Neuron types and Neurotransmitters

Faisal I. Mohammed. PhD, MD

Objectives

- Understand synaptic transmission
- List types of sensory neurons
- Classify neurotransmitters
- Explain the mechanism of neurotransmission
- Judge the types of receptors for the neurotrasmitters

Functional Unit (Neuron)

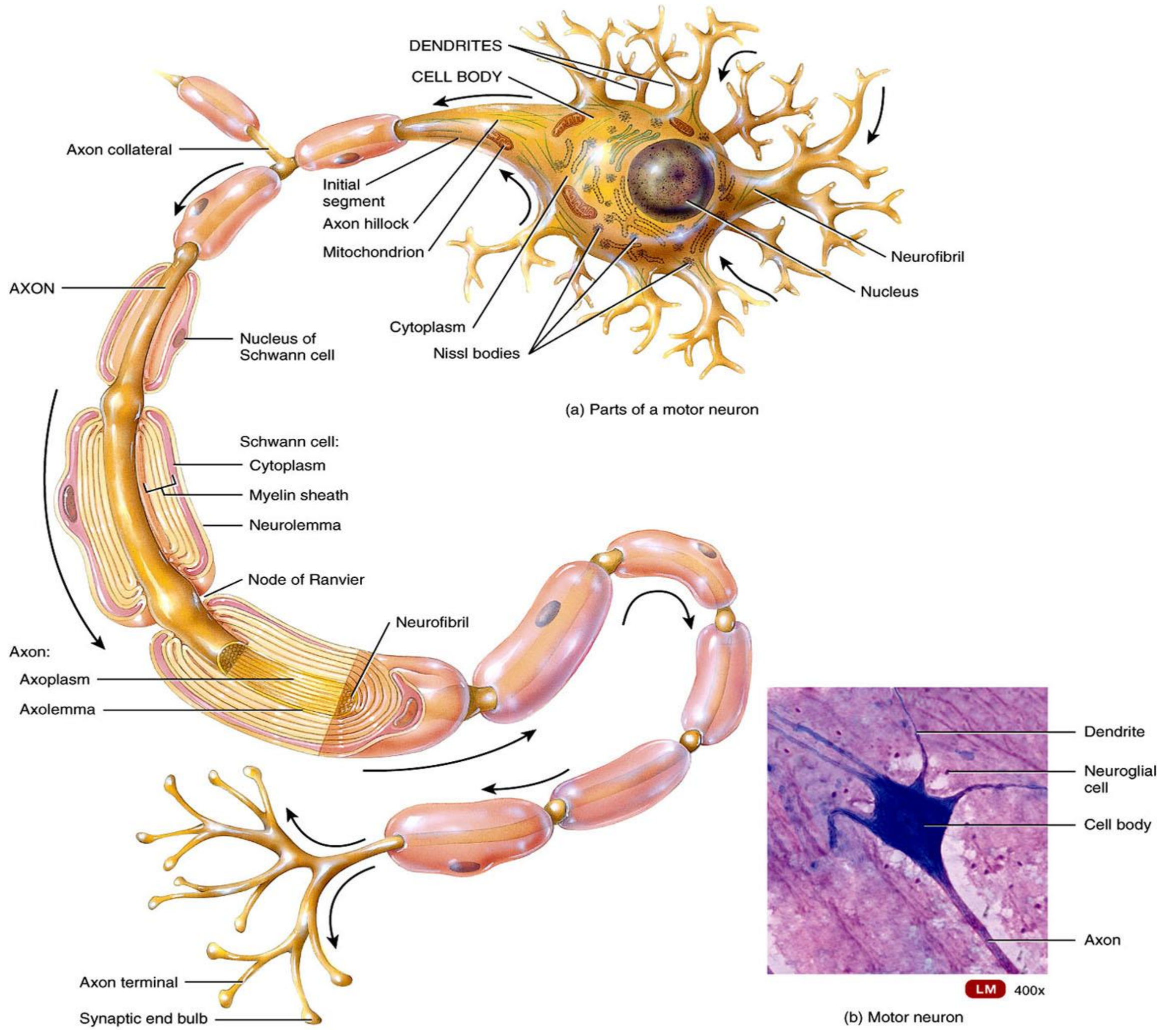


Figure 12.02 Tortora - PAP 12/e

Transmission of Receptor Information to the Brain

- The larger the nerve fiber diameter the faster the rate of transmission of the signal
- Velocity of transmission can be as fast as 120 m/sec or as slow as 0.5 m/sec
- Nerve fiber classification
  - type A - myelinated fibers of varying sizes, generally fast transmission speed
    - subdivided into α, β, γ, δ

    type B- partially myelinated neurons (3-14m/sec speed)
  - type C - unmyelinated fibers, small with slow transmission speed

Types of Nerve Fiber

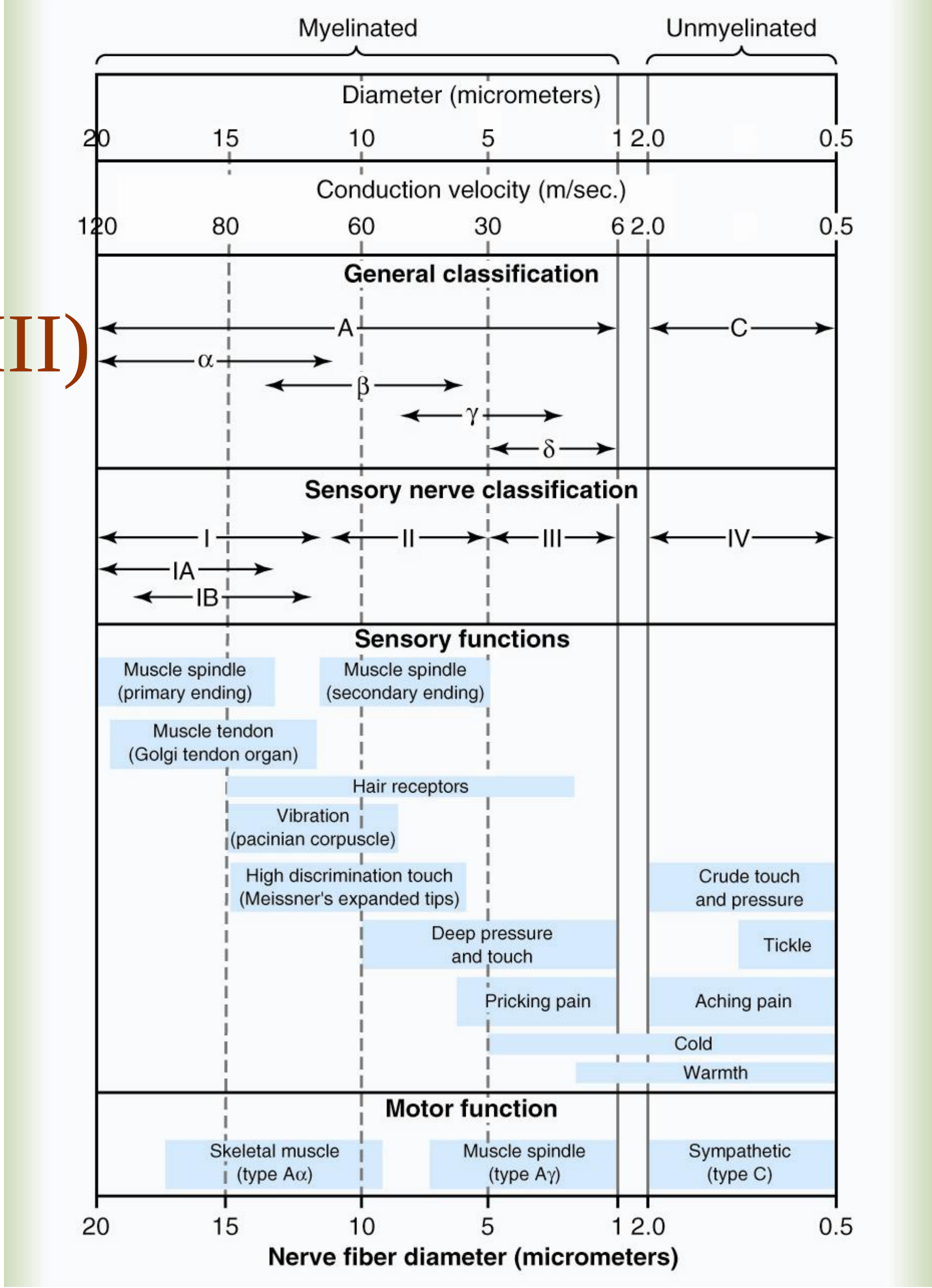
-Myelinated fibers –

Type A (types I, II and III)

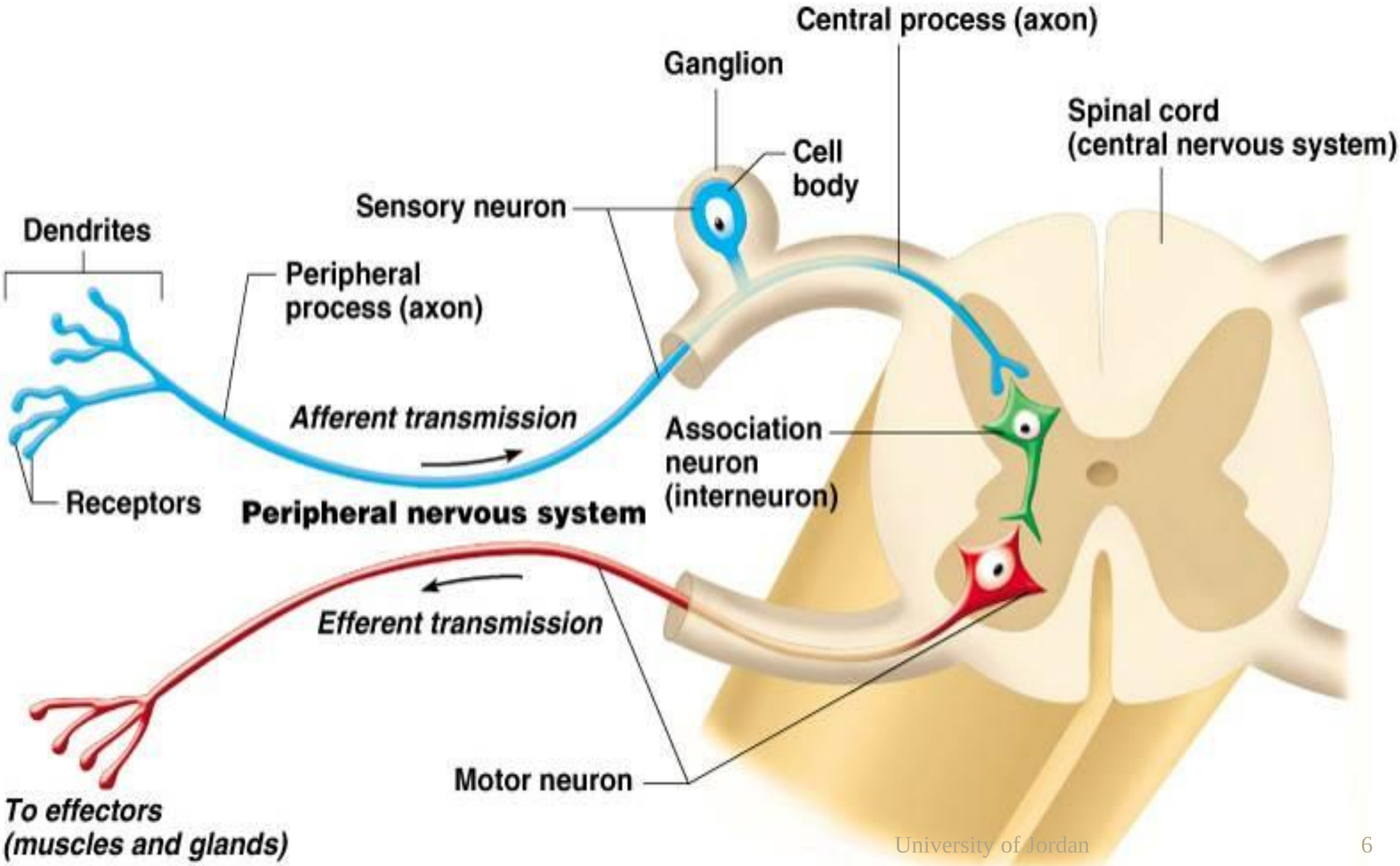
- A α
- A β
- A γ
- A δ

-Umyelinated Fibers-

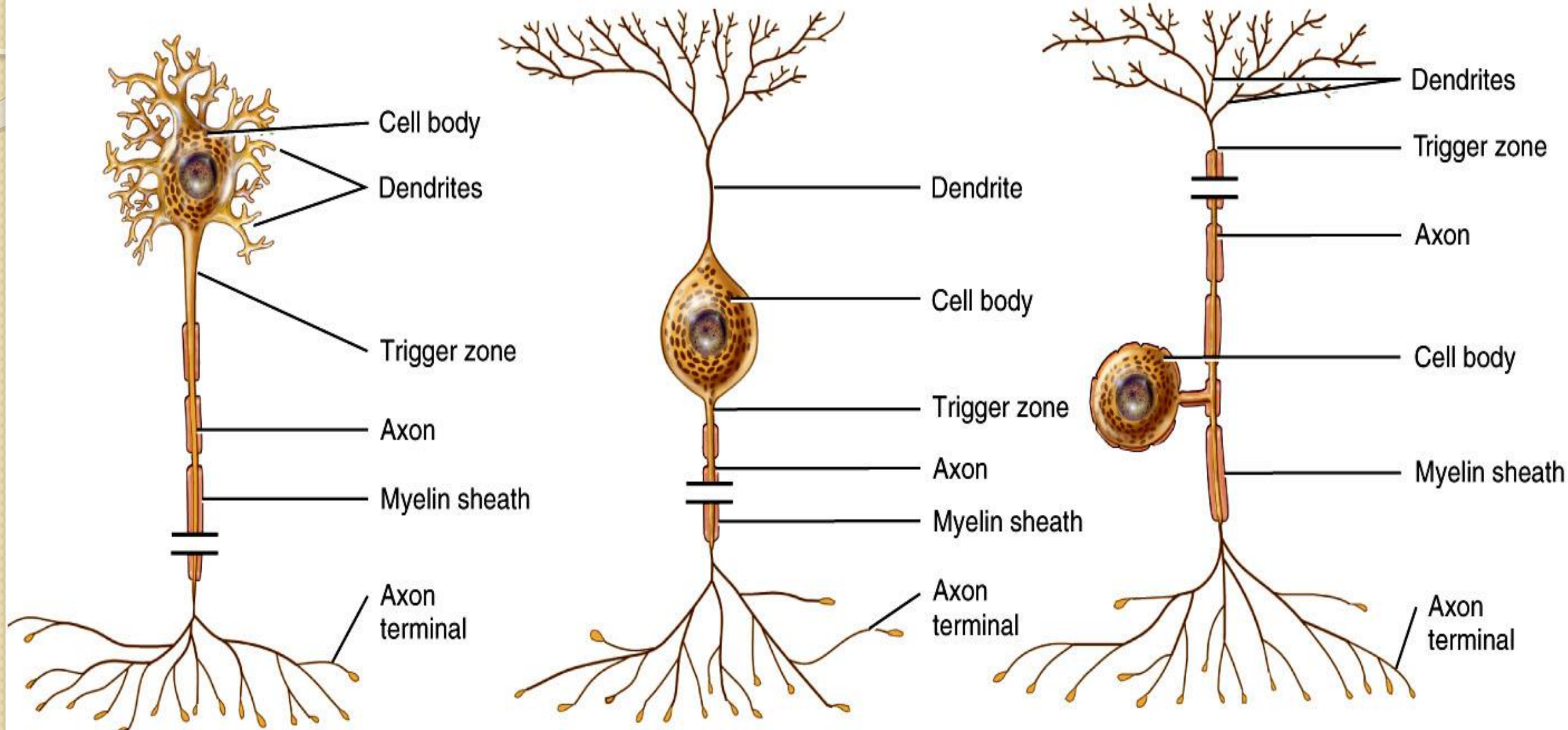
Type C (type IV)



Neuron Classification



Structural Classification of Neurons



(a) Multipolar neuron (b) Bipolar neuron (c) Unipolar neuron

Figure 12.03 Tortora - PAP 12/e

Neurotransmitters

- Chemical substances that function as synaptic transmitters

1. Small molecules which act as rapidly acting transmitters
   - acetylcholine, norepinephrine, dopamine, serotonin, GABA, glycine, glutamate, NO
2. Neuropeptides (Neuromodulators)
   - more potent than small molecule transmitters, cause more prolonged actions
   - endorphins, enkephalins, VIP, ect.
   - hypothalamic releasing hormones
   - TRH, LHRH, ect.
   - pituitary peptides
   - ACTH, prolactin, vasopressin, ect.

Neurotransmitters

Table 45–1

Small-Molecule, Rapidly Acting Transmitters

Class I
- Acetylcholine

Class II: The Amines
- Norepinephrine
- Epinephrine
- Dopamine
- Serotonin
- Histamine

Class III: Amino Acids
- Gamma-aminobutyric acid (GABA)
- Glycine
- Glutamate
- Aspartate

Class IV
- Nitric oxide (NO)

Table 45–2

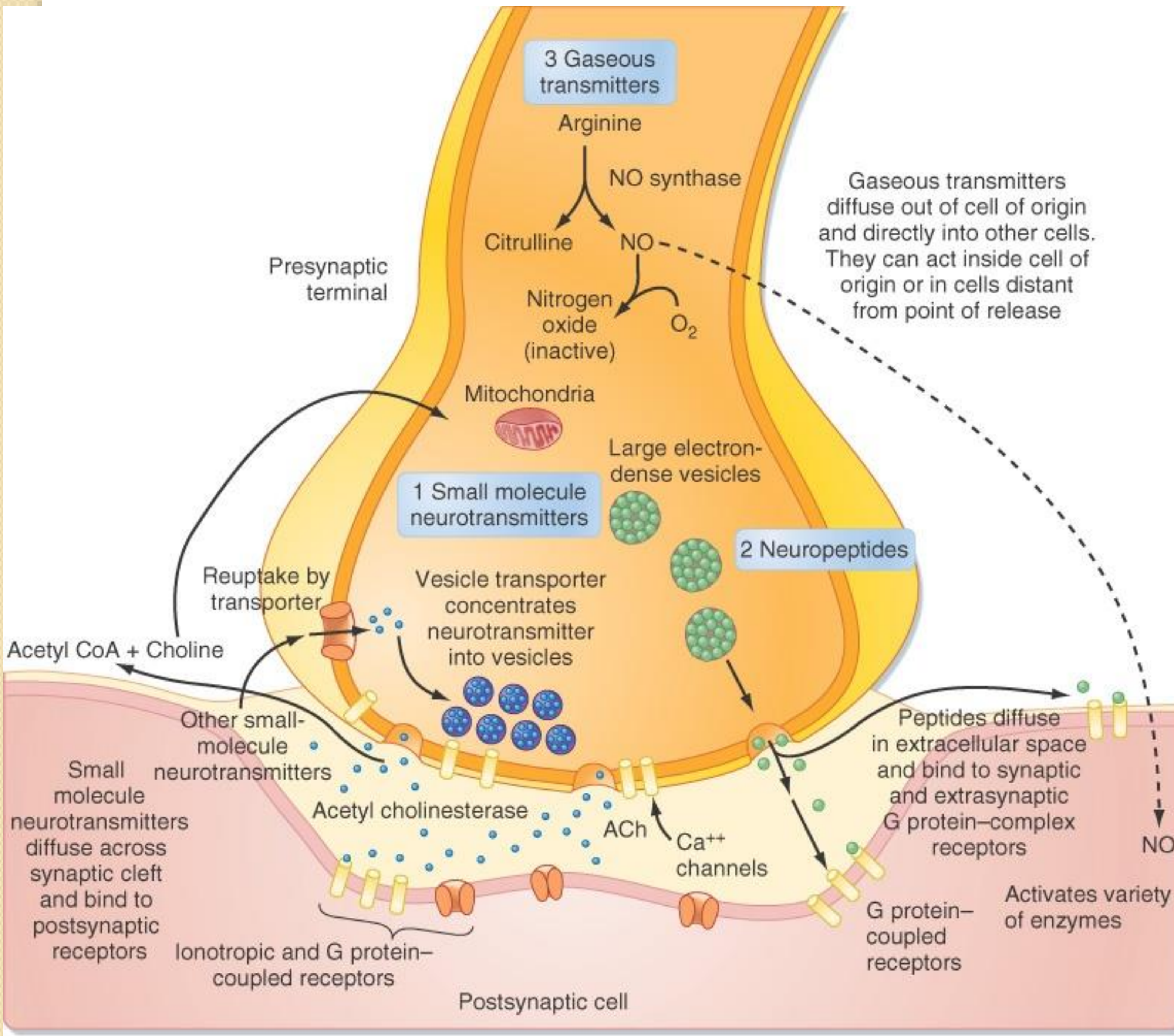
Neuropeptide, Slowly Acting Transmitters or Growth Factors

Hypothalamic-releasing hormones
- Thyrotropin-releasing hormone
- Luteinizing hormone–releasing hormone
- Somatostatin (growth hormone inhibitory factor)

Pituitary peptides
- Adrenocorticotropic hormone (ACTH)
- β-Endorphin
- α-Melanocyte-stimulating hormone
- Prolactin
- Luteinizing hormone
- Thyrotropin
- Growth hormone
- Vasopressin
- Oxytocin

Peptides that act on gut and brain
- Leucine enkephalin
- Methionine enkephalin
- Substance P
- Gastrin
- Cholecystokinin
- Vasoactive intestinal polypeptide (VIP)
- Nerve growth factor
- Brain-derived neurotropic factor
- Neurotensin
- Insulin
- Glucagon

From other tissues
- Angiotensin II
- Bradykinin
- Carnosine
- Sleep peptides
- Calcitonin


3 Gaseous transmitters
Arginine
NO synthase
Citrulline
NO
Nitrogen oxide (inactive)
O_2
Gaseous transmitters diffuse out of cell of origin and directly into other cells. They can act inside cell of origin or in cells distant from point of release
Presynaptic terminal
Mitochondria
Large electron-dense vesicles
1 Small molecule neurotransmitters
2 Neuropeptides
Reuptake by transporter
Vesicle transporter concentrates neurotransmitter into vesicles
Acetyl CoA + Choline
Other small-molecule neurotransmitters
Small molecule neurotransmitters diffuse across synaptic cleft and bind to postsynaptic receptors
Acetyl cholinesterase
ACh
Ca^{++} channels
Peptides diffuse in extracellular space and bind to synaptic and extrasynaptic G protein–complex receptors
NO
Activates variety of enzymes
G protein–coupled receptors
Ionotropic and G protein–coupled receptors
Postsynaptic cell

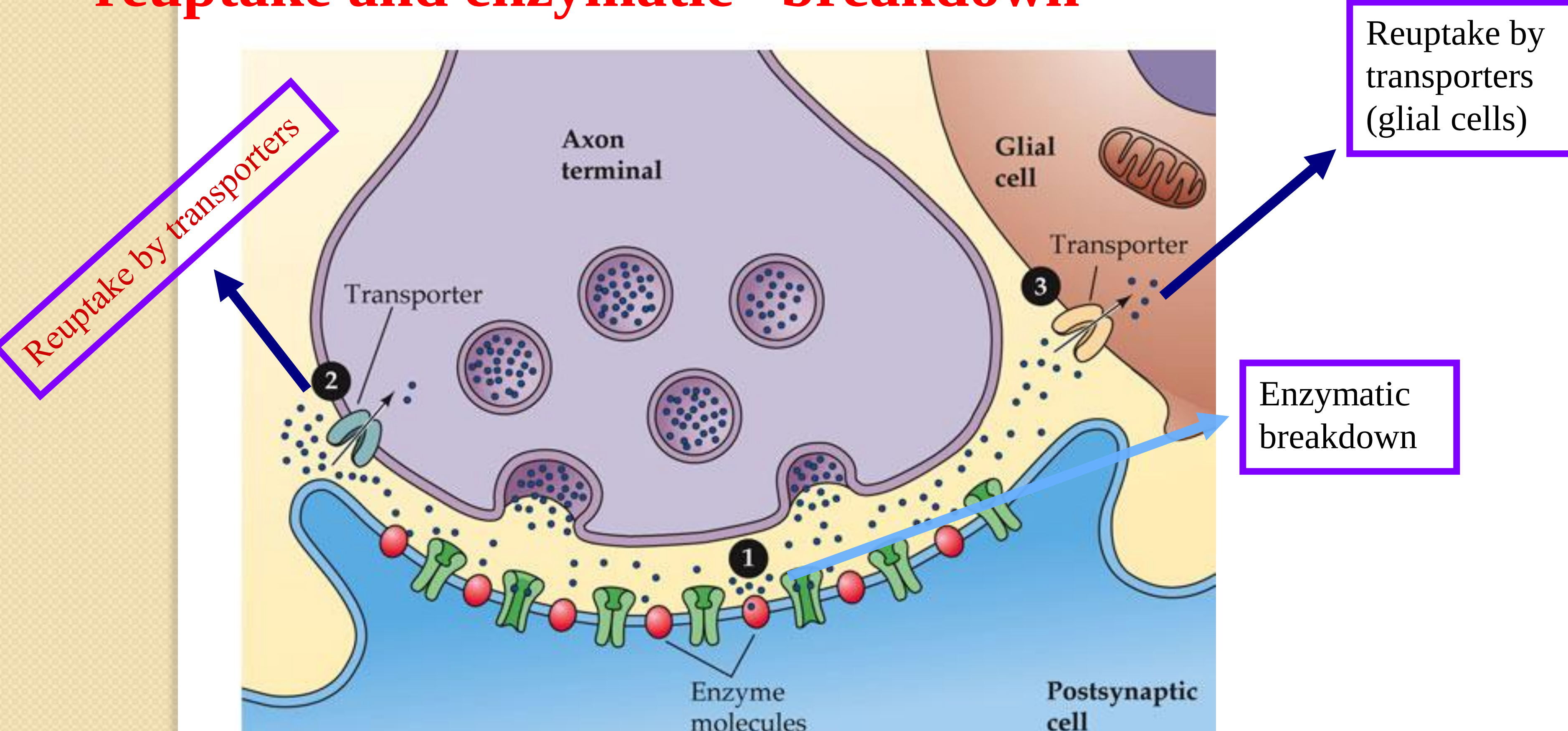
Comparison between Small Molecules and Neuropeptides Neurotramsmitters (NT)

- Small molecules NT are rapidly acting as compared to slowly acting neuropepides
- Neuron has only one NT but may have one or more NP
- Small molecules NT are have short lived action compared to prolonged time of action for neuropeptides
- Small molecules NT are excreted in larger amounts compared to smaller quantities of neuropeptide
- Small molecules NT vesicles are recycled but neuropeptide ones are not
- Neuropeptides are co-secreted with small molecules NT
- Neuropeptides are synthesized at the soma while small molecules could be formed at the presynaptic terminals

