Neuronal Pools

- Note: The illustrations presented are a gross oversimplification of an actual neuron pool
- Most neuron pools consist of thousands of neurons and include inhibitory as well as excitatory neurons