Removal of Neurotransmitter

- Diffusion
  - move down concentration gradient
- Enzymatic degradation
  - Acetylcholinesterase for (Ach), peptidases for neuropeptides
- Uptake by neurons or glia cells
  - neurotransmitter transporters
  - Prozac = serotonin reuptake inhibitor

- **Transmitter Inactivation: reuptake and enzymatic breakdown**



Neurotransmitter can be recycled in presynaptic terminal or can be broken down by enzymes within the cell

II Neurotransmitters and receptors

Basic Concepts of NT and receptor

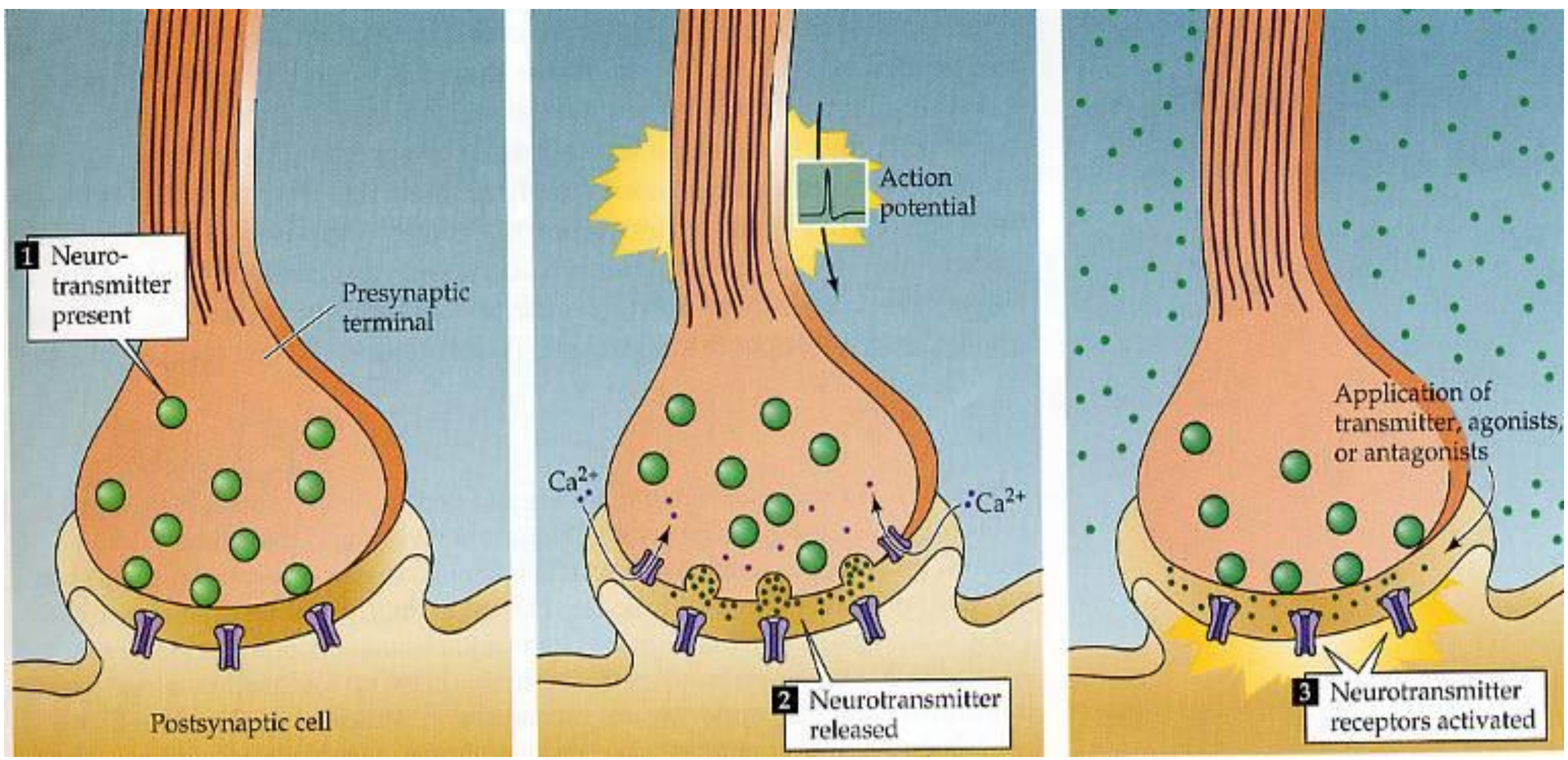
Neurotransmitter: Endogenous signaling molecules that alter the behaviour of neurons or effector cells.

Neuroreceptor: Proteins on the cell membrane or in the cytoplasm that could bind with specific neurotransmitters and alter the behavior of neurons of effector cells

- Vast array of molecules serve as neurotransmitters
- The properties of the transmitter do not determine its effects on the postsynaptic cells
- The properties of the **receptor** determine whether a transmitter is excitatory or inhibitory

A neurotransmitter must (classical definition)

- Be synthesized and released from neurons
- Be found at the presynaptic terminal
- Have same effect on target cell when applied externally
- Be blocked by same drugs that block synaptic transmission
- Be removed in a specific way



Agonist

A substance that mimics a specific neurotransmitter,

is able to attach to that neurotransmitter's receptor

and thereby produces the same action that the neurotransmitter usually produces.

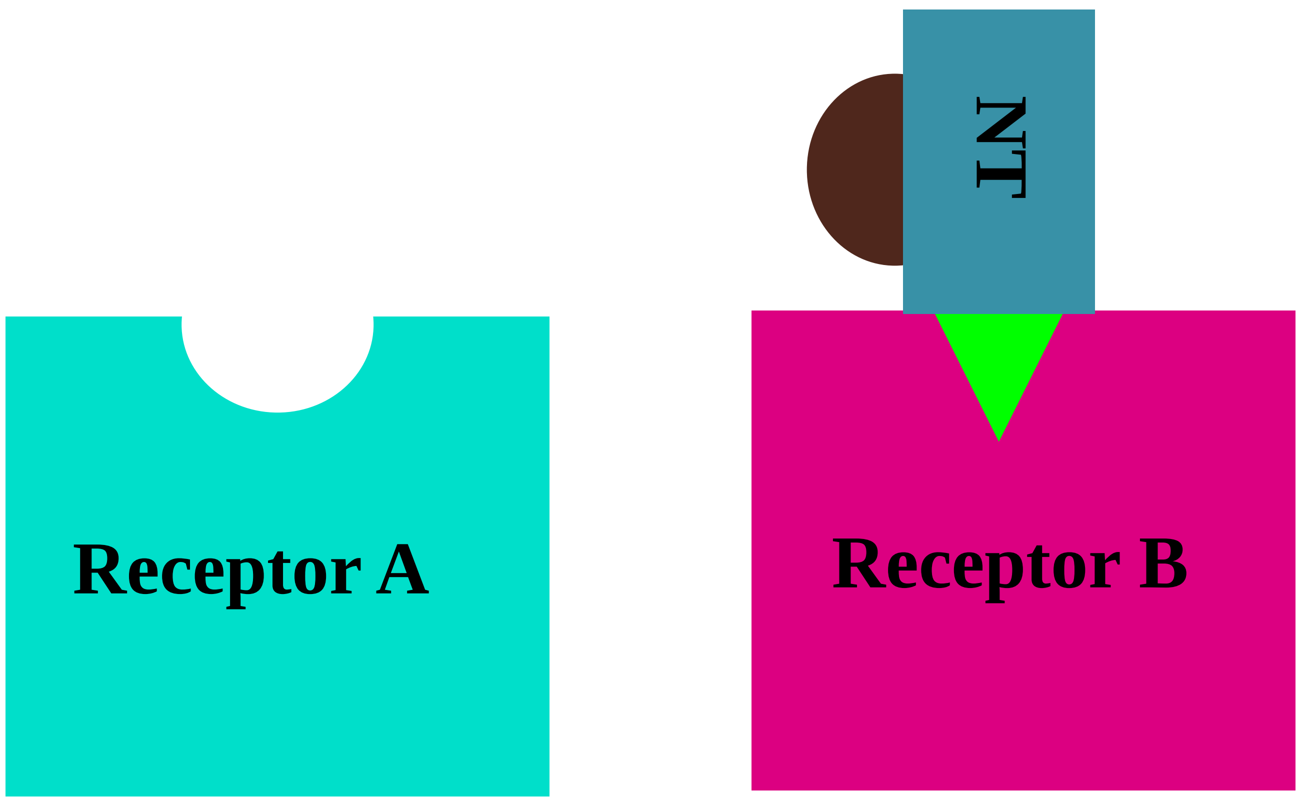
Drugs are often designed as receptor agonists to treat a variety of diseases and disorders when the original chemical substance is missing or depleted.

Antagonist

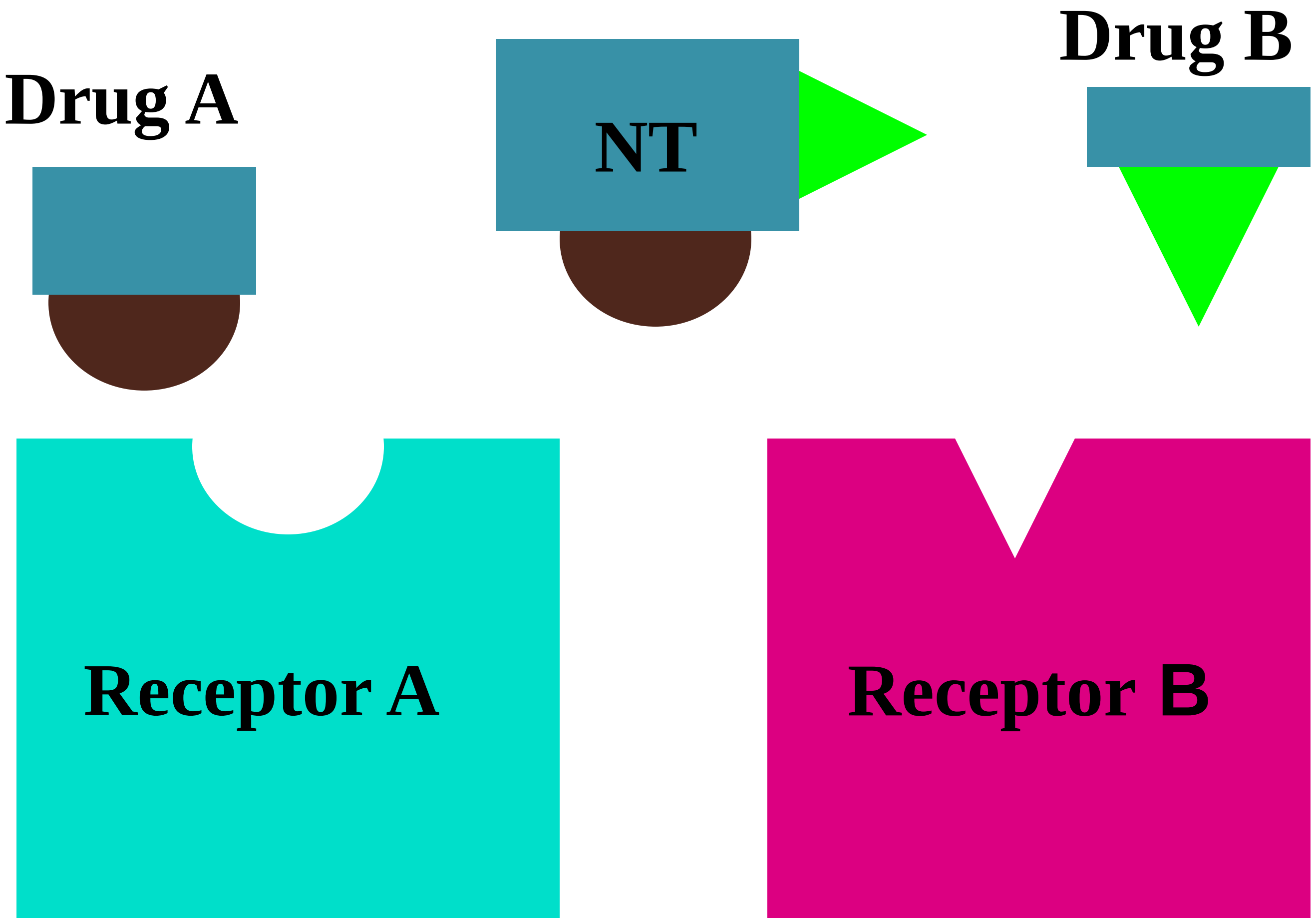
Drugs that bind to but do not activate neuroreceptors,

thereby blocking the actions of neurotransmitters or the neuroreceptor agonists.

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

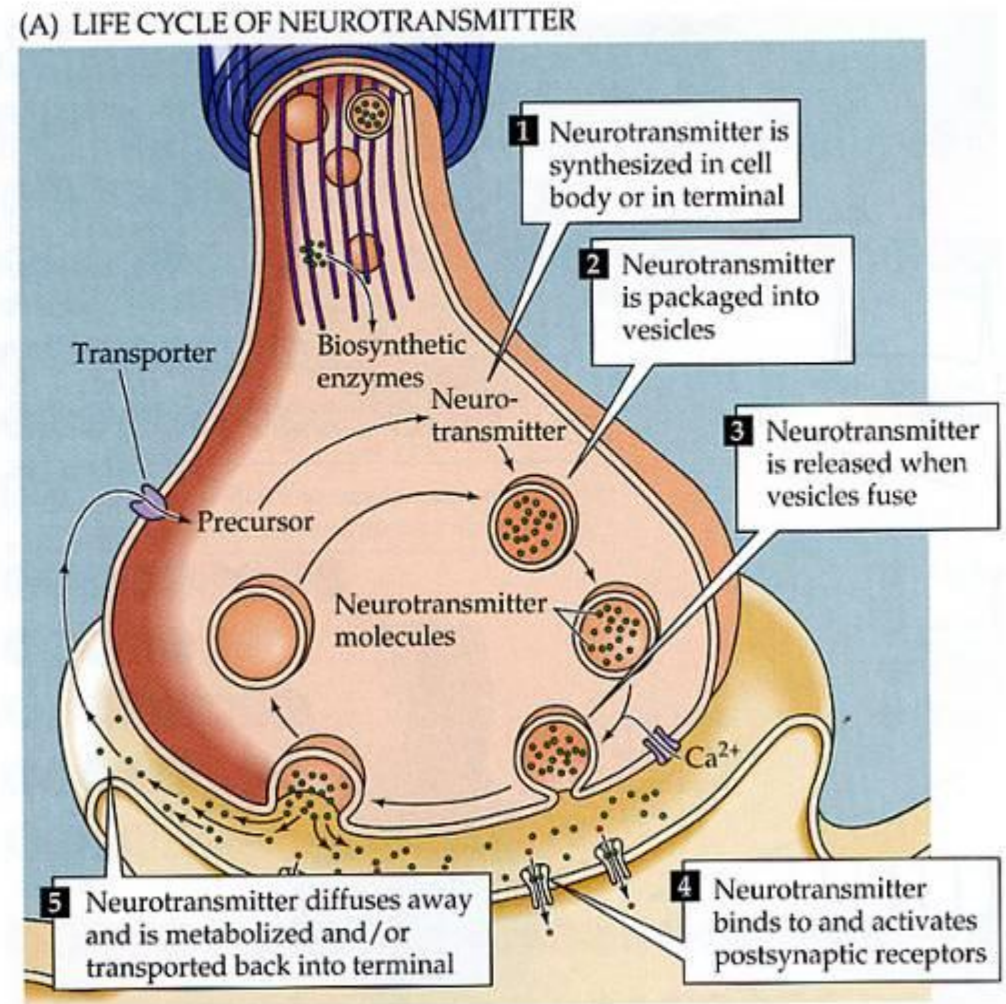


Specificity of drugs

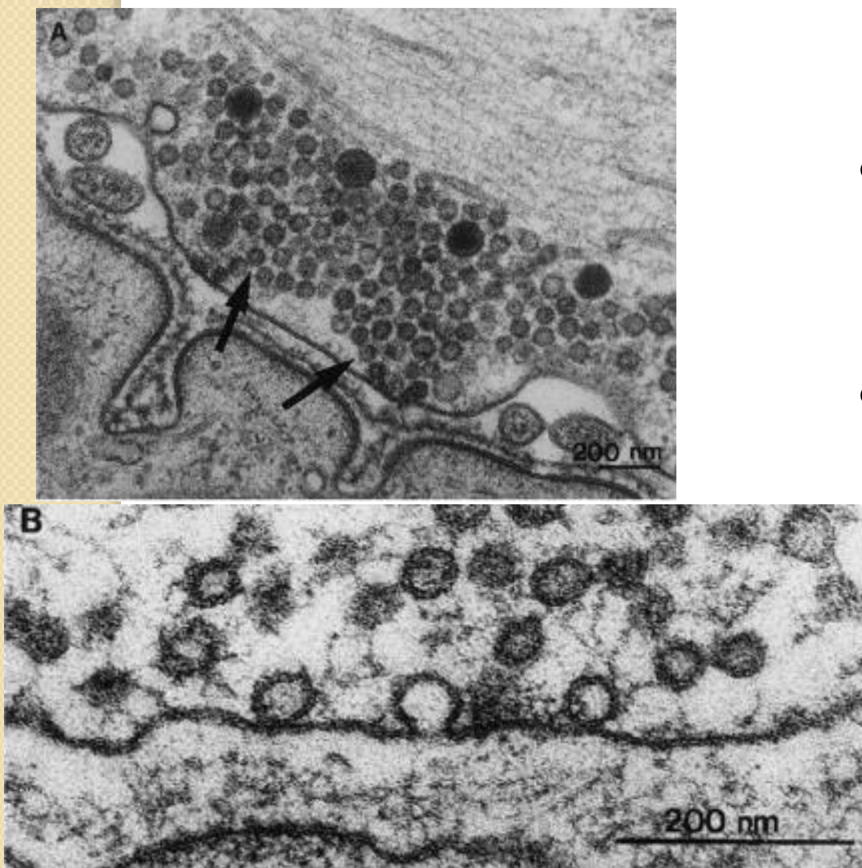


Five key steps in neurotransmission

- Synthesis
- Storage
- Release
- Receptor Binding
- Inactivation



Synaptic vesicles



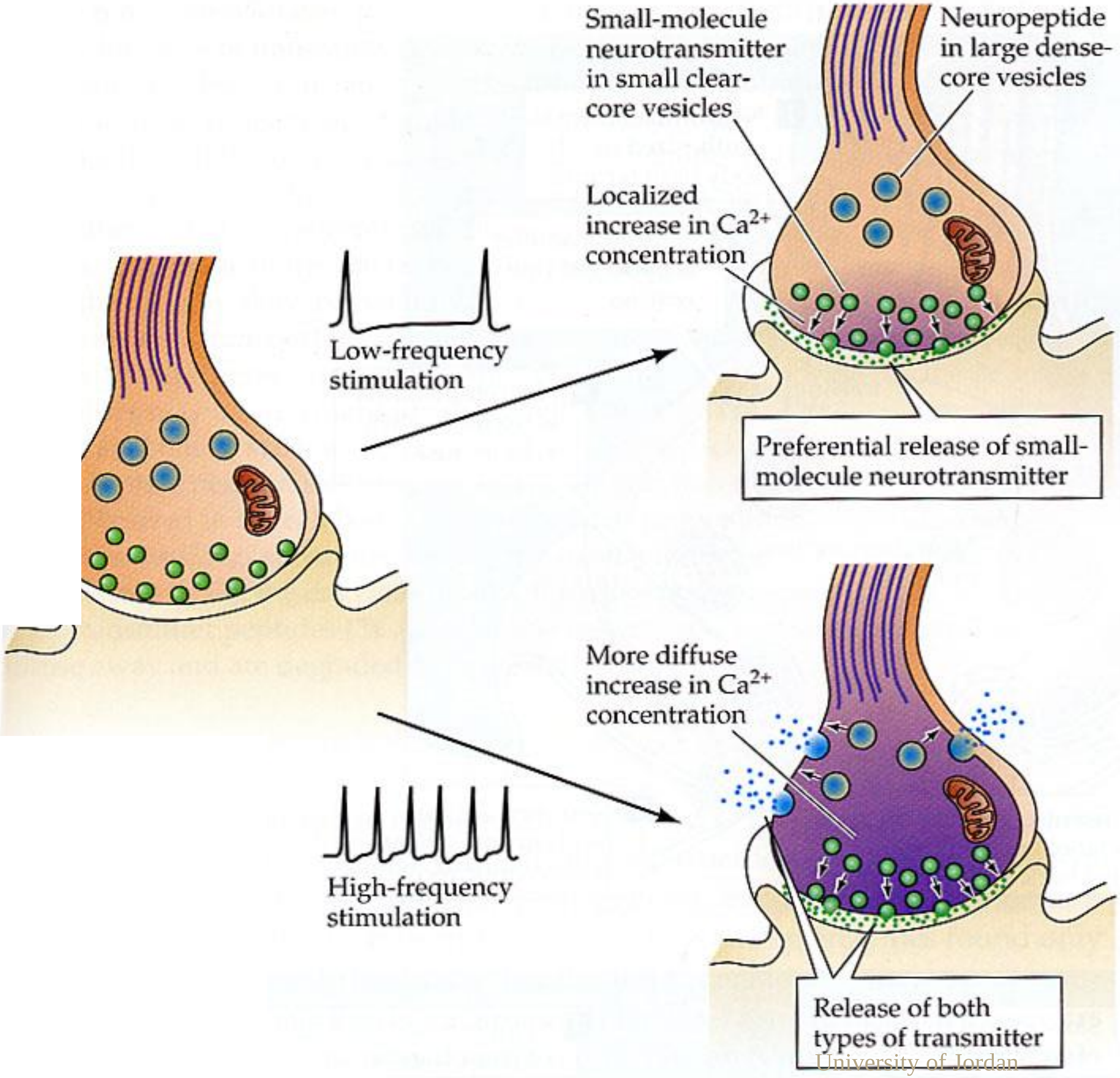
- Concentrate and protect transmitter
- Can be docked at active zone
- Differ for classical transmitters (small, clear-core) vs. neuropeptides (large, dense-core)

Neurotransmitter Co-existence (Dale principle)

Some neurons in both the PNS and CNS produce both a classical neurotransmitter (ACh or a catecholamine) and a polypeptide neurotransmitter.

They are contained in different synaptic vesicles that can be distinguished using the electron microscope.

The neuron can thus release either the classical neurotransmitter or the polypeptide neurotransmitter under different conditions.



Small-molecule neurotransmitter in small clear-core vesicles
Neuropeptide in large dense-core vesicles
Localized increase in Ca^{2+} concentration
Low-frequency stimulation
Preferential release of small-molecule neurotransmitter
More diffuse increase in Ca^{2+} concentration
High-frequency stimulation
Release of both types of transmitter

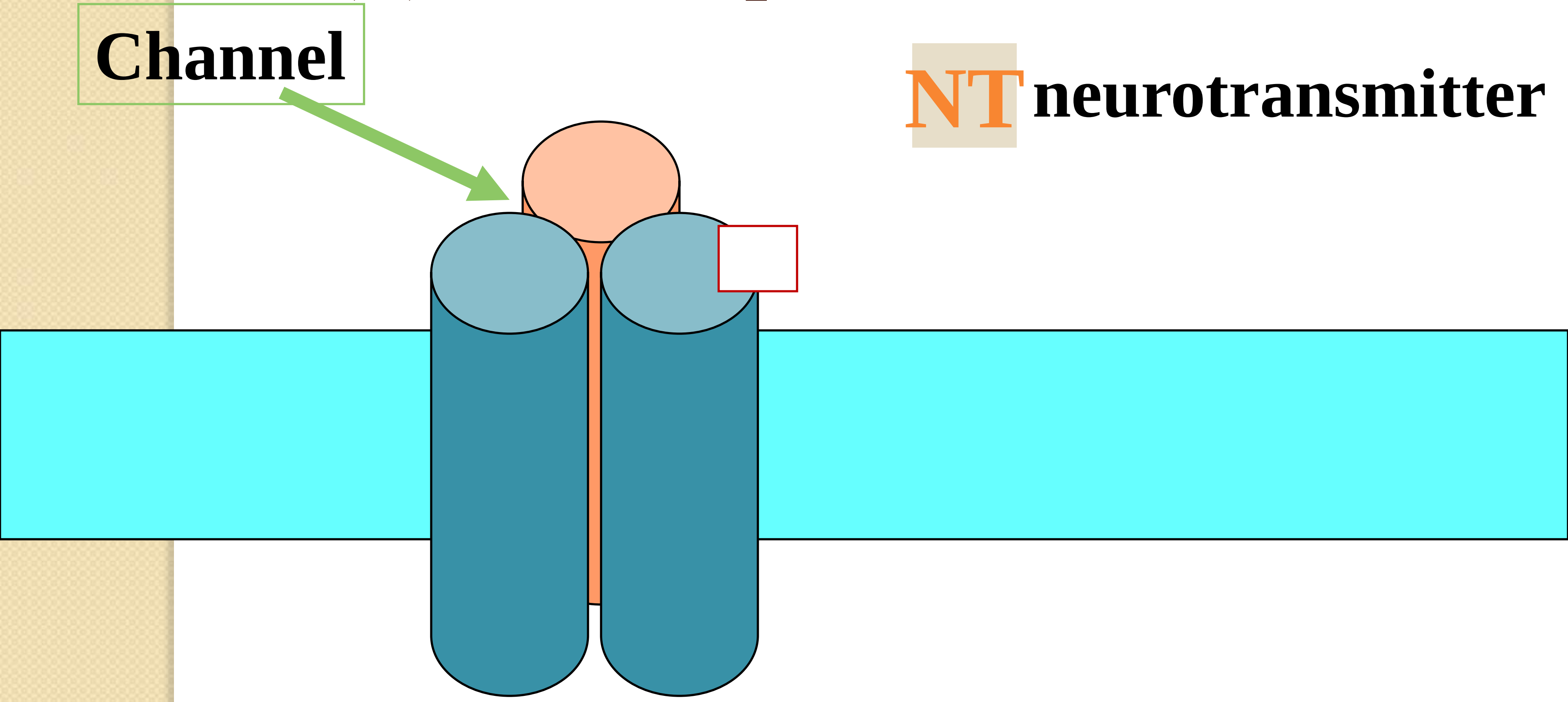
Receptors determine whether:

- Synapse is excitatory or inhibitory
  - NE is excitatory at some synapses, inhibitory at others
- Transmitter binding activates ion channel directly or indirectly.
  - Directly
    - ionotropic receptors
    - fast
  - Indirectly
    - metabotropic receptors
    - G-protein coupled
    - slow

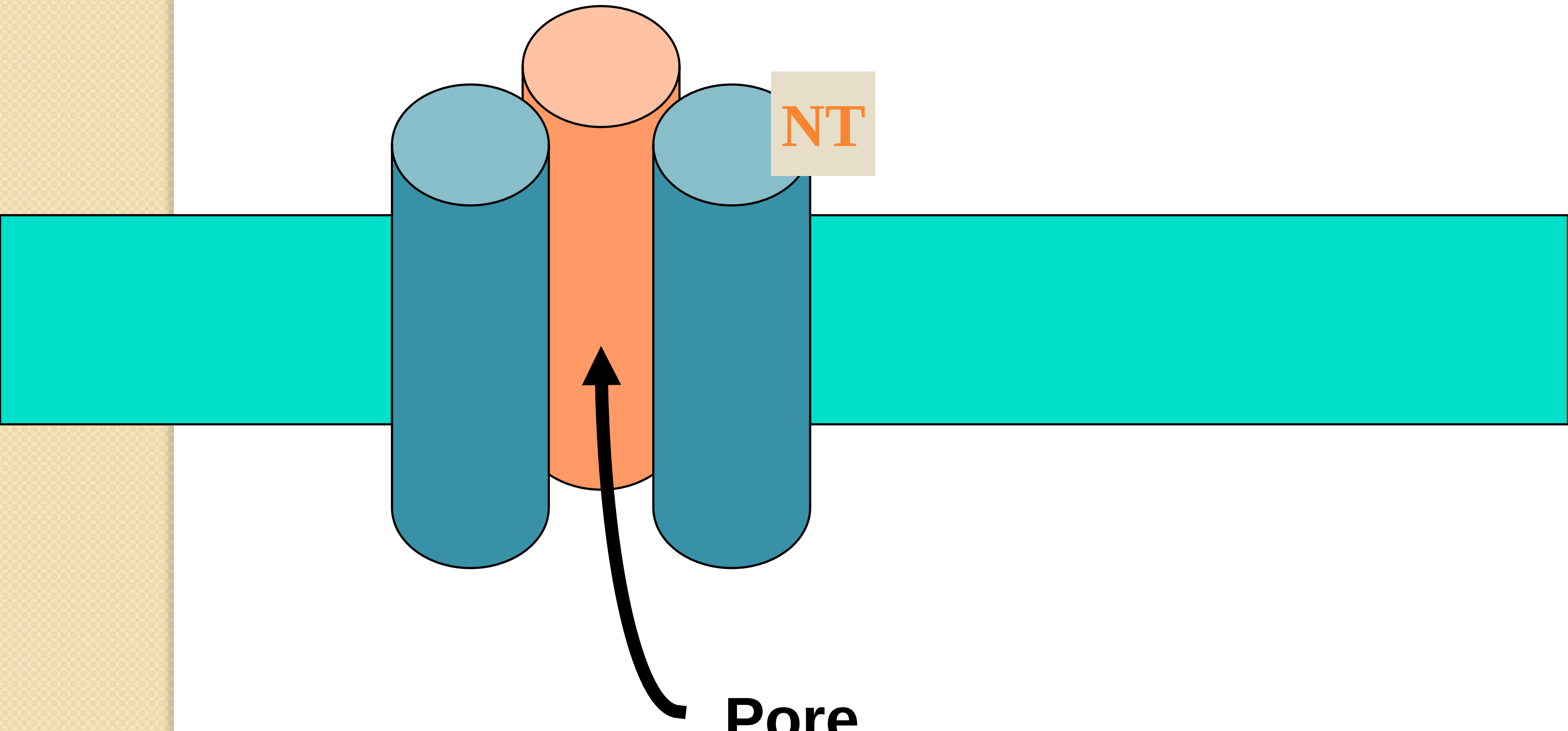
Receptor Activation

- Ionotropic channel
  - directly controls channel
  - fast
- Metabotropic channel
  - second messenger systems
  - receptor indirectly controls channel ~

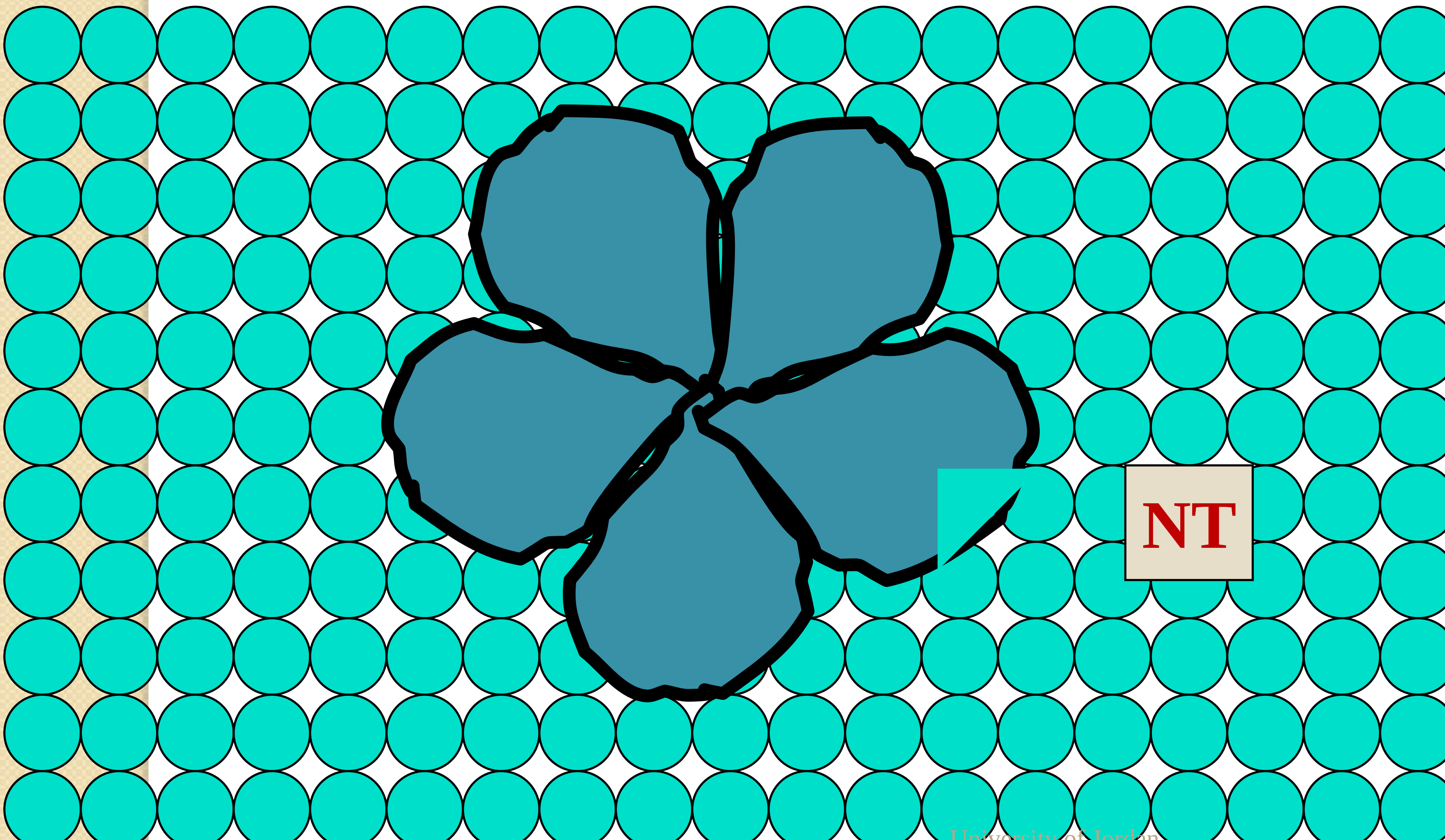
(1) Ionotropic Channels



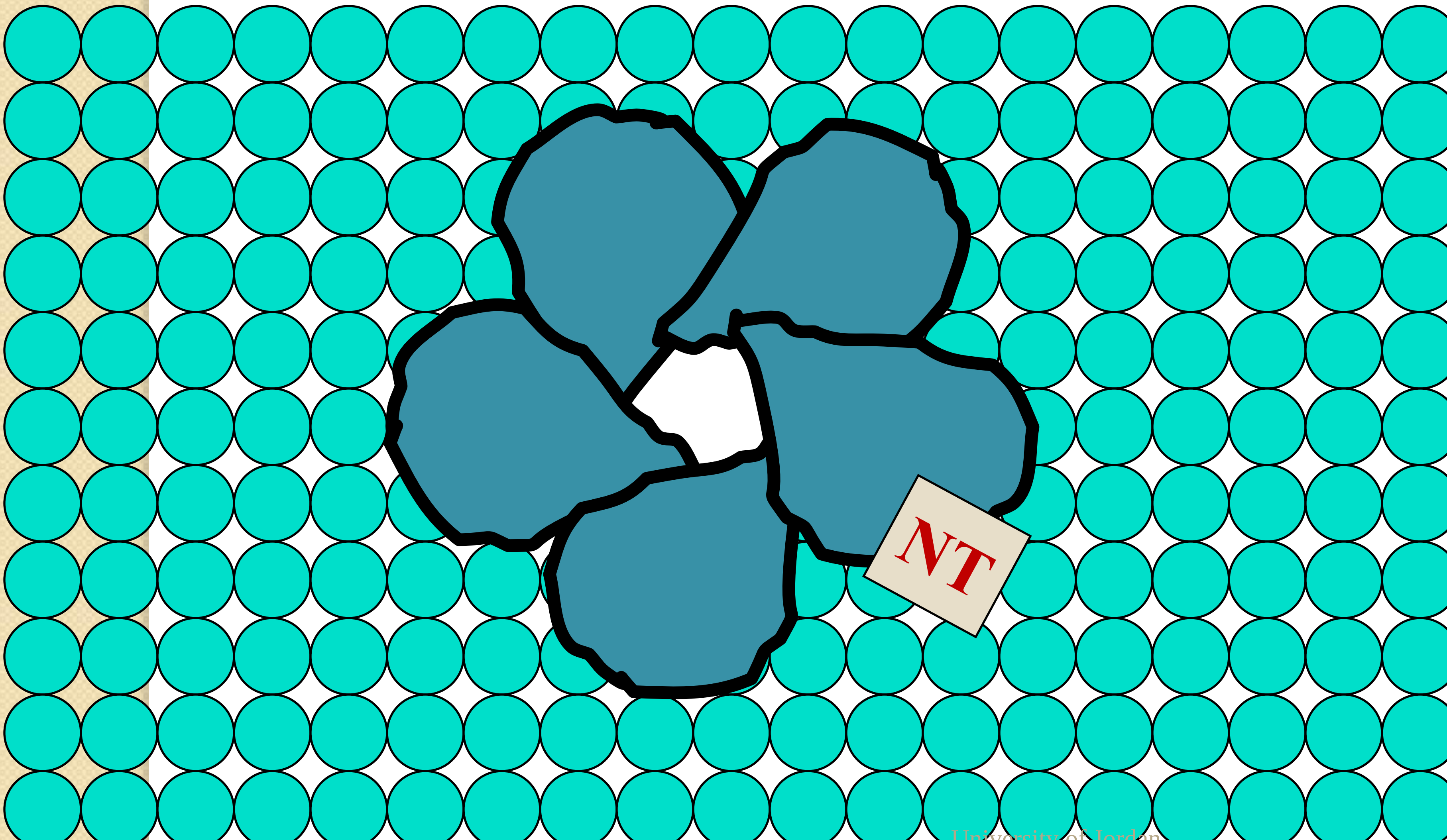
Ionotropic Channels



Ionotropic Channels



Ionotropic Channels



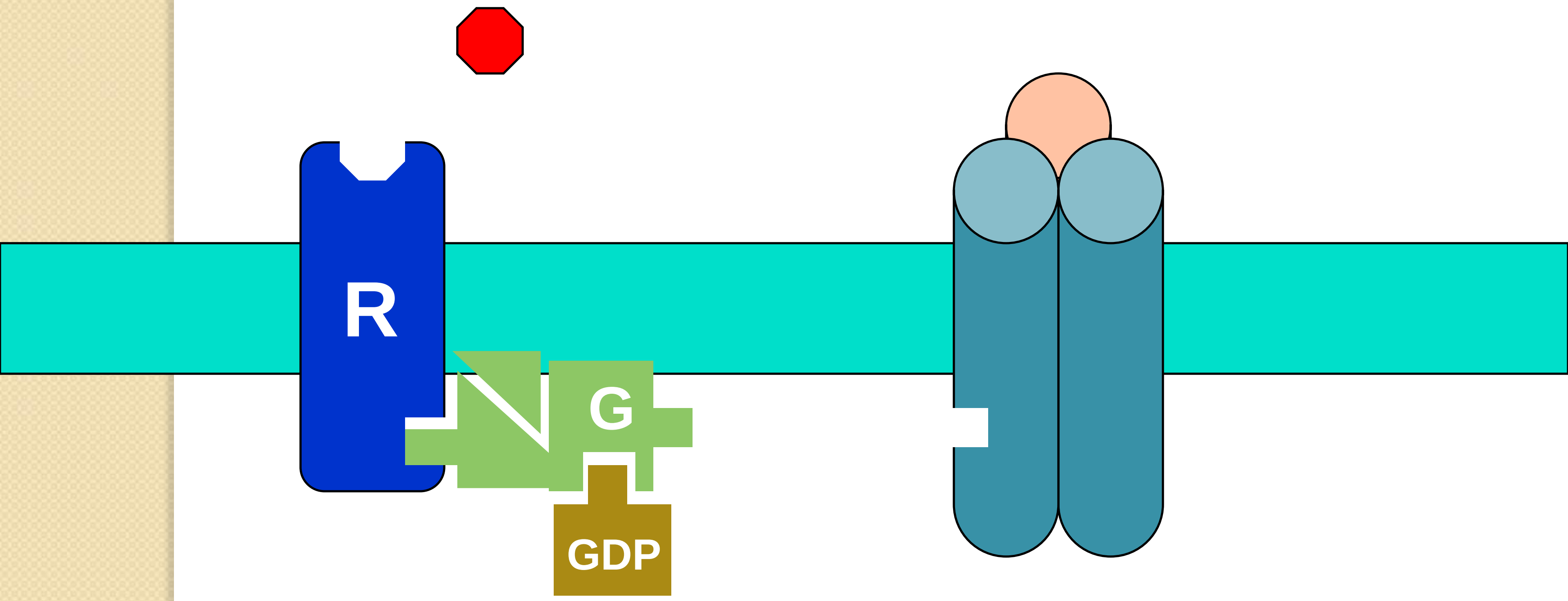
Metabotropic Channels

- Receptor separate from channel
- G proteins
- 2nd messenger system
  - cAMP
  - other types
- Effects
  - Control channel
  - Alter properties of receptors
  - regulation of gene expression ~

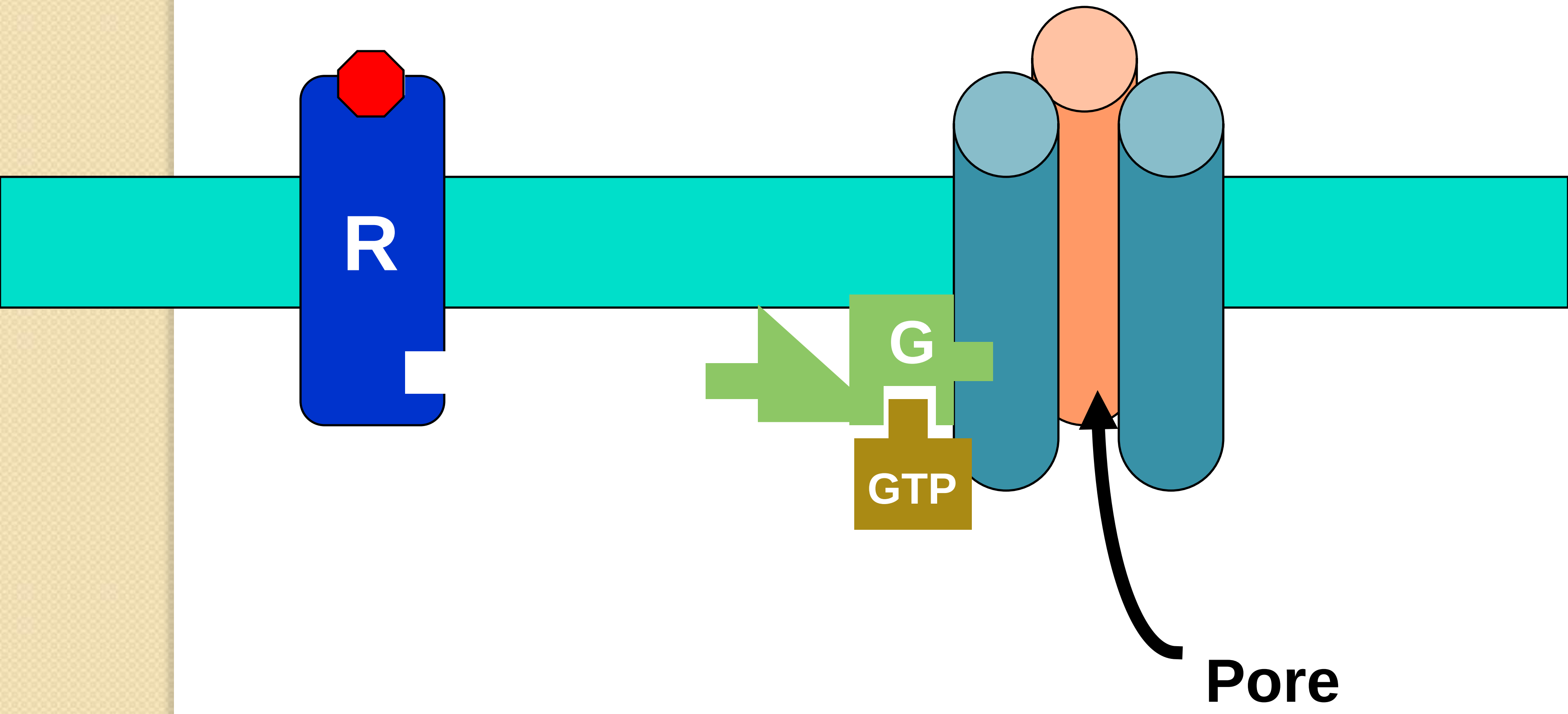
G protein: direct control

- NT is 1st messenger
- G protein binds to channel
  - opens or closes
  - relatively fast ~

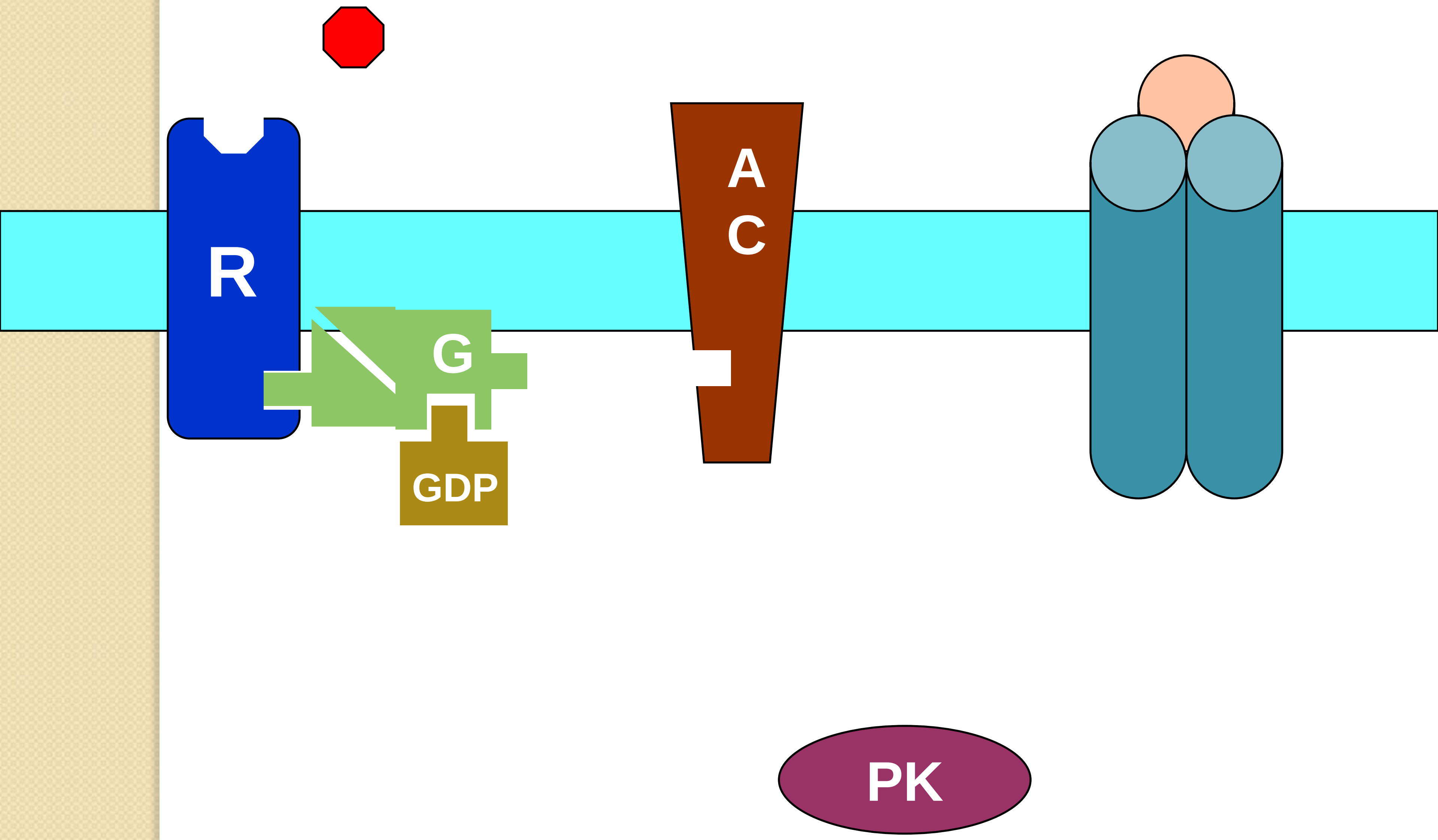
G protein: direct control



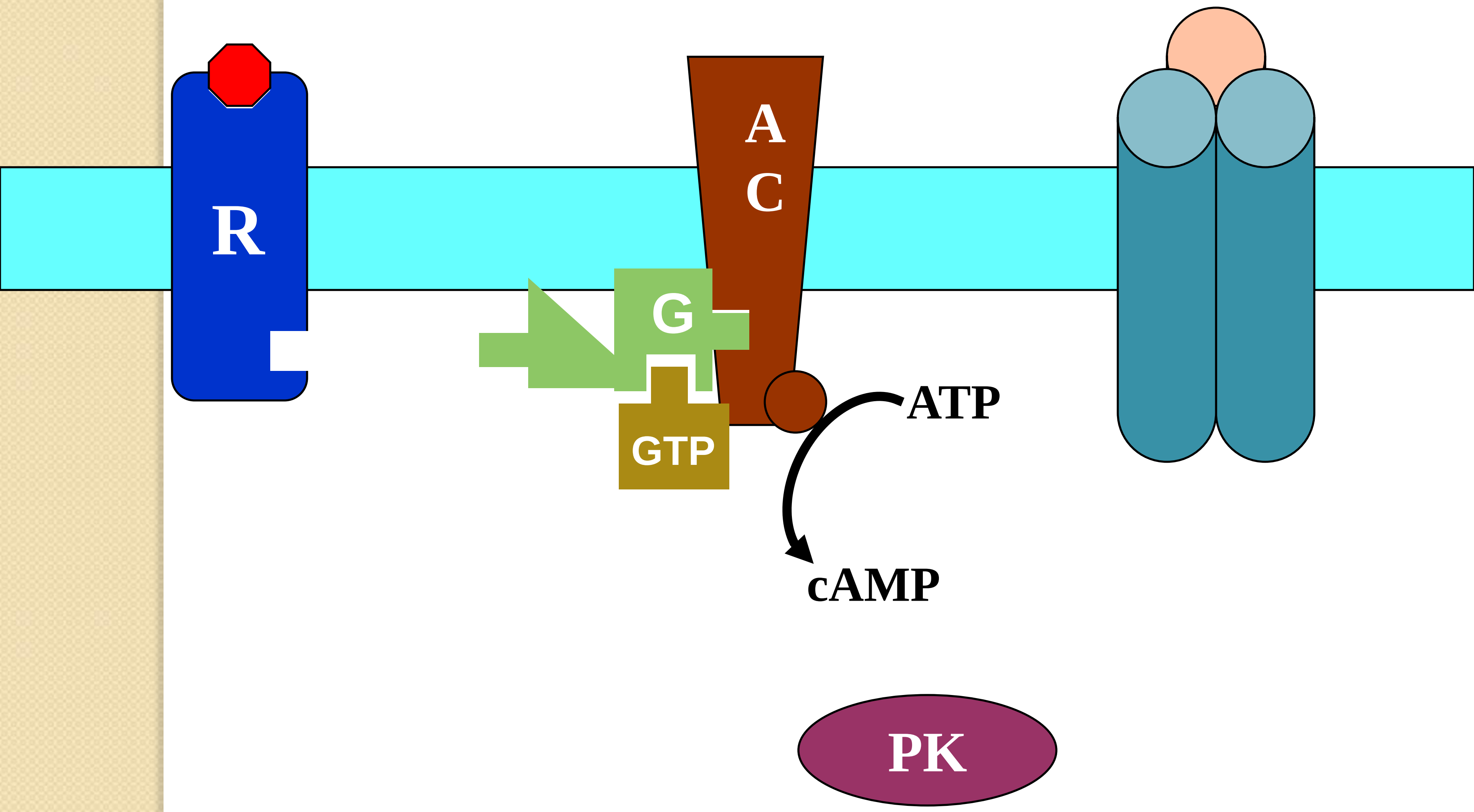
G protein: direct control



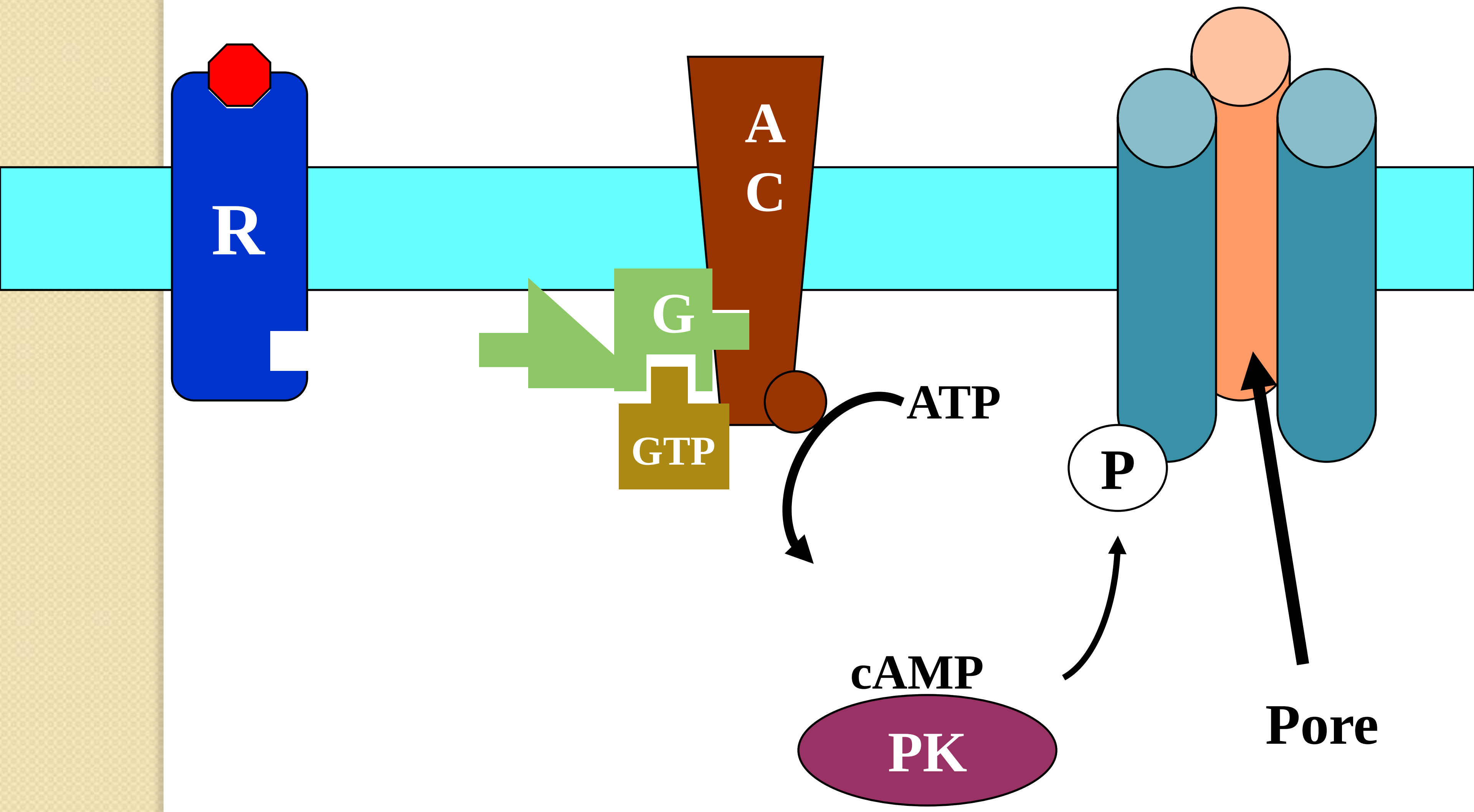
G protein: Protein Phosphorylation



G protein: Protein Phosphorylation

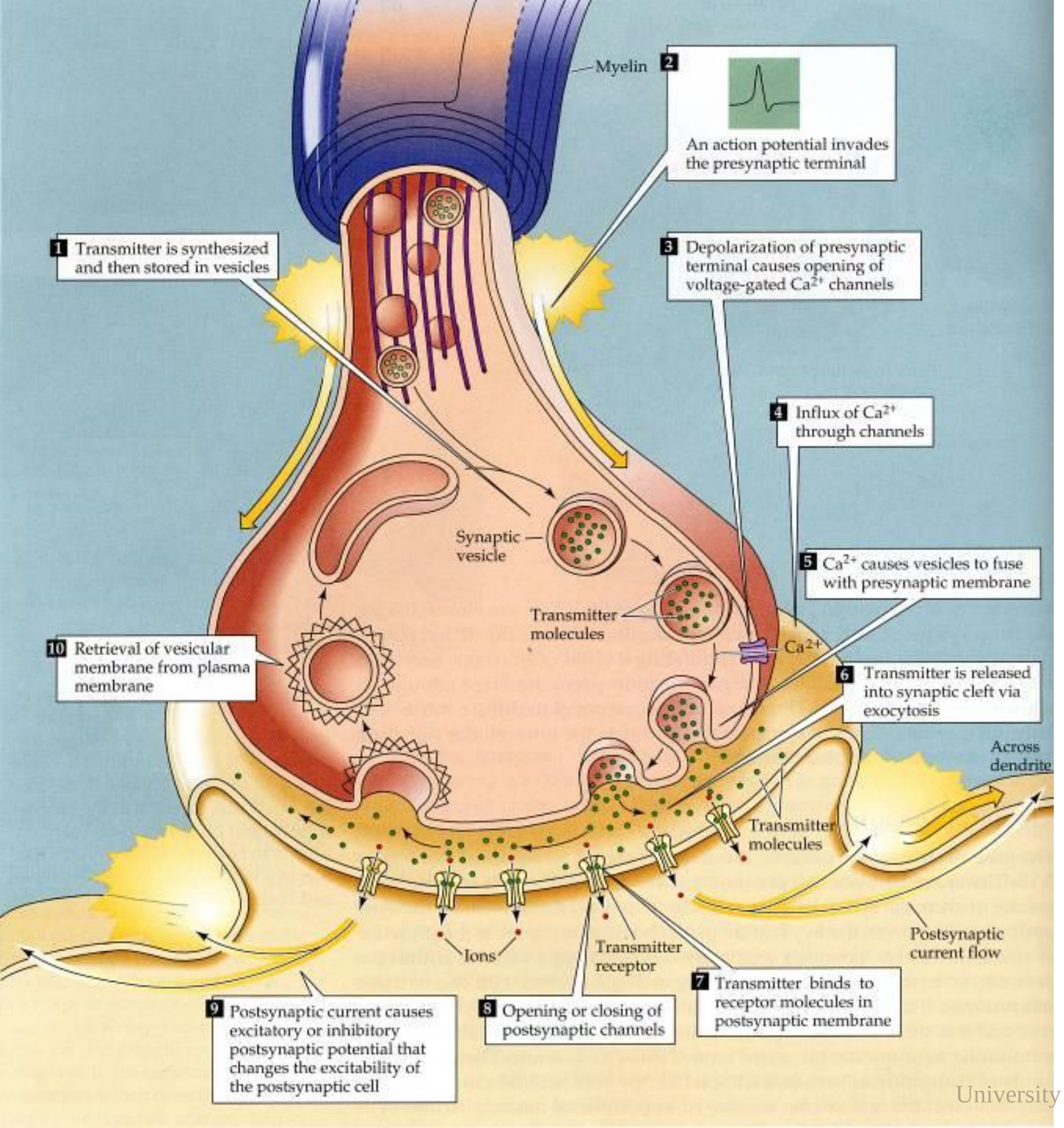


G protein: Protein Phosphorylation



Transmitter Inactivation

- Reuptake by presynaptic terminal
- Uptake by glial cells
- Enzymatic degradation
- Presynaptic receptor
- Diffusion
- Combination of above



Summary of Synaptic Transmission

Purves,2001


THANK YOU

Some Important Transmitters

(1) Acetylcholine (ACh) as NT

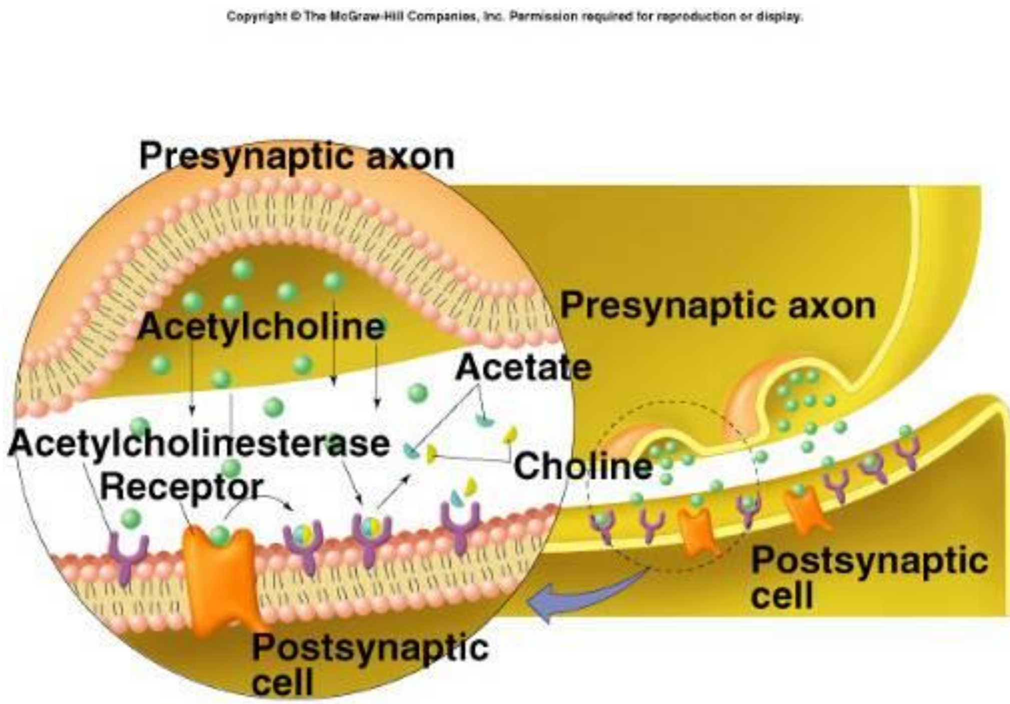
Acetylcholine Synthesis

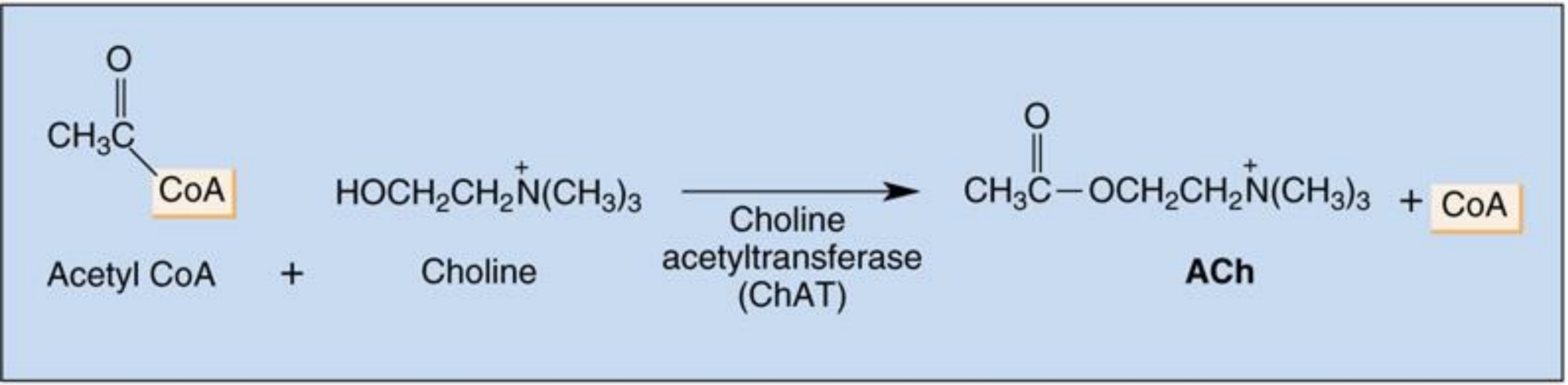
choline acetyltransferase

choline + acetyl CoA → ACh + CoA

Acetylcholinesterase (AChE)

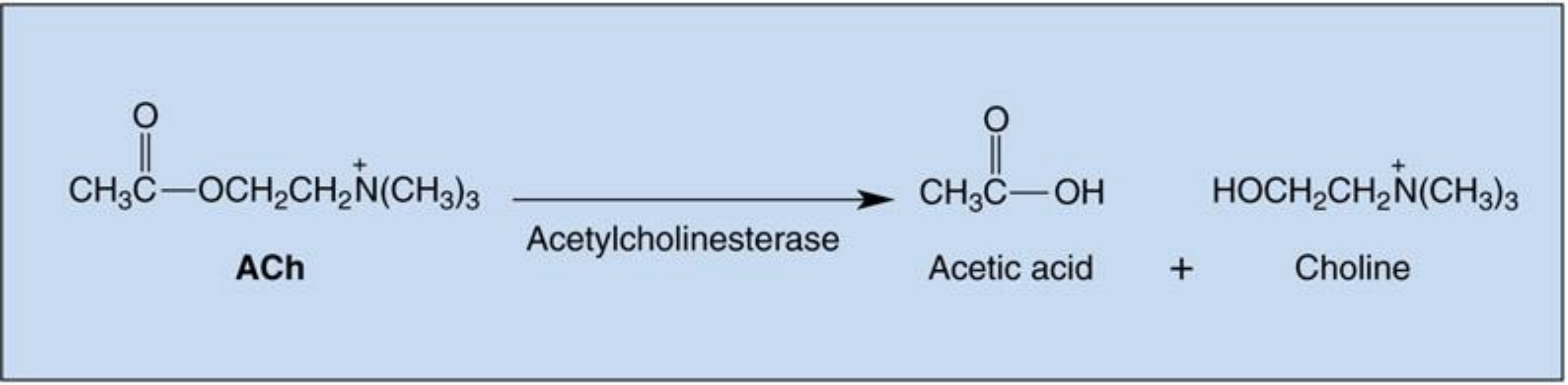
- Enzyme that inactivates ACh.
  - Present on postsynaptic membrane or immediately outside the membrane.
- Prevents continued stimulation.





Acetyl CoA
Choline
Choline acetyltransferase (ChAT)
ACh

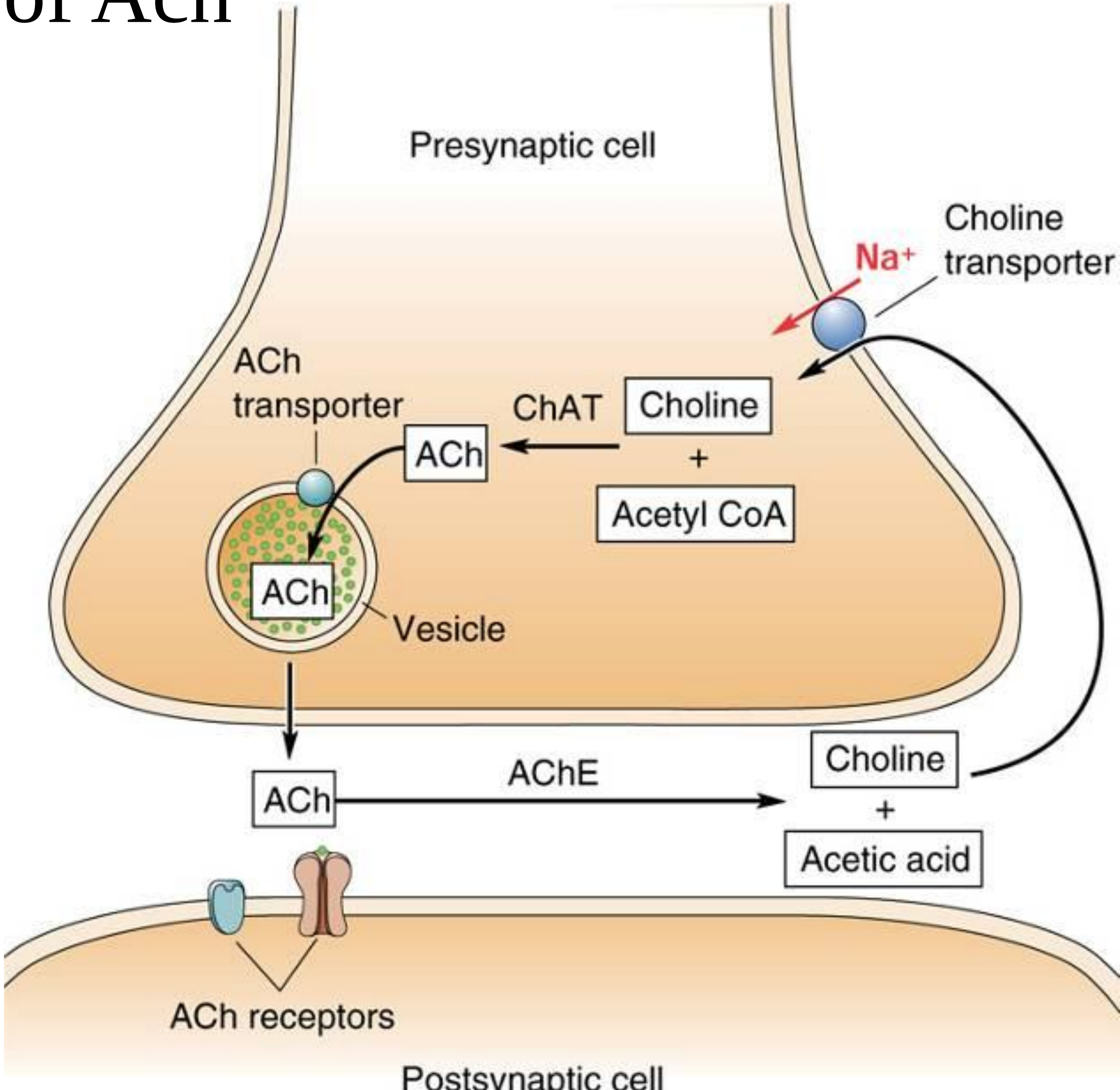
(a)



ACh
Acetylcholinesterase
Acetic acid
Choline

(b)

The Life Cycle of Ach



Ach - Distribution

- **Peripheral N.S.**
  - Excites somatic skeletal muscle (neuro-muscular junction)
  - Autonomic NS

    Ganglia

    Parasympathetic NS--- Neuroeffector junction

    Few sympathetic NS – Neuroeffector junction
- Central N.S. - widespread

    Hippocampus

    Hypothalamus ~

Ach Receptors

- ACh is both an excitatory and inhibitory NT, depending on organ involved.
  - Causes the opening of chemical gated ion channels.
- Nicotinic ACh receptors:
  - Found in autonomic ganglia (N_1) and skeletal muscle fibers (N_2).
- Muscarinic ACh receptors:
  - Found in the plasma membrane of smooth and cardiac muscle cells, and in cells of particular glands .

Acetylcholine Neurotransmission

- “Nicotinic” subtype Receptor:
  - Membrane Channel for Na^+ and K^+
  - Opens on ligand binding
  - Depolarization of target (neuron, muscle)
  - Stimulated by Nicotine, etc.
  - Blocked by Curare, etc.
  - Motor endplate (somatic) (N_2),
  - all autonomic ganglia, hormone producing cells of adrenal medulla (N_1)

Acetylcholine Neurotransmission

- “Muscarinic” subtype Receptor: M_1
  - Use of signal transduction system
    - Phospholipase C, IP_3, DAG, cytosolic Ca^{++}
  - Effect on target: cell specific (heart ↓, smooth muscle intestine ↑)
  - Blocked by Atropine, etc.
  - All parasympathetic target organs
  - Some *sympathetic* targets (endocrine sweat glands, skeletal muscle blood vessels - dilation)

Acetylcholine Neurotransmission

- "Muscarinic" subtype: M_2
  - Use of signal transduction system
    - via G-proteins, opens K^+ channels, decrease in cAMP levels
  - Effect on target: cell specific
  - CNS
  - Stimulated by ?
  - Blocked by Atropine, etc.

Cholinergic Agonists

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

Cholinergic Antagonists

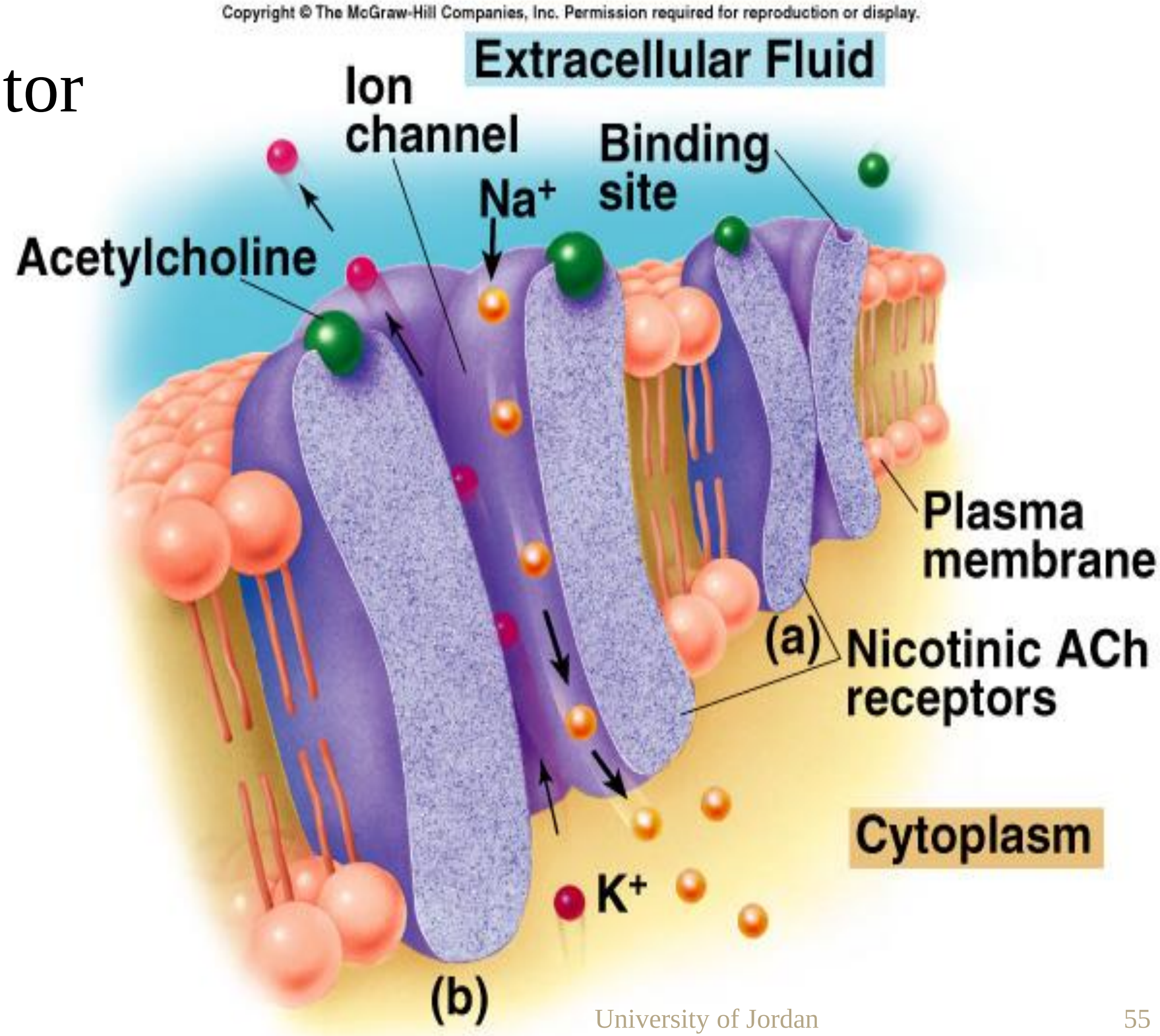
- Direct

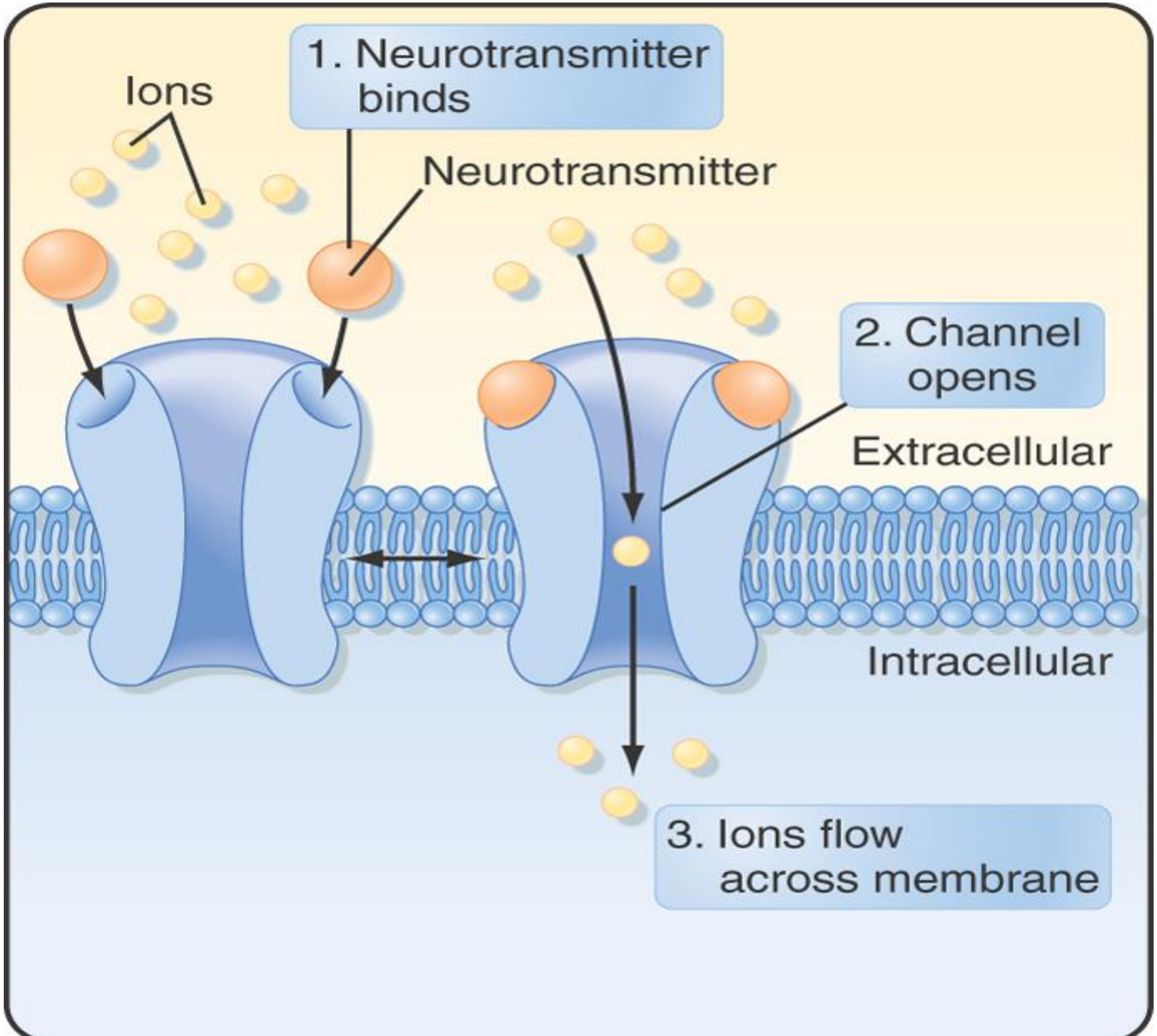
    Nicotinic - Curare

    Muscarinic - Atropine

Ligand-Operated ACh Channels

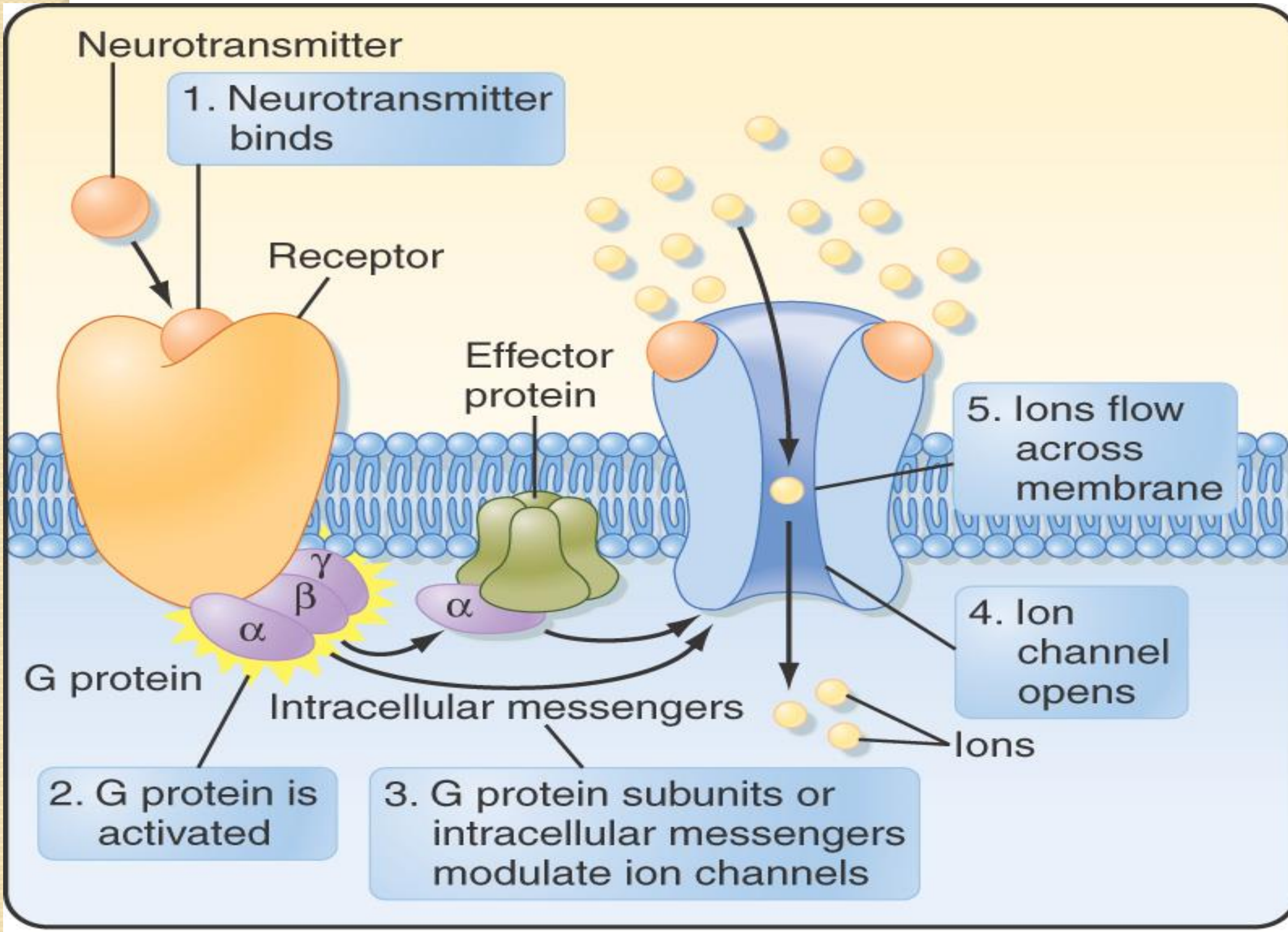
N Receptor





A Ligand-gated ion channels (ionotropic)

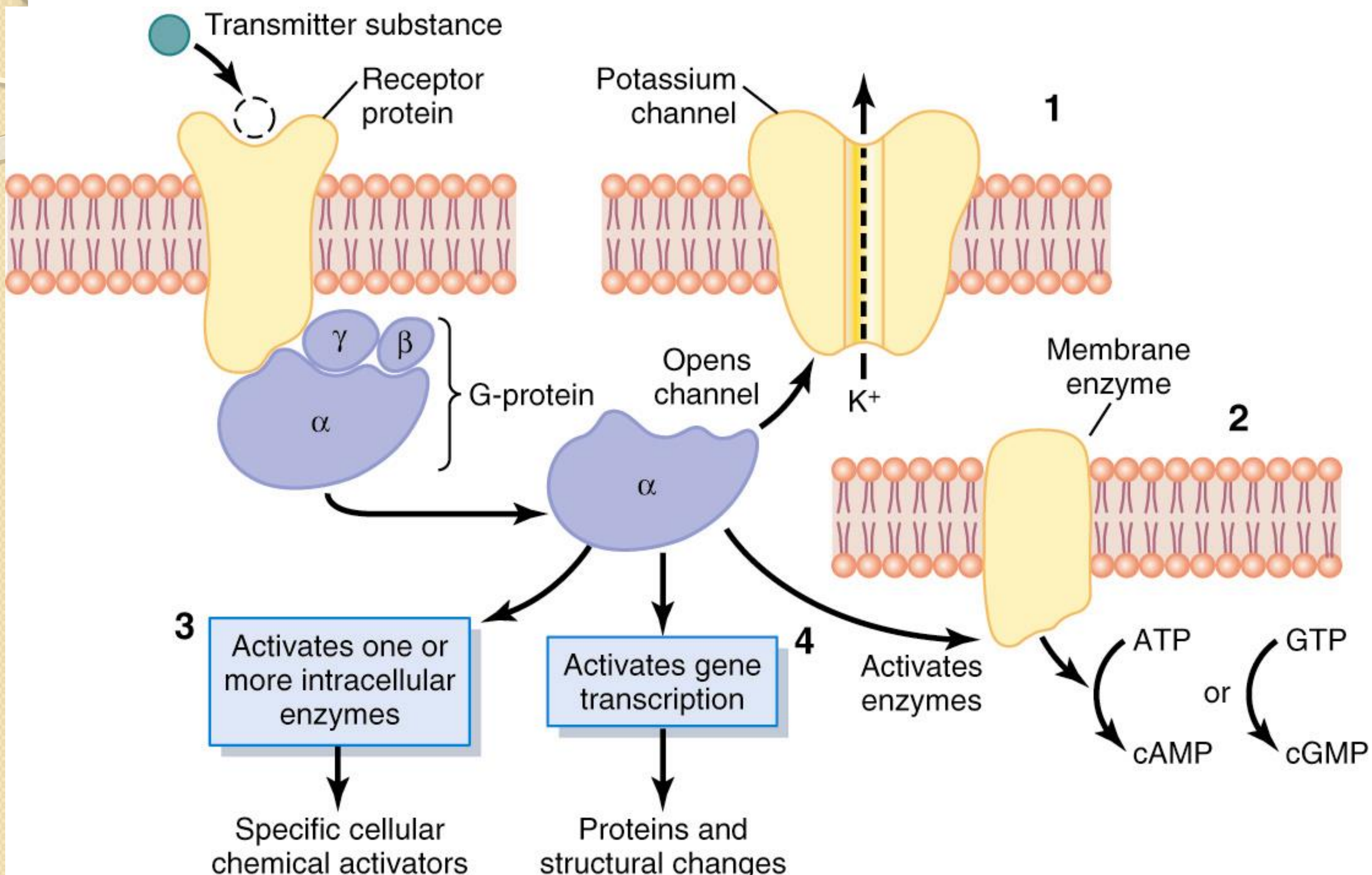
(Purves D, Augustine GJ, Fitzpatrick D, Neuroscience, 2nd ed. Sunderland, MA, Sinaver Associates, 2001.)



B G protein–coupled receptors (metabotropic)

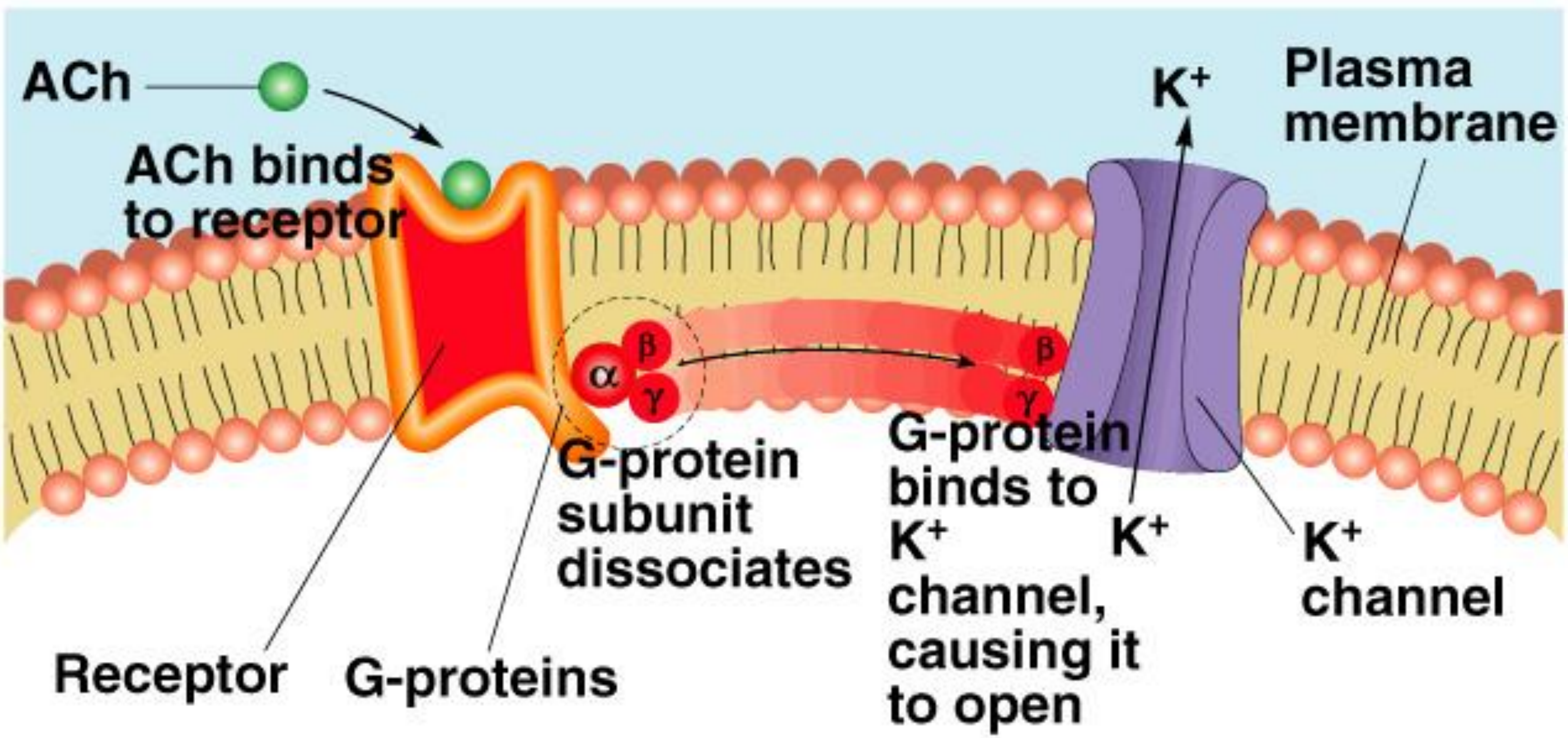
(Purves D, Augustine GJ, Fitzpatrick D, Neuroscience, 2nd ed. Sunderland, MA, Sinaver Associates, 2001.)

Neurotransmitter "Second Messenger" System



G Protein-Operated ACh Channel

M receptor



(2) Monoamines as NT

Monoamines

- Catecholamines –

Dopamine - DA

Norepinephrine - NE

Epinephrine - E

- Indolamines -

Serotonin - 5-HT

Synthesis of Monoamine NT

Tyrosine

↓ *tyrosine hydroxylase*

L-Dopa

↓ *dopa decarboxylase*

Dopaminergic Neurons — **Dopamine**

↓ *dopamine β-hydroxylase*

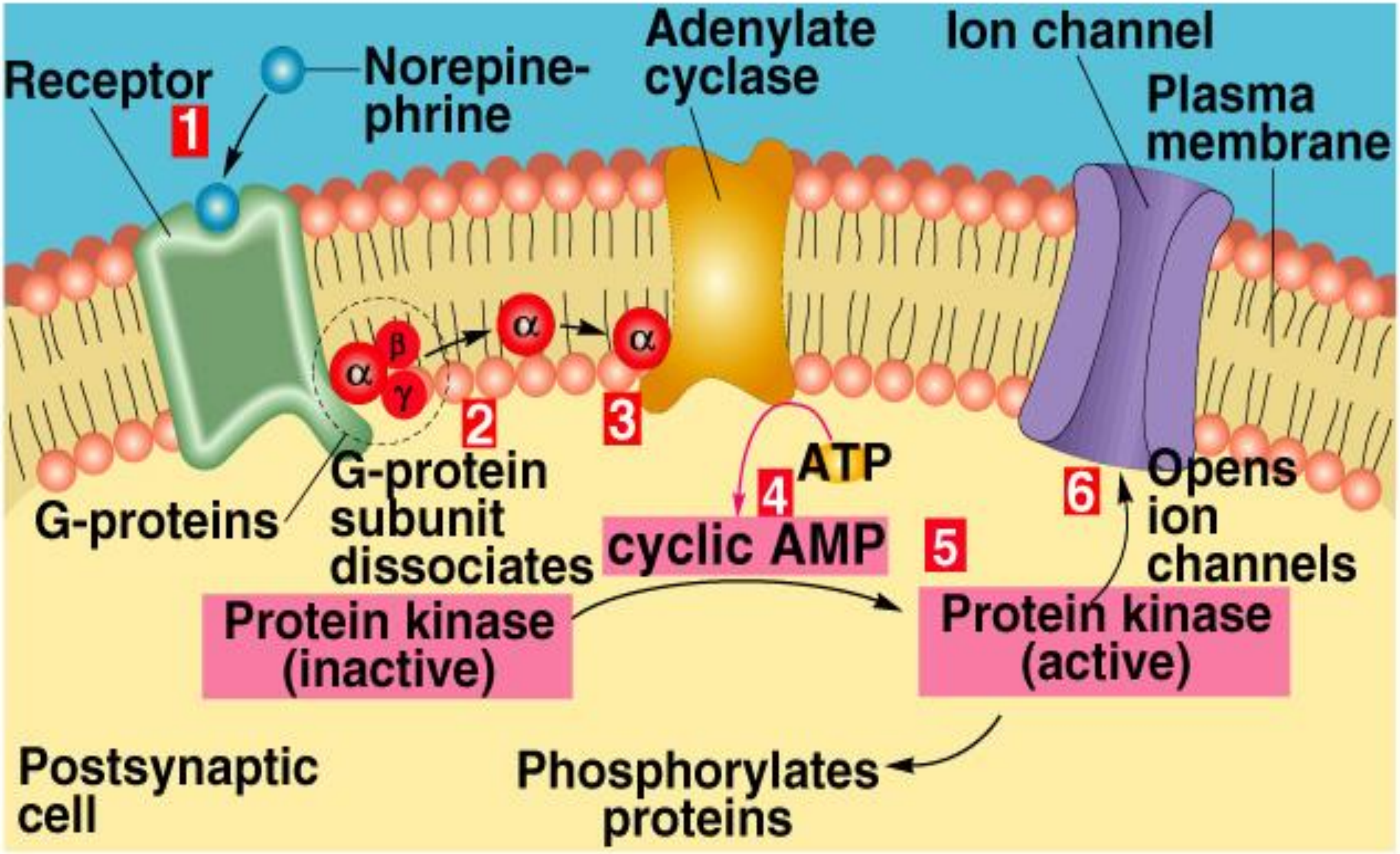
Adrenergic Neurons — **Norepinephrine**

↓ *phenylethanolamine-N-methyltransferase*

Epinephrine

Adrenal Glands

Mechanism of Action (β receptor)



Norepinephrine (NE) as NT

- NT in both PNS and CNS.
- PNS:
  - Smooth muscles, cardiac muscle and glands.
    - Increase in blood pressure, constriction of arteries.
- CNS:
  - General behavior.

Adrenergic Receptors

α_1	α_2	β
$(\alpha_{1a}, \alpha_{1b}, \alpha_{1d})$	$(\alpha_{2a}, \alpha_{2b}, \alpha_{2c})$	$(\beta_1, \beta_2, \beta_3)$
$G_{q/11}$	G_i	G_s
increase $[Ca^{2+}]_i$	inhibit adenylyl cyclase	stimulate adenylyl cyclase

Adrenergic Neurotransmission

- α_1 Receptor
  - Stimulated by NE, E,
  - blood vessels of skin, mucosa, abdominal viscera, kidneys, salivary glands
  - vasoconstriction, sphincter constriction, pupil dilation

Adrenergic Neurotransmission

- α_2 Receptor
  - stimulated by, NE, E, ...
  - Membrane of adrenergic axon terminals (pre-synaptic receptors), platelets
  - inhibition of NE release (autoreceptor),
  - promotes blood clotting, pancreas decreased insulin secretion

Adrenergic Neurotransmission

- β_1 receptor
  - stimulated by E, ….
  - Mainly heart muscle cells,
  - increased heart rate and strength

Adrenergic Neurotransmission

- β_2 receptor
  - stimulated by E ..
  - Lungs, most other sympathetic organs, blood vessels serving the heart (coronary vessels),
  - dilation of bronchioles & blood vessels (coronary vessels), relaxation of smooth muscle in GI tract and pregnant uterus

Adrenergic Neurotransmission

- β_3 receptor
  – stimulated by E, ….
  – Adipose tissue,
  – stimulation of lipolysis

(3) Amino Acids as NT

- Glutamate acid and aspartate acid:
  - Excitatory Amino Acid (EAA)
- Gamma-amino-butyric acid (GABA) and glycine:
  - Inhibitory AA

(4) Polypeptides as NT

- CCK: (cholecystokinin)
  - Promote satiety following meals.
- Substance P:
  - Major NT in sensations of pain.

(5) Monoxide Gas: NO and CO

- Nitric Oxide (NO)
  - Exerts its effects by stimulation of cGMP.
  - Involved in memory and learning.
  - Smooth muscle relaxation.
- Carbon monoxide (CO):
  - Stimulate production of cGMP within neurons.
  - Promotes odor adaptation in olfactory neurons.
  - May be involved in neuroendocrine regulation in hypothalamus.


THANK YOU

Sensory Receptors; Neuronal Circuits For Processing Information

Faisal I. Mohammed, MD, PhD

Objectives

- Define receptors (Transducers) and classify them
- Describe the generator (receptor) potential and its importance in sensory coding
- List the types of somatic receptors in the skin
- Explain the mechanism of sensory coding
- Interpret the mechanism of receptor adaptation and classify the types of receptors accordingly (Phasic and Tonic receptors)
- Describe sensory neuronal processing and its functional importance

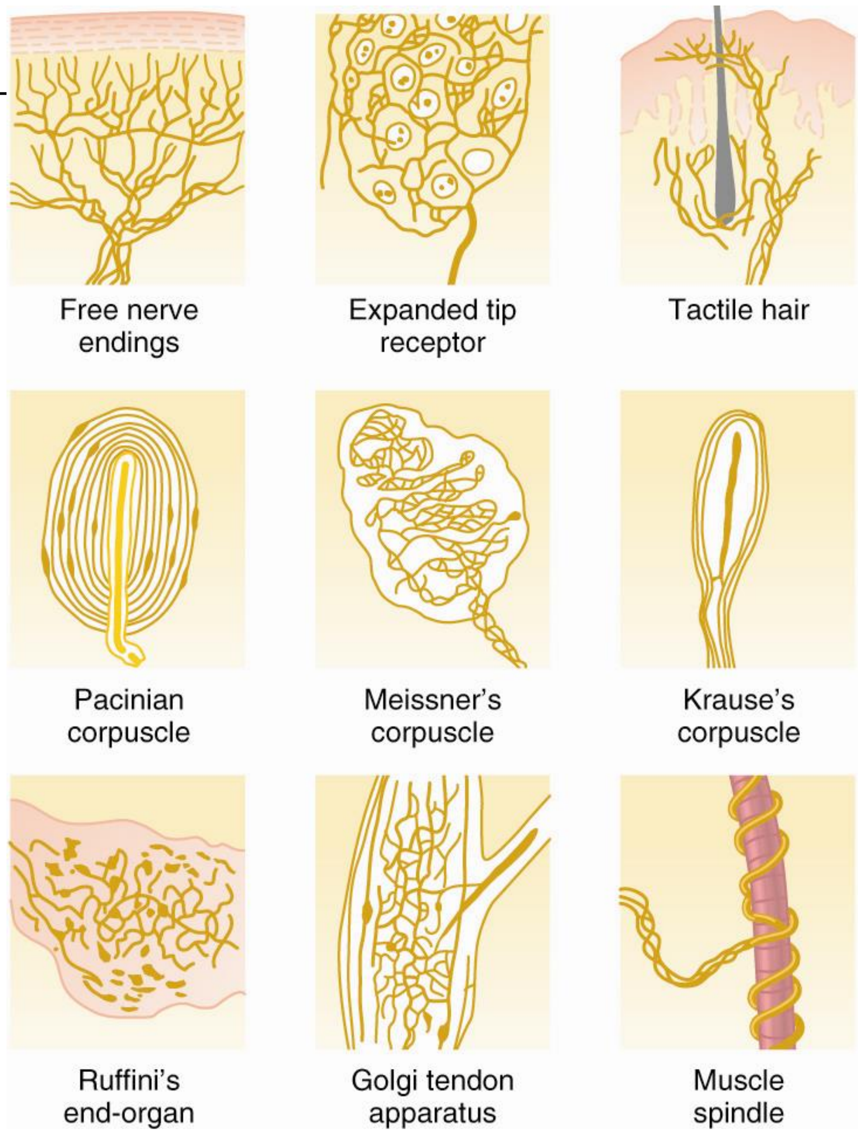
Types of Sensory Receptors: Classification by Modality (Stimulus they transduce)

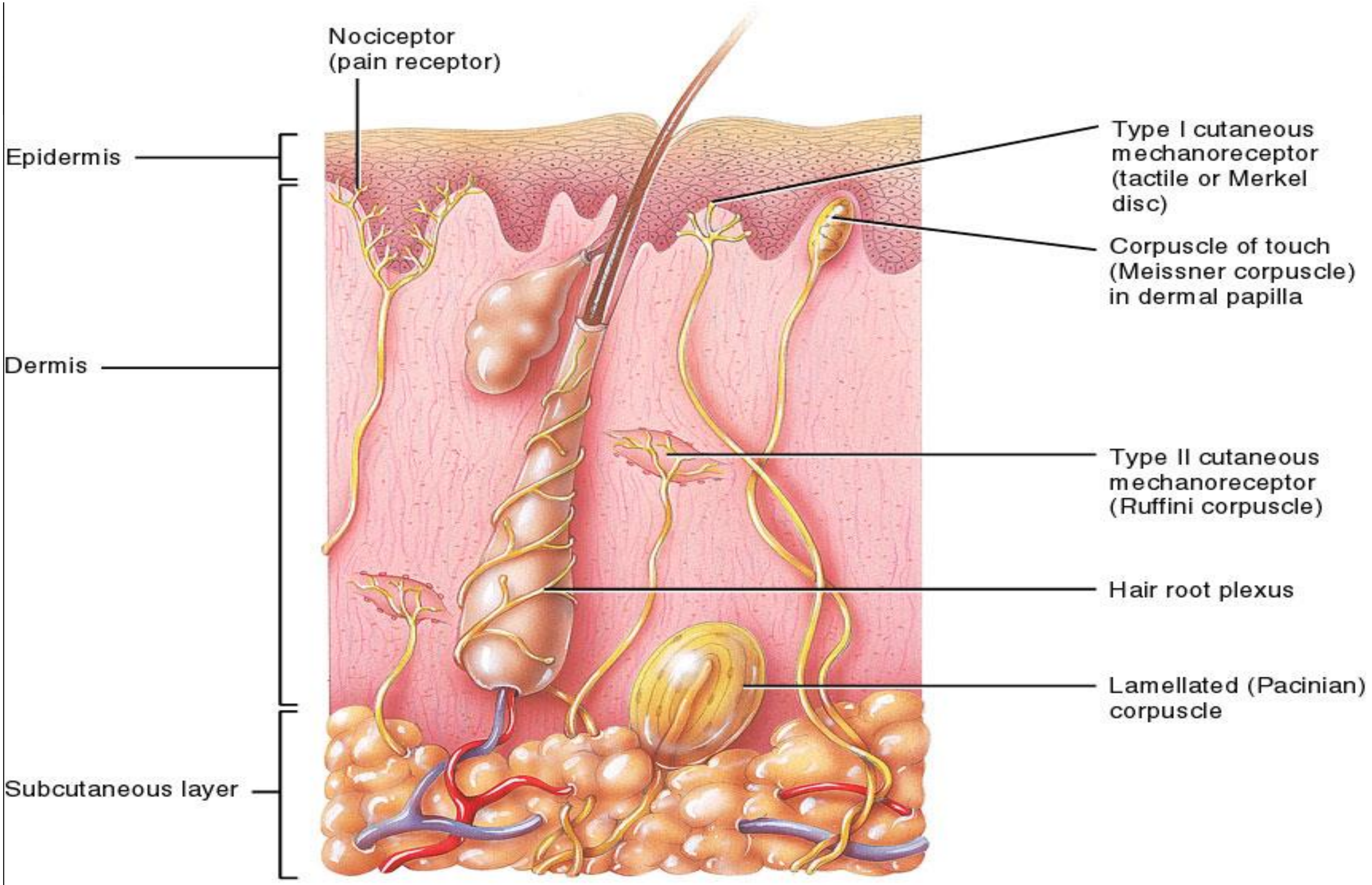
- Mechanoreceptors
  - detect deformation, Touch and Prssure
- Thermoreceptors
  - detect change in temperature
- Nociceptors
  - detect tissue damage (pain receptors)
- Electromagnetic (Photoreceptors)
  - detect light (Rods and Cones)
- Chemoreceptors
  - taste, smell, CO_2, O_2, etc.

Classification by Location

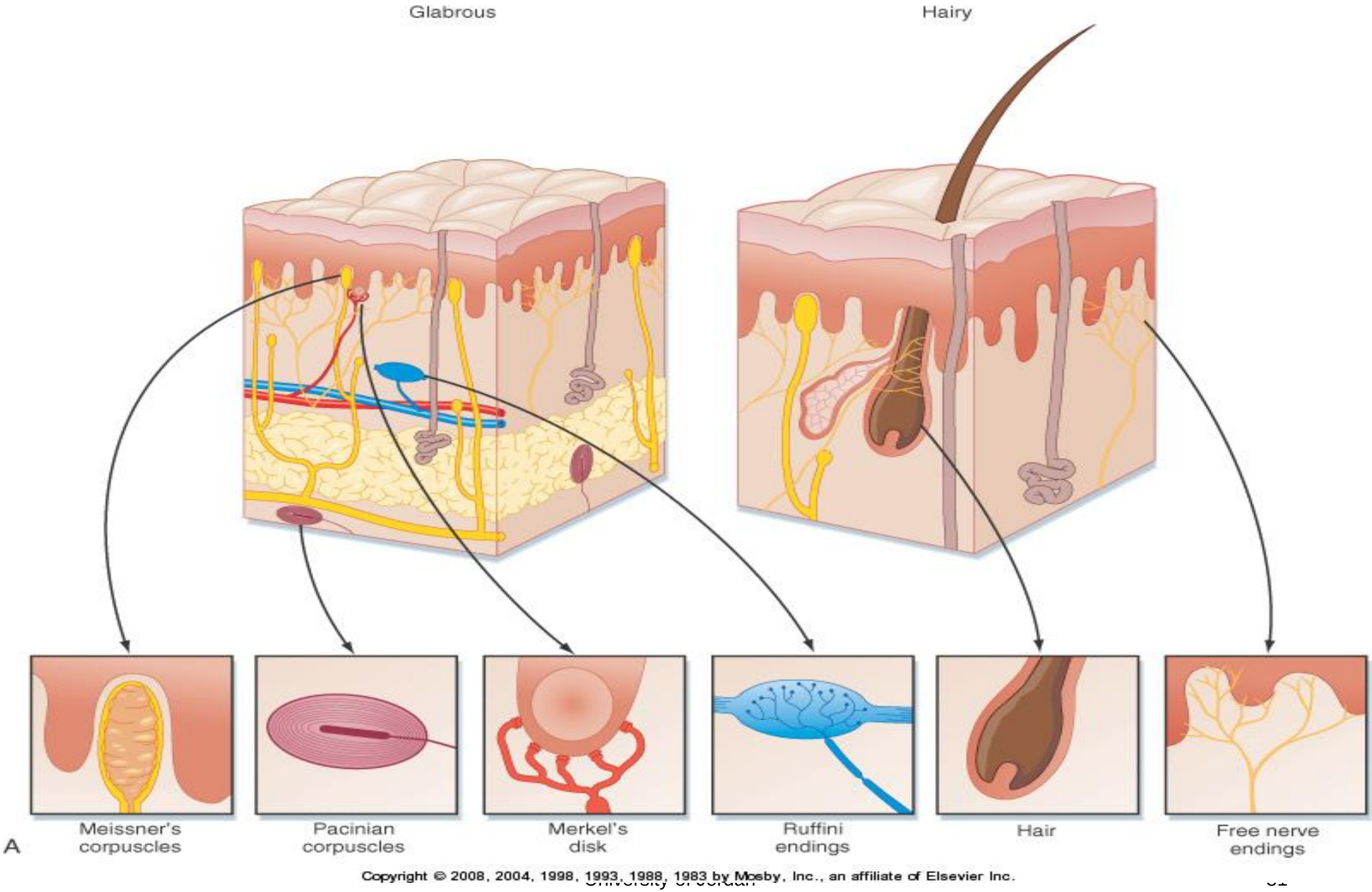
- Exteroceptors – sensitive to stimuli arising from outside the body
  - Located at or near body surfaces
  - Include receptors for touch, pressure, pain, and temperature
- Interoceptors – (visceroceptors) receive stimuli from internal viscera
  - Monitor a variety of stimuli (distension of viscera, pain)
- Proprioceptors – sense of position- monitor degree of stretch
  - Located in musculoskeletal organs (muscle, tendons and skin around joints)

Types of Sensory Receptors




Nociceptor
(pain receptor)
Epidermis
Dermis
Subcutaneous layer
Type I cutaneous mechanoreceptor (tactile or Merkel disc)
Corpuscle of touch (Meissner corpuscle) in dermal papilla
Type II cutaneous mechanoreceptor (Ruffini corpuscle)
Hair root plexus
Lamellated (Pacinian) corpuscle

15.02


Glabrous
Hairy
Meissner's corpuscles
Pacinian corpuscles
Merkel's disk
Ruffini endings
Hair
Free nerve endings
A
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Merckel's disc for mechanical sensation (Touch in hairy skin)

Iggo dome receptors

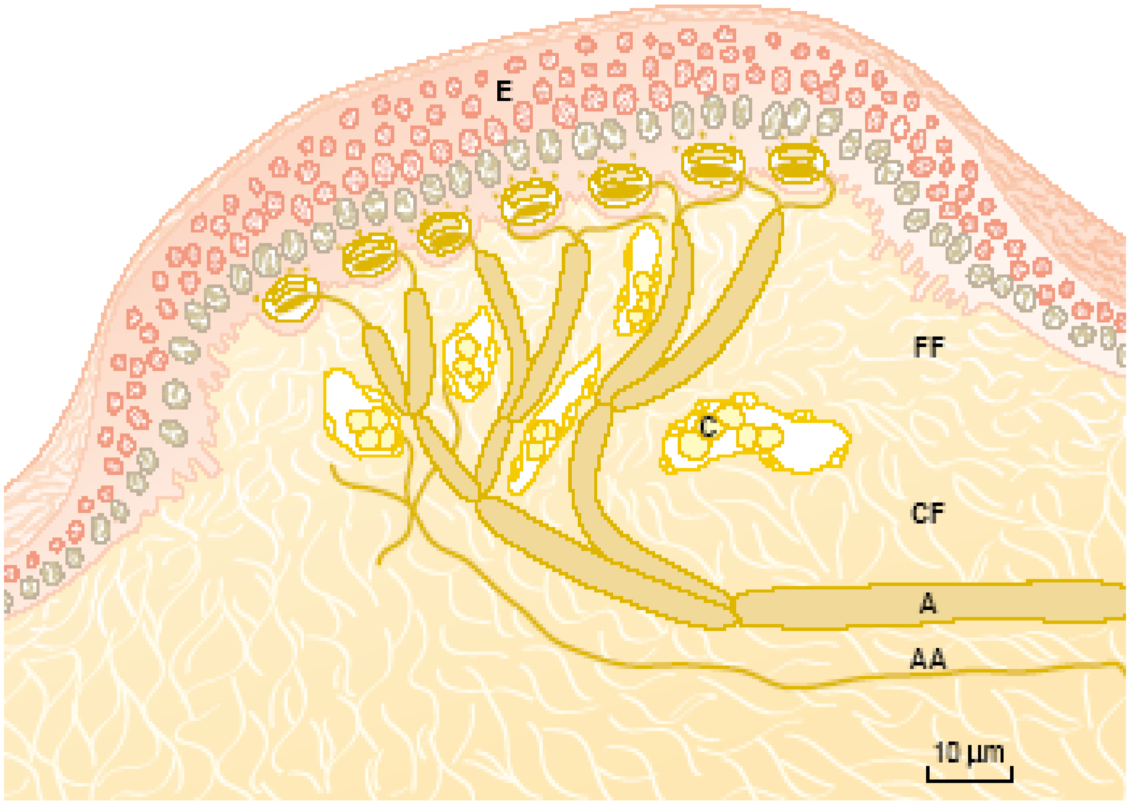


Figure 47–1

Iggo dome receptor. Note the multiple numbers of Merkel's discs connecting to a single large myelinated fiber and abutting tightly the undersurface of the epithelium. (From Iggo A, Muir AR: The structure and function of a slowly adapting touch corpuscle in hairy skin. J Physiol 200: 763, 1969.)

Tactile Receptors

- Free nerve endings (Aδ and C fibers)
  - detect touch and pressure
  - found everywhere in the skin and other tissues
- Meissner's corpuscles (Aβ)
  - rapidly adapting (within a fraction of a second) and detect movement of light objects over skin
  - found on **nonhairy skin (glabrous skin),** fingertips and lips
- Merkel's discs (Aβ)
  - respond rapidly at first and then slowly adapt, detect the "steady state"
  - found on **hairy as well a glabrous (non hairy) skin**

Tactile Receptors

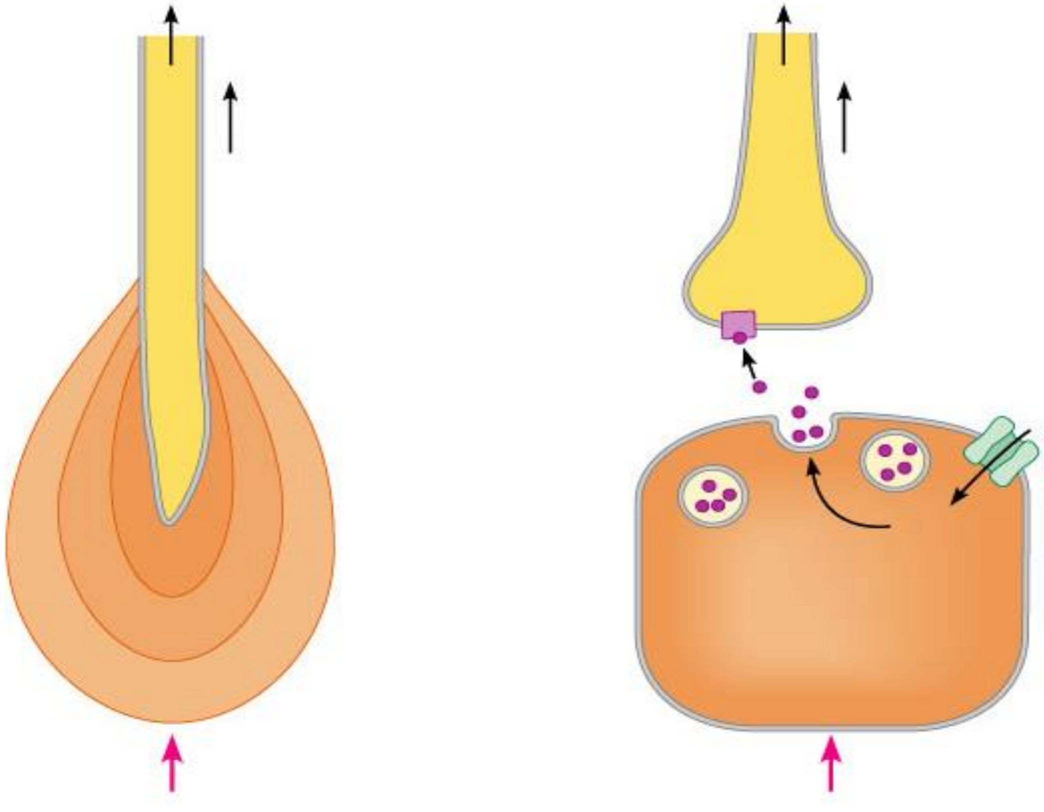
- Hair end organ
  - adapts rapidly and detects movement over the body
- Ruffini's end organ
  - slowly adapting and respond to continual deformation of the skin and joint rotation
- Pacinian corpuscle
  - very rapidly adapting and is stimulated only by rapid movement
  - detects vibration and other rapid changes in the skin

Tactile Sense Transmission

- Meissner's corpuscles, hair receptors, Pacinian corpuscles and Ruffini's end organs transmit signals in type Aβ nerve fibers at 30-70 m/sec.
- Free nerve endings transmit signals in type Aδ nerve fibers at 5-30 m/sec, some by type C unmyelinated fibers at 0.5-2 m/sec.
- The more critical the information the faster the rate of transmission.

Sensory Receptors: General structure

Receptor area is None-excitable region so as it can discriminate different intensities, otherwise it will not be able to differentiate strengths of stimuli

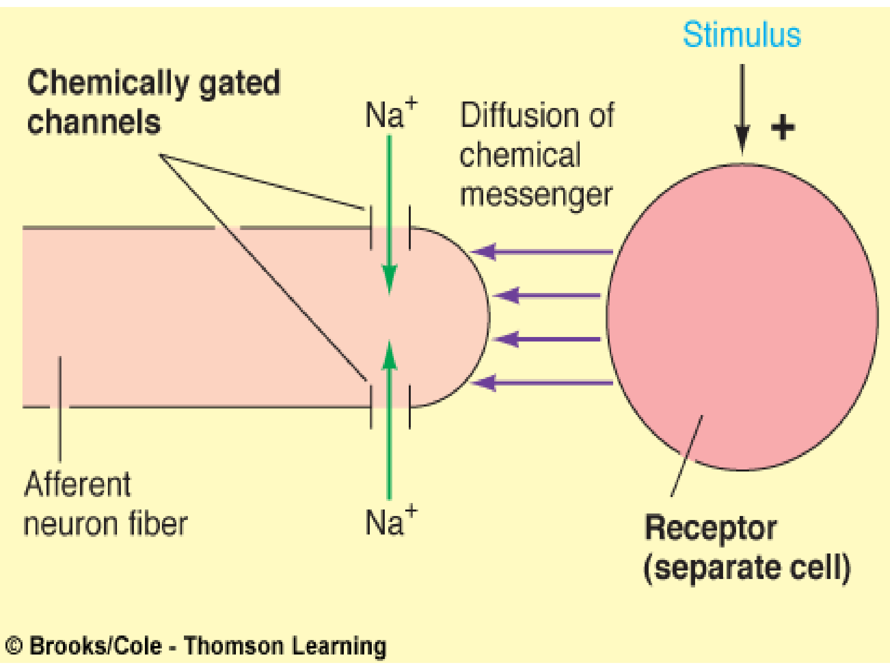


(a)

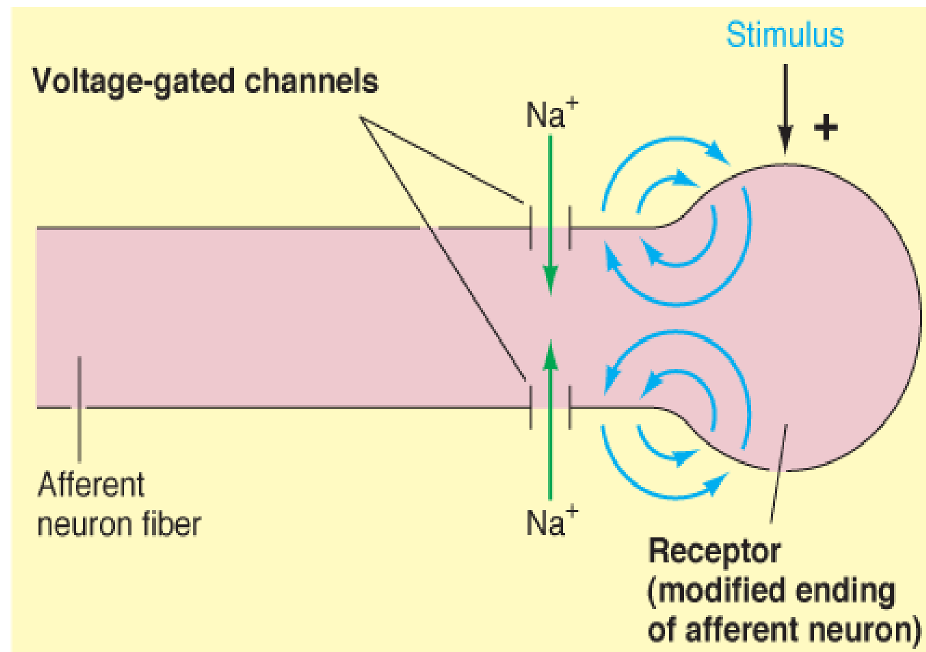
(b)

Conversion of Receptor and Generator Potentials into Action Potentials

Receptor Potential



Generator Potential



Law of Specific Nerve Energies

- Sensation characteristic of each sensory neuron is that produced by its normal or adequate stimulus.
- Adequate stimulus:
  - Requires least amount of energy to activate a receptor.
- Regardless of how a sensory neuron is stimulated, only one sensory modality will be perceived (specificity of receptors)
  - Allows brain to perceive the stimulus accurately under normal conditions.

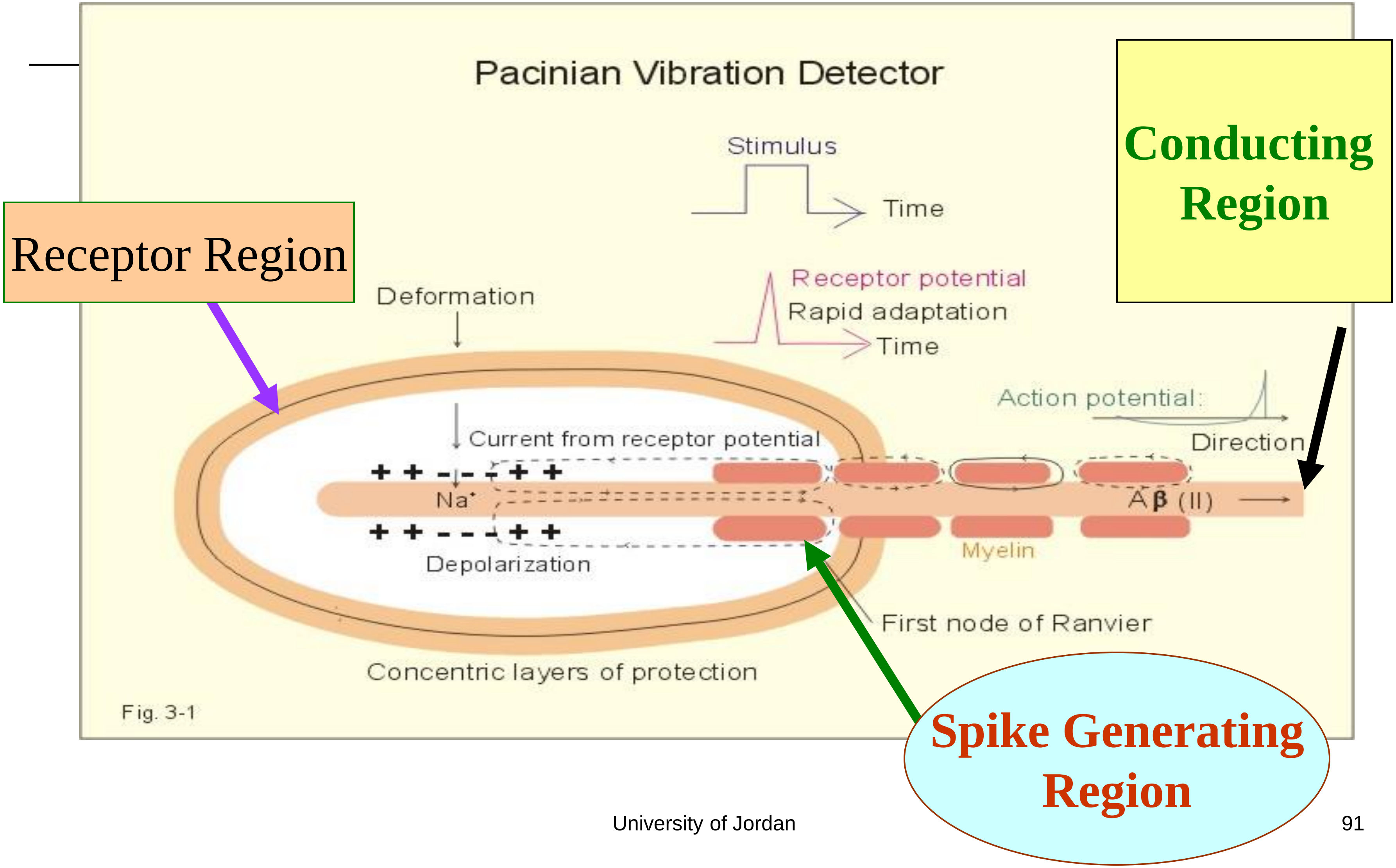
Sensation

- Each of the principle types sensation; touch, pain, sight, sound, is called a *modality of sensation*.
- Each receptor is responsive to one type of stimulus energy. Specificity is a key property of a receptor, it underlines the most important coding mechanism***, the labeled line principle***
- How the sensation is perceived is determined by the characteristics of the receptor and the central connections of the axon connected to the receptor.

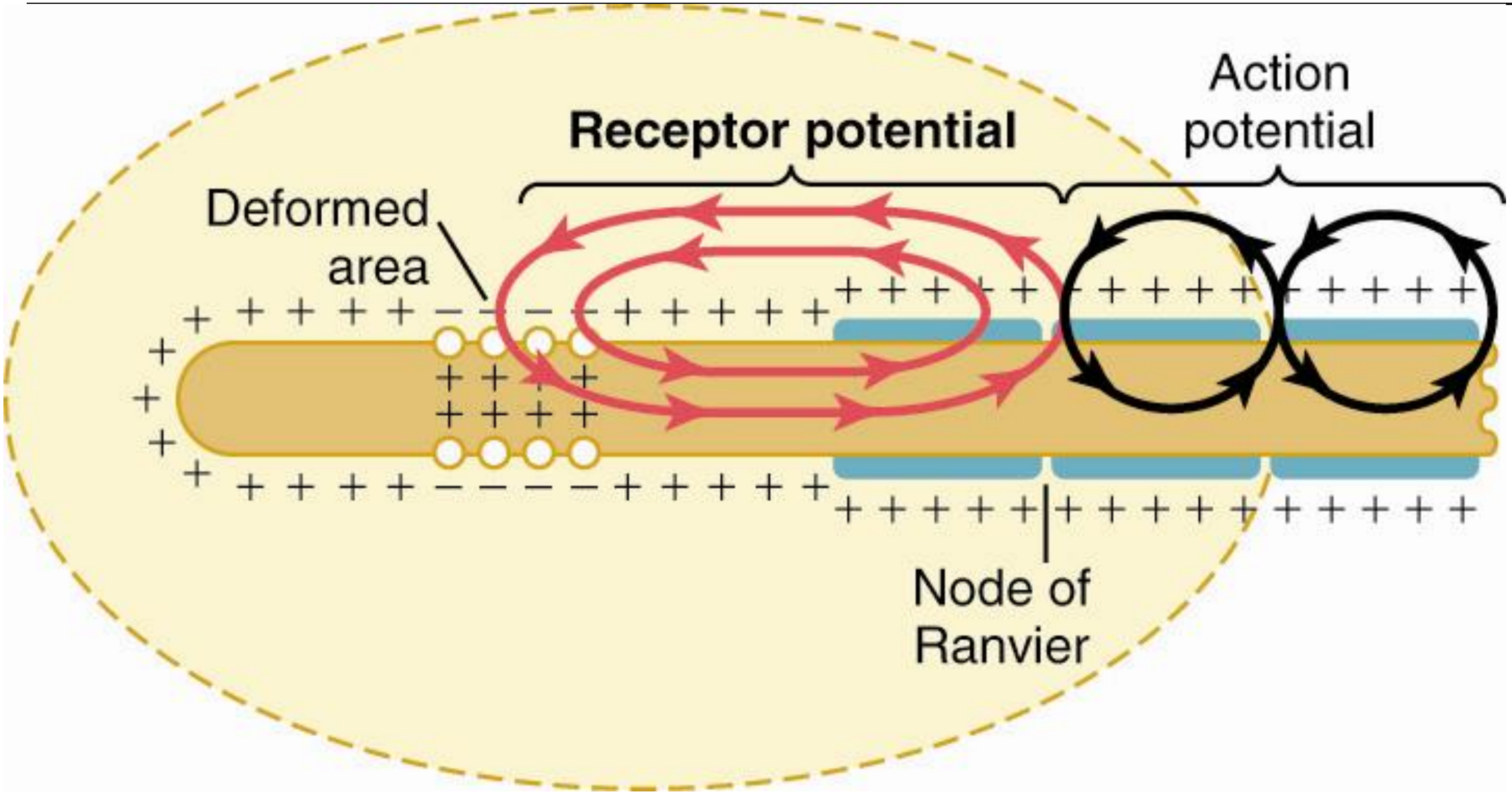
Receptor Excitation

- mechanical deformation which stretches the membrane and opens ion channels
- application of chemicals which also opens ion channels
- change in temperature which alters the permeability of the membrane through changing the metabolic rate
- electromagnetic radiation that changes the membrane characteristics

General Structure of Receptors



Receptor Excitation

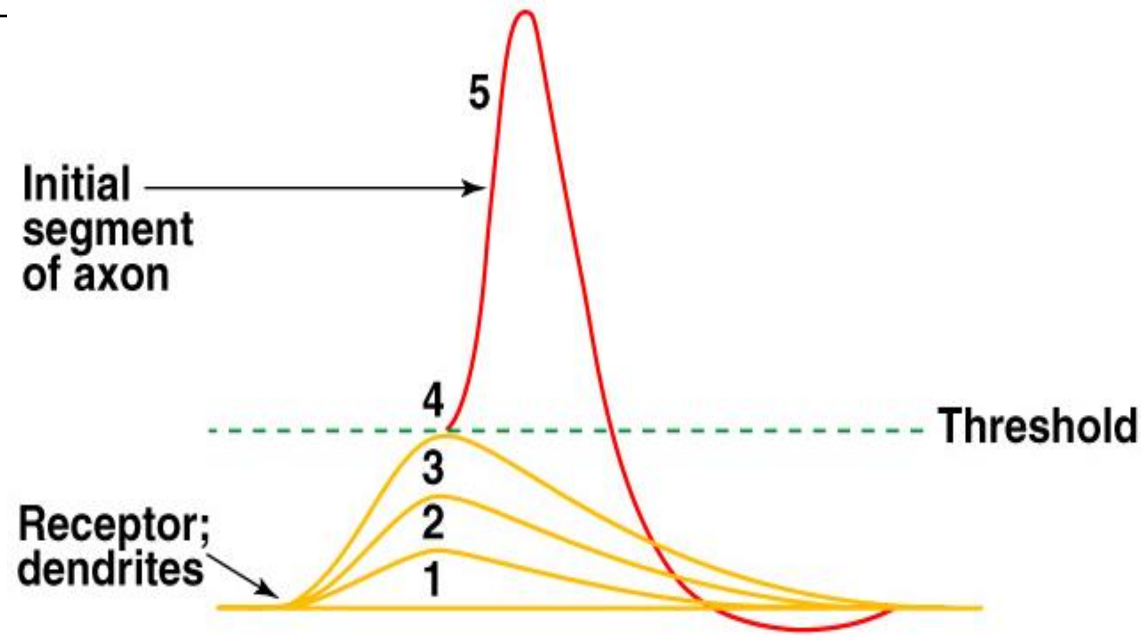


Receptor Potential

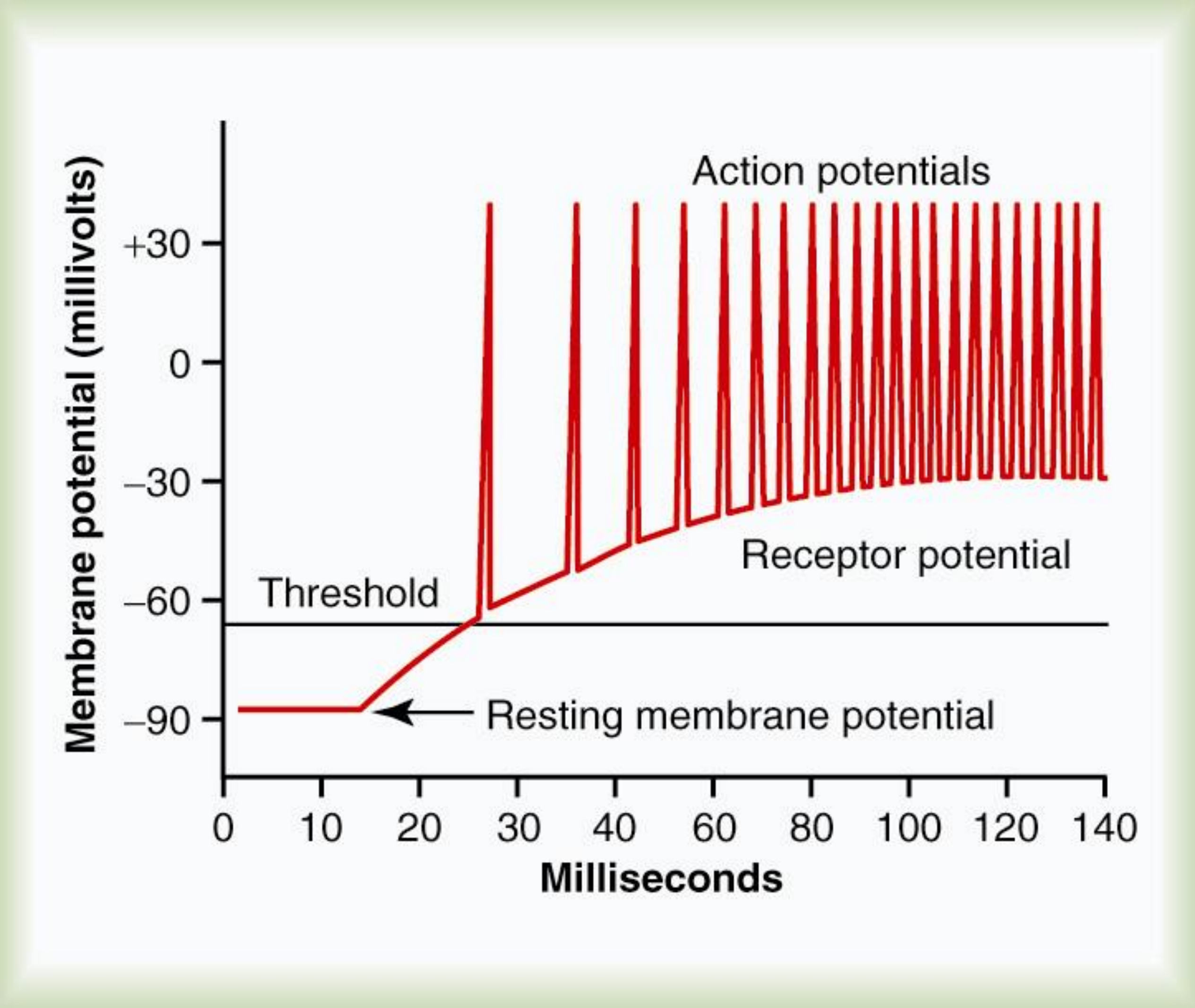
- The membrane potential of the receptor
  - Excitation of the receptor results from a change in this potential.
  - When the receptor potential rises above the threshold, action potentials appear and the receptor is active.
  - The greater the intensity of the stimulus, the greater the receptor potential, and the greater the rate of action potential generation.

Generator Potentials

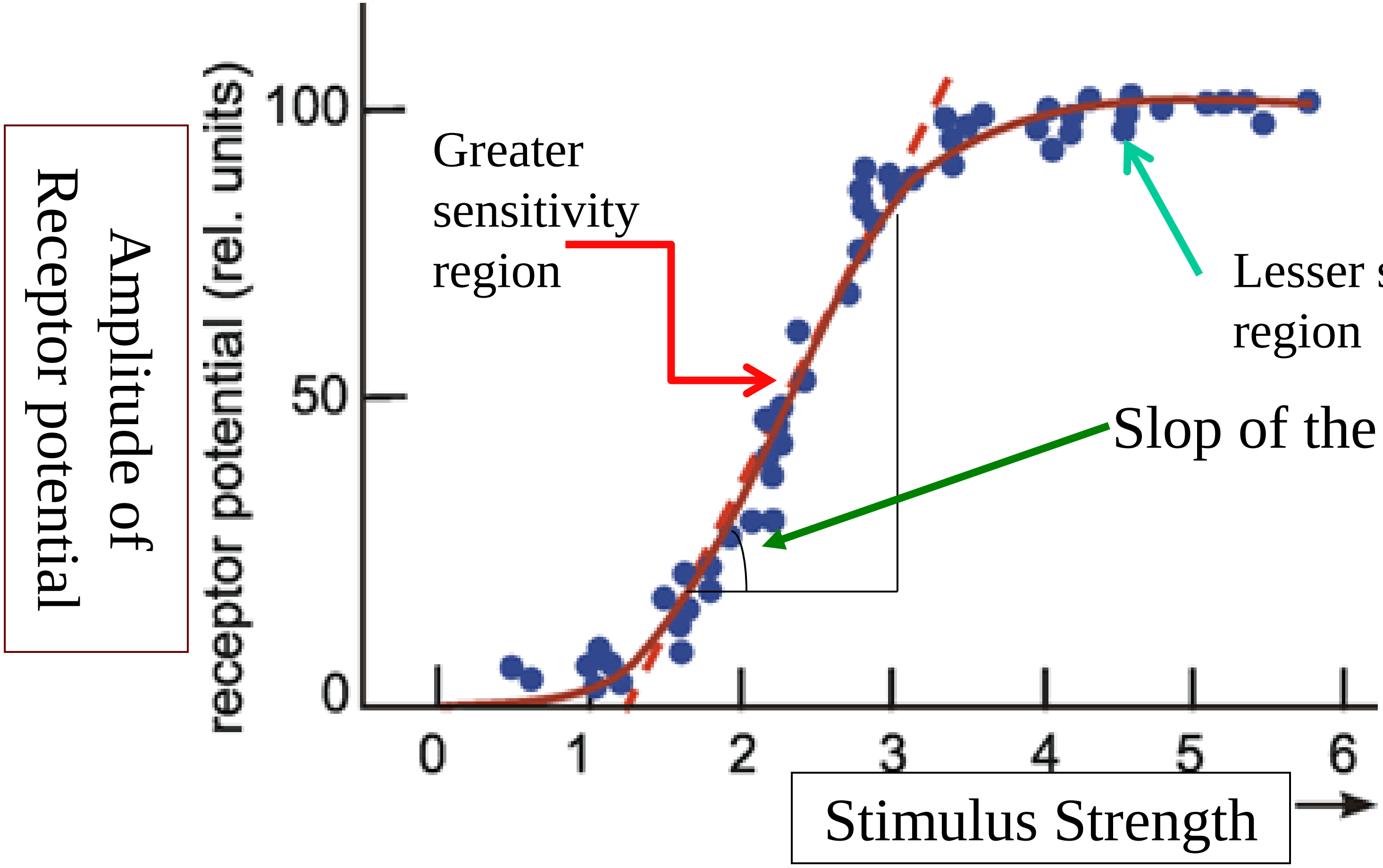
- In response to stimulus, sensory nerve endings produce a local graded change in membrane potential.
- Potential changes are called receptor or generator potential.
  - Analogous to EPSPs.



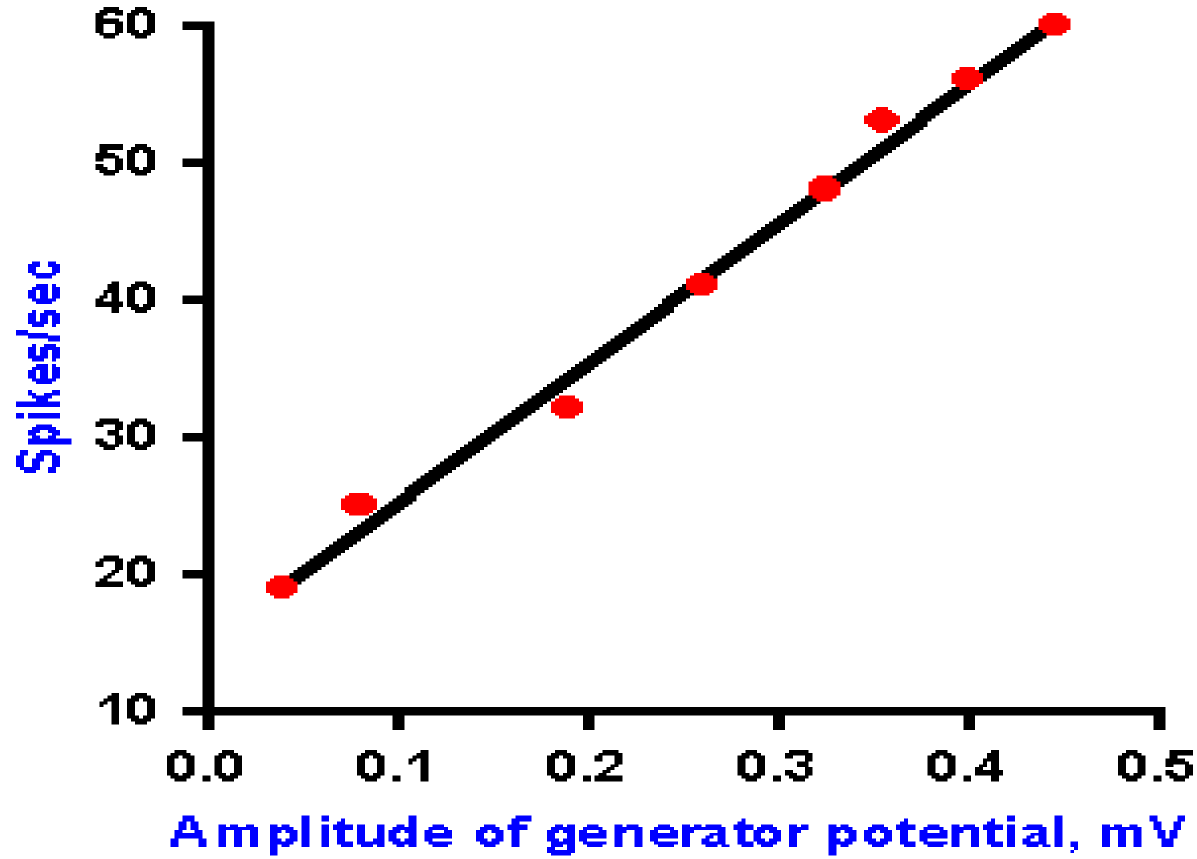
Relationship between Receptor Potential and Action Potentials



The effect of stimulus strength on RP amplitude

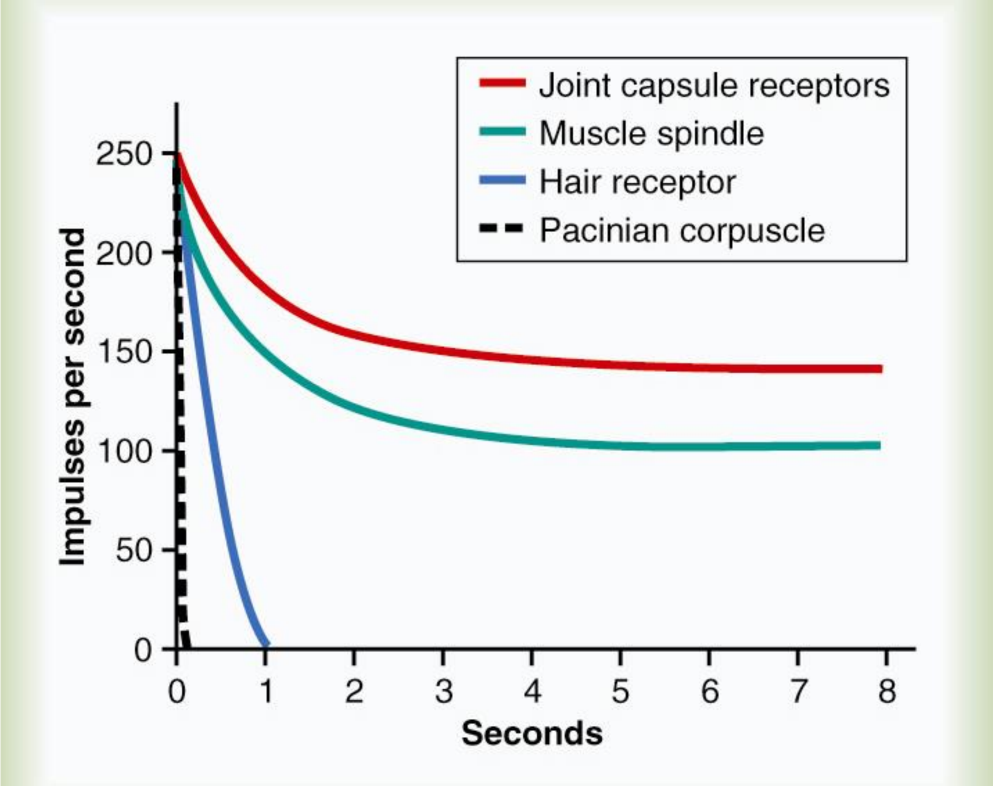


The effect of the amplitude of RP on the frequency of impulses generated



Adaptation of Receptors

- When a continuous stimulus is applied, receptors respond rapidly at first, but response declines until all receptors stop firing.



Adaptation

- Rate of adaptation varies with type of receptor.
- Therefore, receptors respond when a change is taking place (i.e., think of the feel of clothing on your skin.)

Adaptation of Sensory Receptors

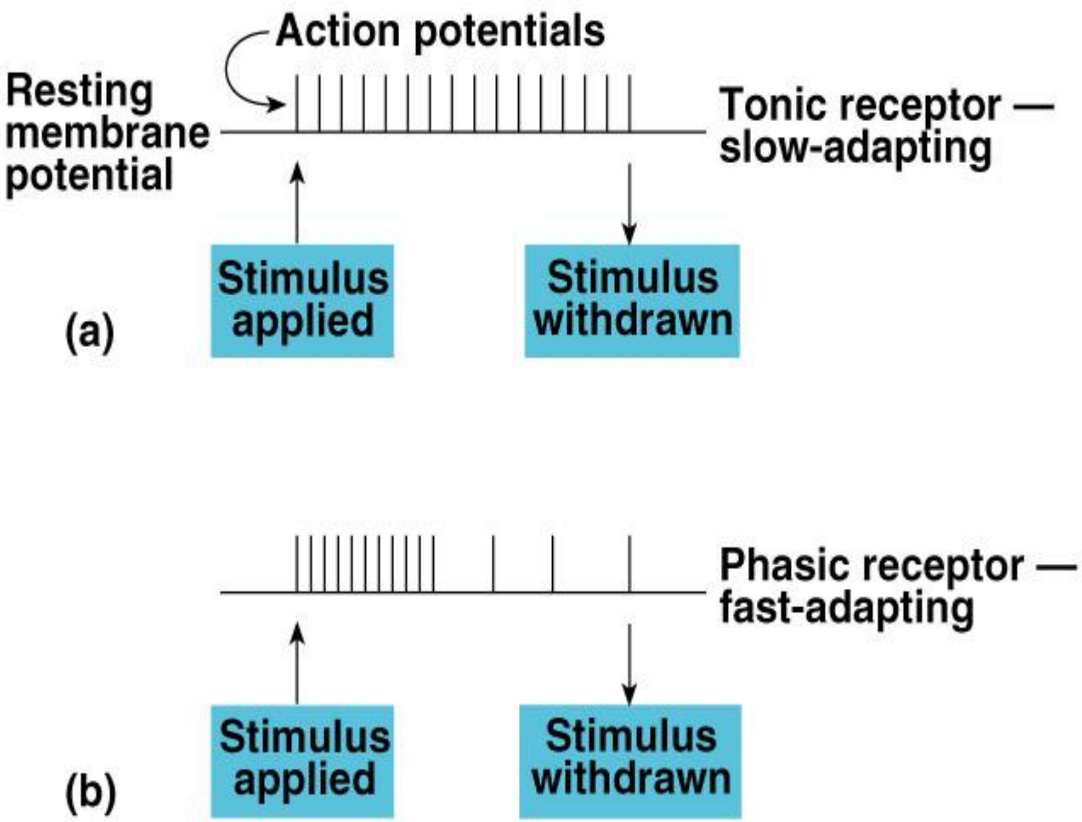
- Receptors responding to pressure, touch, and smell adapt quickly
- Receptors responding slowly include Merkel's discs, Ruffini's corpuscles, and interoceptors that respond to chemical levels in the blood
- Pain receptors and proprioceptors do not exhibit adaptation

Slowly Adapting (Tonic) Receptors

- continue to transmit impulses to the brain for long periods of time while the stimulus is present
- keep brain apprised of the status of the body with respect to its surroundings
- will adapt to extinction as long as the stimulus is present, however, this may take hours or days
- these receptors include: *muscle spindle*, *golgi tendon apparatus*, *Ruffini's endings*, *Merkels discs*, *Macula*, *chemo- and baroreceptors*

Sensory Adaptation

- Tonic receptors:
  - Produce constant rate of firing as long as stimulus is applied.
    - Pain.
- Phasic receptors:
  - Burst of activity but quickly reduce firing rate (adapt) if stimulus maintained.
  - Sensory adaptation:
    - Cease to pay attention to constant stimuli.

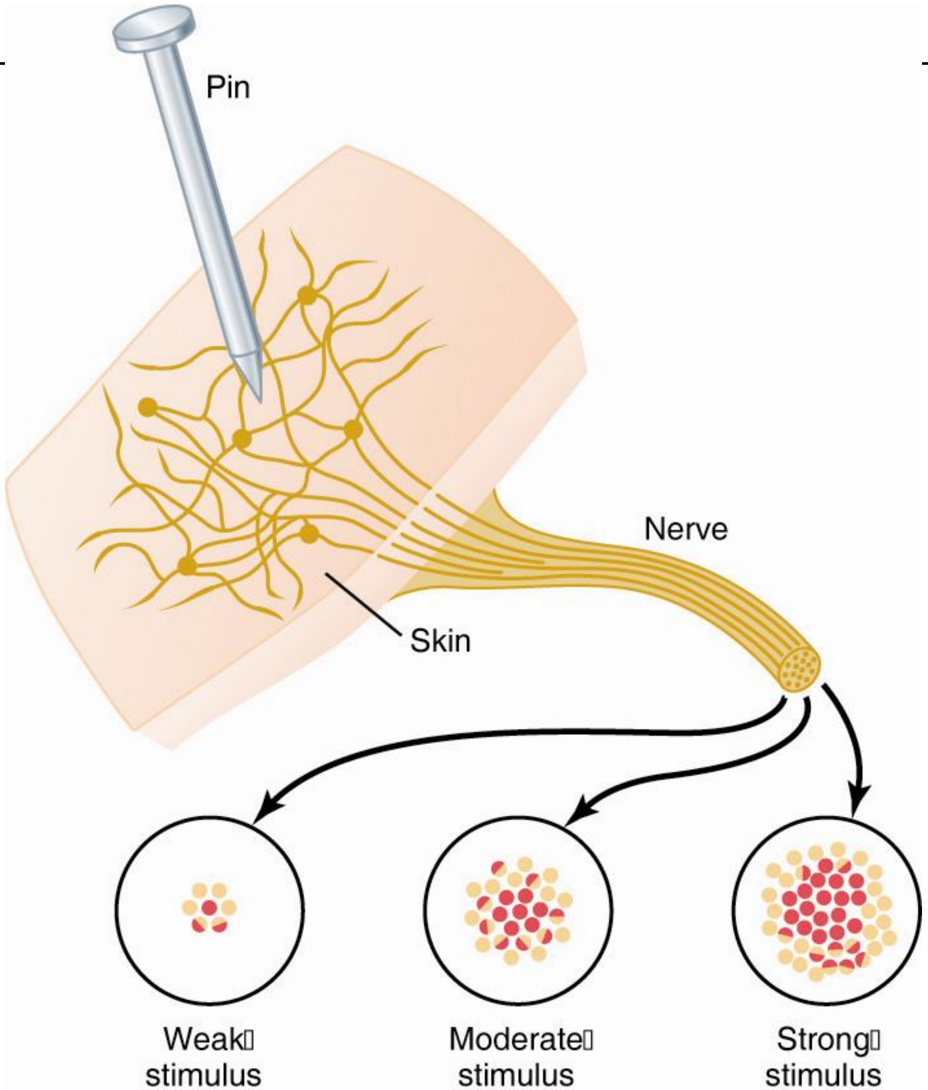


Rapidly Adapting (Phasic) Receptors

- respond only when change is taking place
- Rate and Strength of the response is related to the Rate and Intensity of the stimulus
- important for predicting the future position or condition of the body
- very important for balance and movement
- types of rapidly adapting receptors: *pacinian corpuscle*, *semicircular canals* in the inner ear

Importance of Signal Intensity

- Signal intensity is critical for interpretation of the signal by the brain (i.e., pain).
- Gradations in signal intensity can be achieved by:
- 1) increasing the number of fibers stimulated, **spatial summation**
- 2) increasing the rate of firing in a limited number of fibers, **temporal summation**.



An example of spatial summation

Figure 46-7;
Guyton & Hall

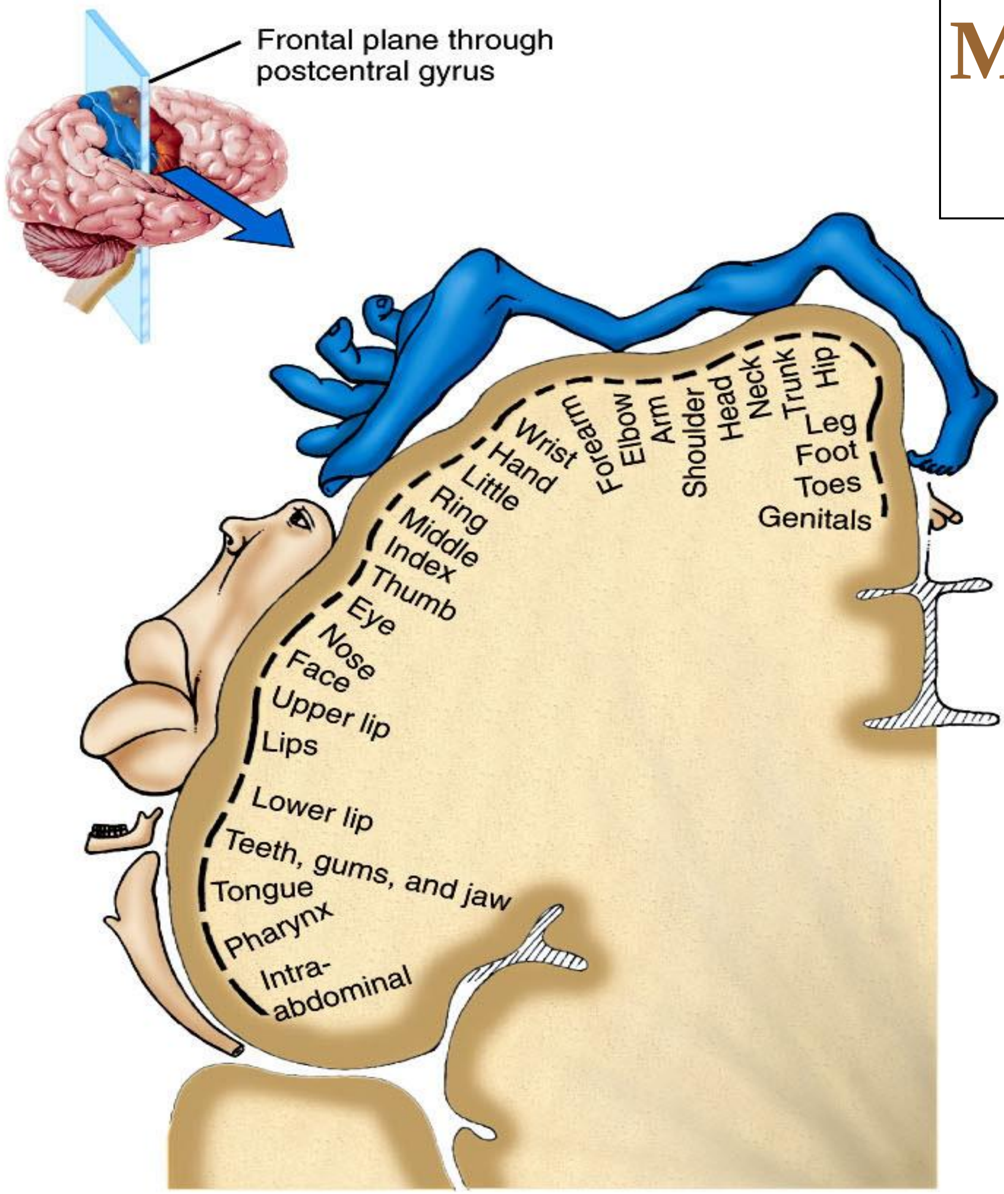
Coding in the sensory system

- Intensity is coded for by:
  - Frequency of action potential
  - The No. of neurons stimulated
- Location is coded for by the labeled line principles
- Type of stimulus is coded for by the kind of receptor stimulated (Adequate stimulus) and specificity of the receptors.

Coding of Sensory Information

STIMULUS PROPERTY	MECHANISM OF CODING
Type of Stimulus (stimulus modality)	Distinguished by the type of receptor activated and the specific pathway over which this information is transmitted to a particular area of the cerebral cortex
Location of Stimulus	Distinguished by the location of the activated receptive field and the pathway that is subsequently activated to transmit this information to the area of the somatosensory cortex representing that particular location
Intensity of Stimulus (stimulus strength)	Distinguished by the frequency of action potentials initiated in an activated afferent neuron and the number of receptors (and afferent neurons) activated

Mapping of the Primary Somatosensory Area



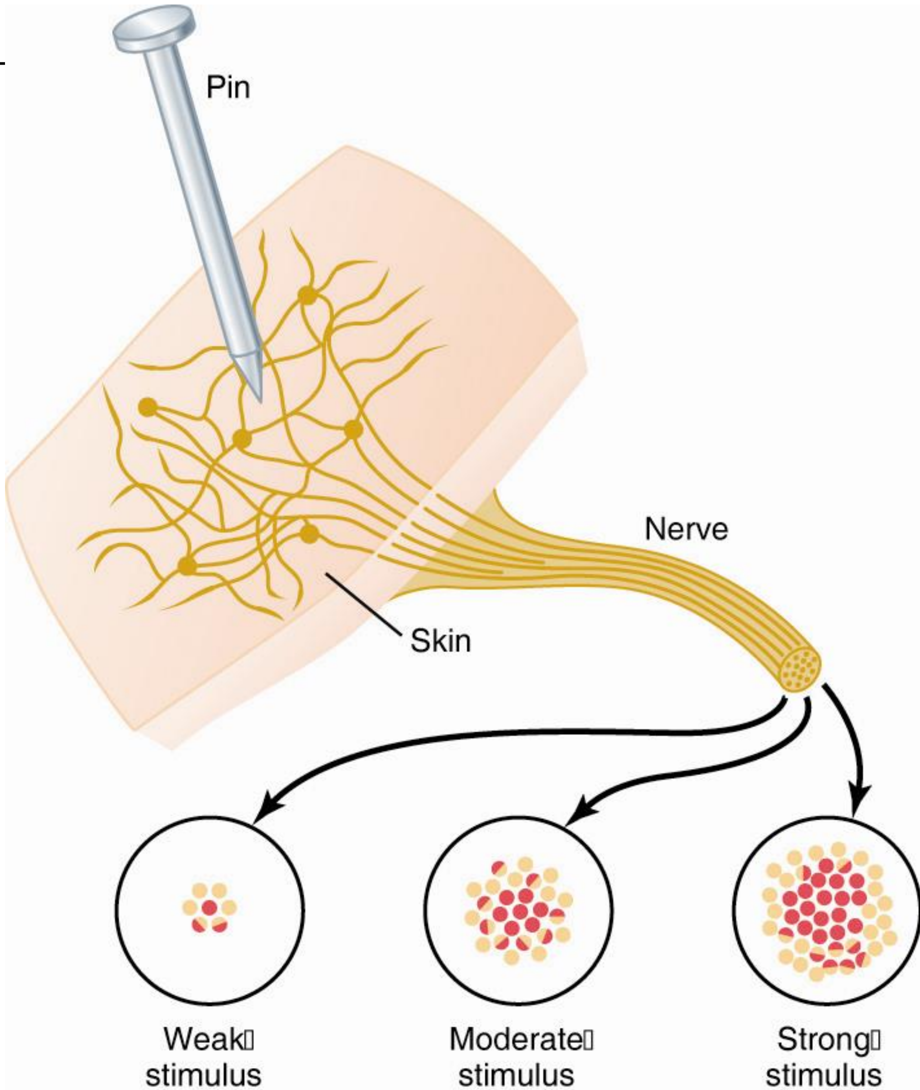
(a) Frontal section of primary somatosensory area in right cerebral hemisphere

Figure 16.08 Tortora - PAP 12/e

- Mapping of the postcentral gyrus.
- Size of the cortical region representing a body part depends on density of receptors on that part and the sensory impulses received from that part.

Receptive Fields

- Area of skin whose stimulation results in changes in the firing rate of the neuron.
  - Area of each receptor field varies inversely with the density of receptors in the region.
- Back and legs have few sensory endings.
  - Receptive field is large.
- Fingertips have large # of cutaneous receptors.
  - Receptive field is small.

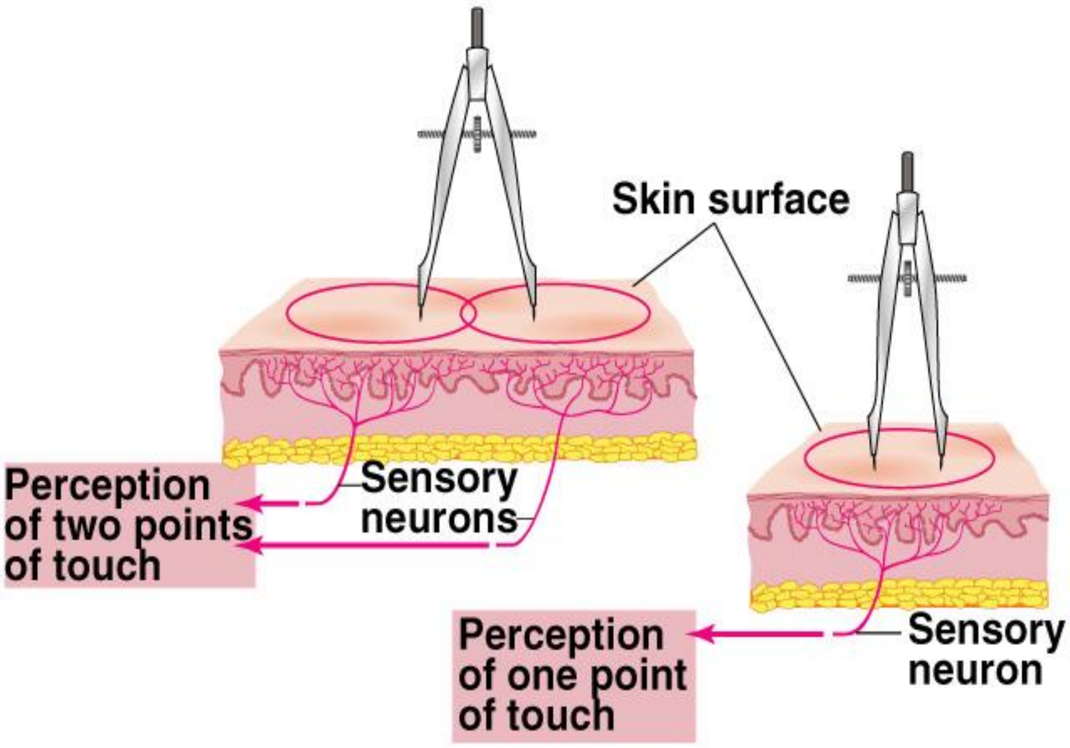


An example of spatial summation

Figure 46-7; Guyton & Hall

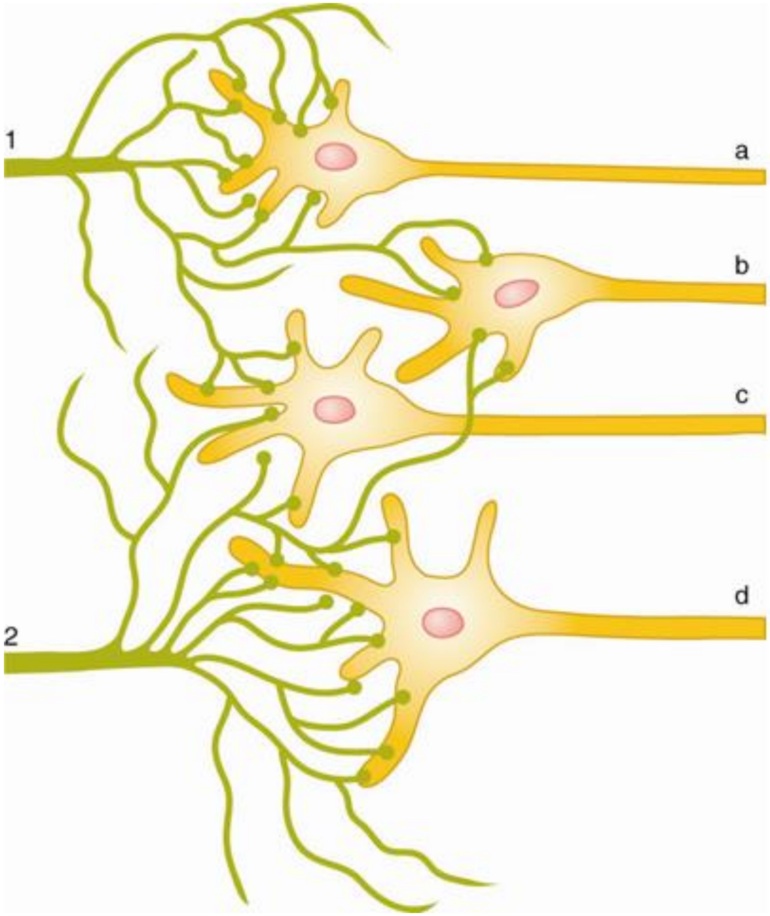
Two-Point Touch Threshold

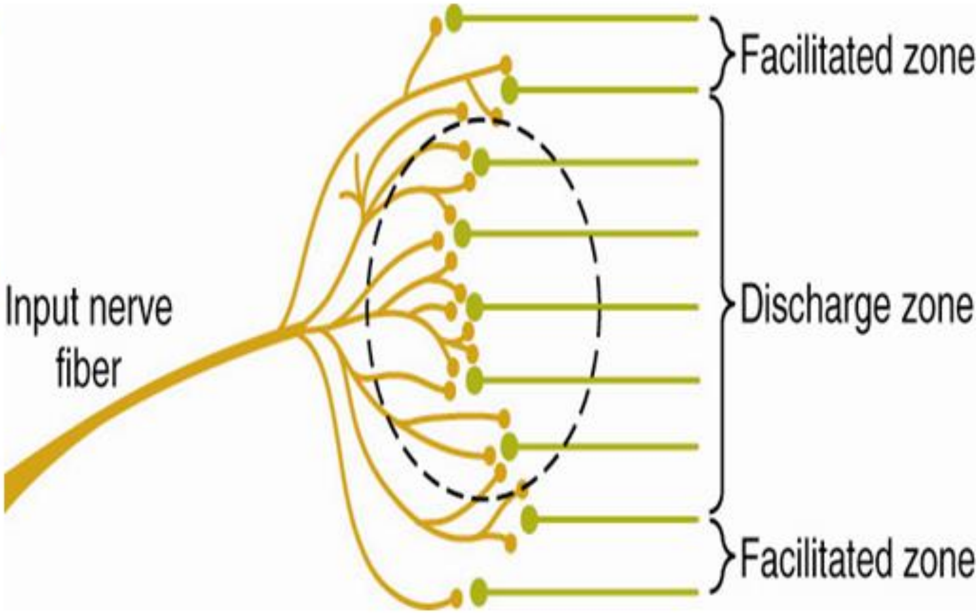
- Minimum distance at which 2 points of touch can be perceived as separate.
  - Measures of distance between receptive fields.
- Indication of tactile acuity.
  - If distance between 2 points is less than minimum distance, only 1 point will be felt.



Neuronal Processing

Relaying Signals through Neuronal Pools

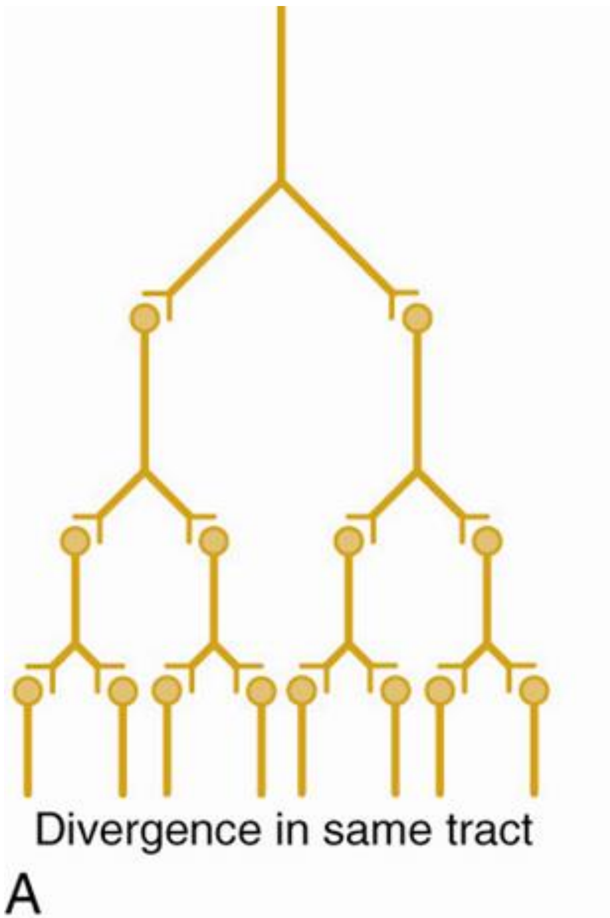


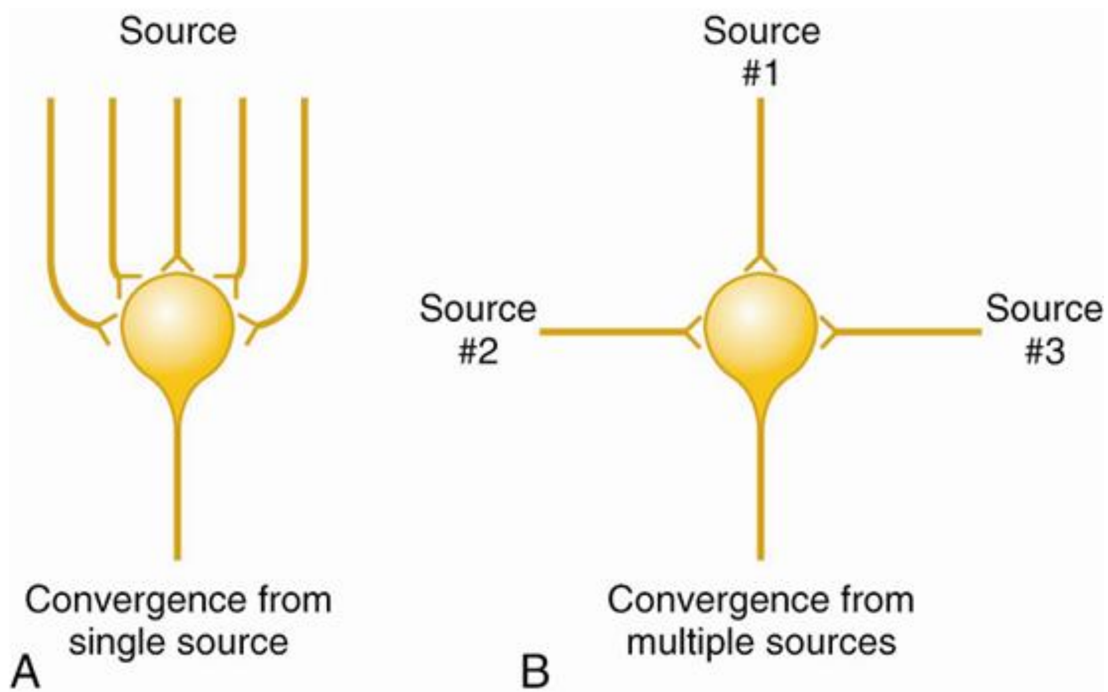


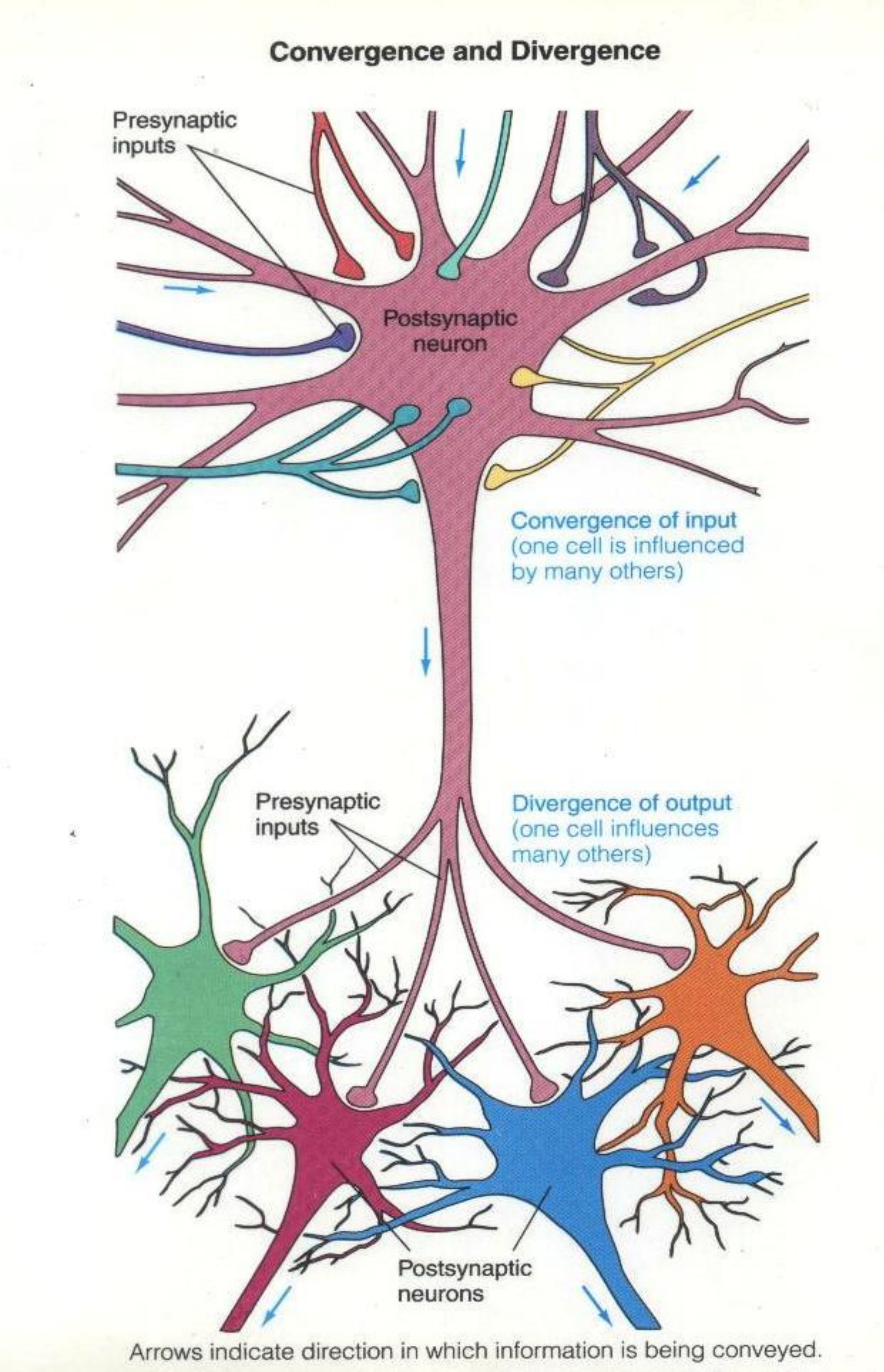
Neuronal Pools

- groups of neurons with special characteristics of organization
- comprise many different types of neuronal circuits
  - converging
  - diverging
  - reverberating

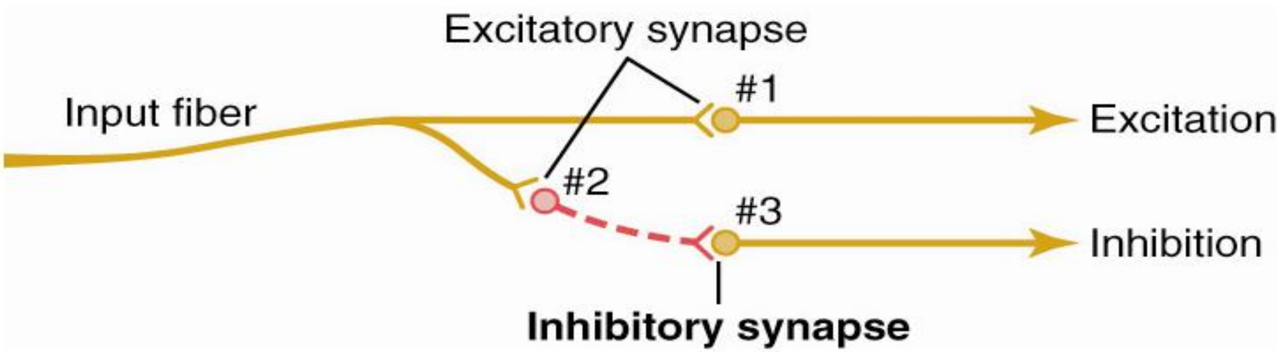
Neuronal Pools: Localization of sensory Information modification






Convergence and Divergence
Presynaptic inputs
Postsynaptic neuron
Convergence of input (one cell is influenced by many others)
Presynaptic inputs
Divergence of output (one cell influences many others)
Postsynaptic neurons
Arrows indicate direction in which information is being conveyed.

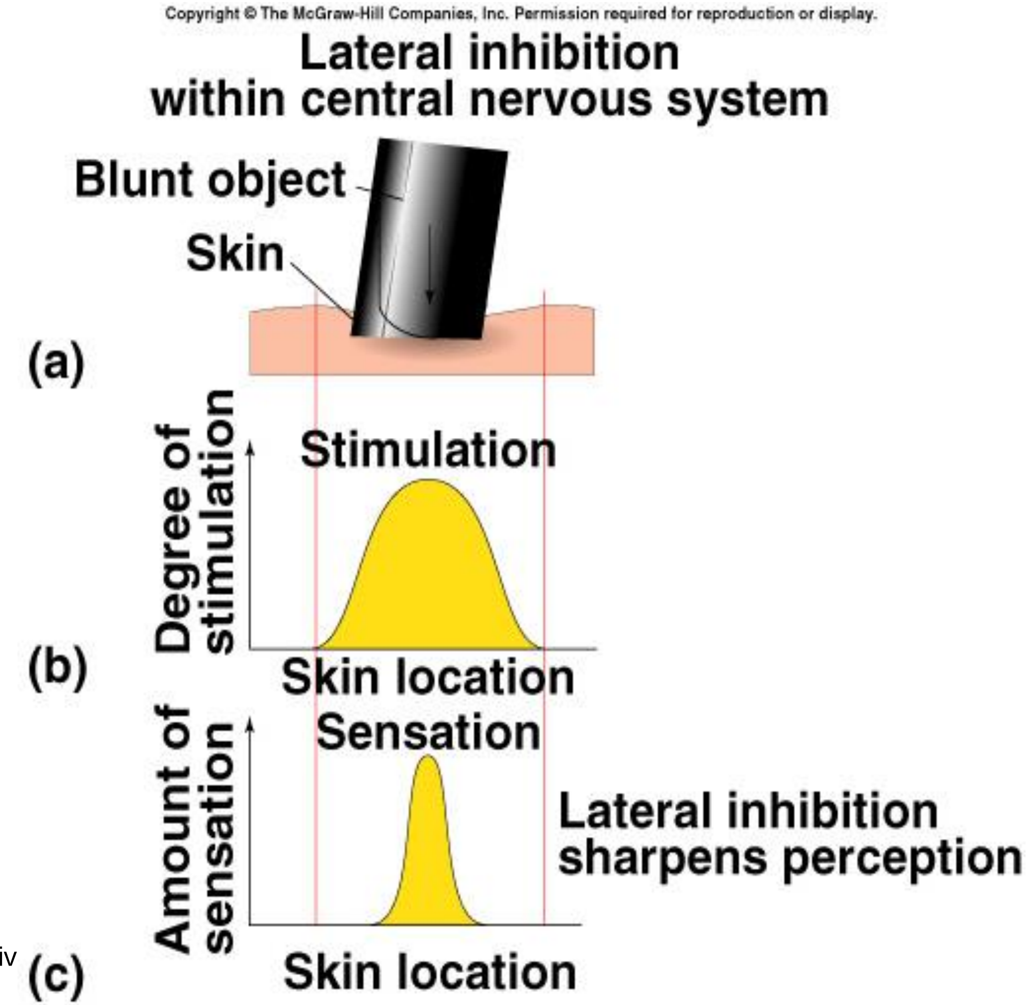
Neuronal Pools: Modification of Localization: Sharpening of signals



Lateral inhibition

Lateral Inhibition

- Sharpening of sensation.
  - When a blunt object touches the skin, sensory neurons in the center areas are stimulated more than neighboring fields.
  - Stimulation will gradually diminish from the point of greatest contact, without a clear, sharp boundary.
    - Will be perceived as a single touch with well defined borders.
  - Occurs within CNS.



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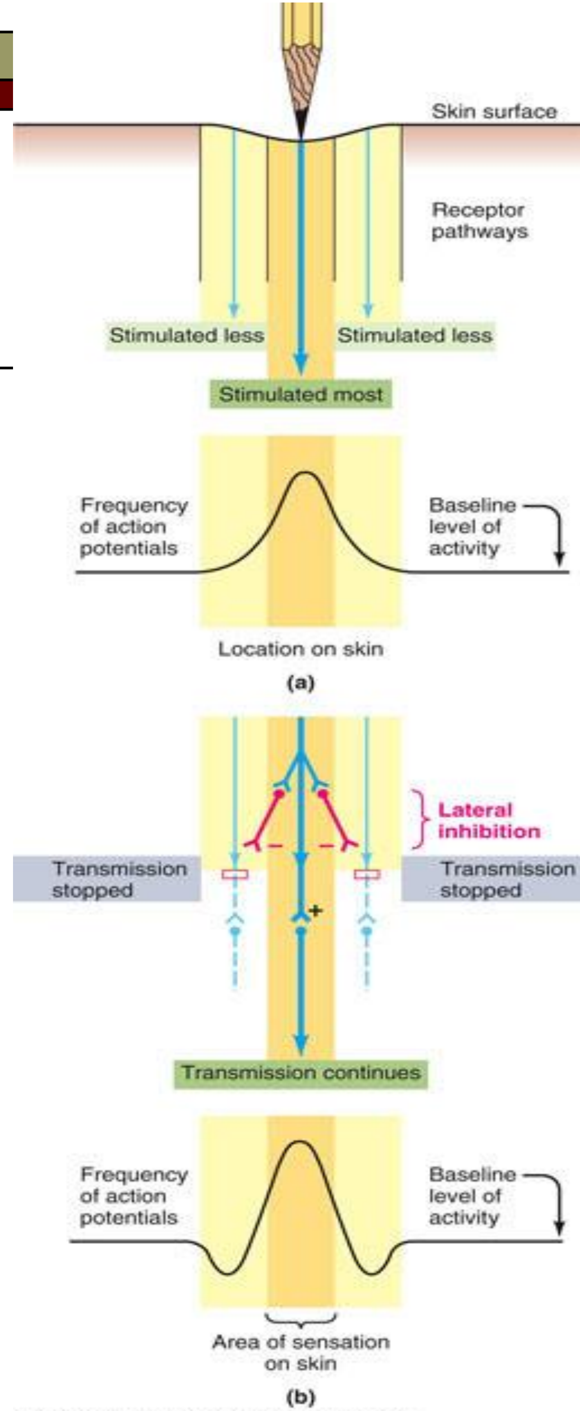
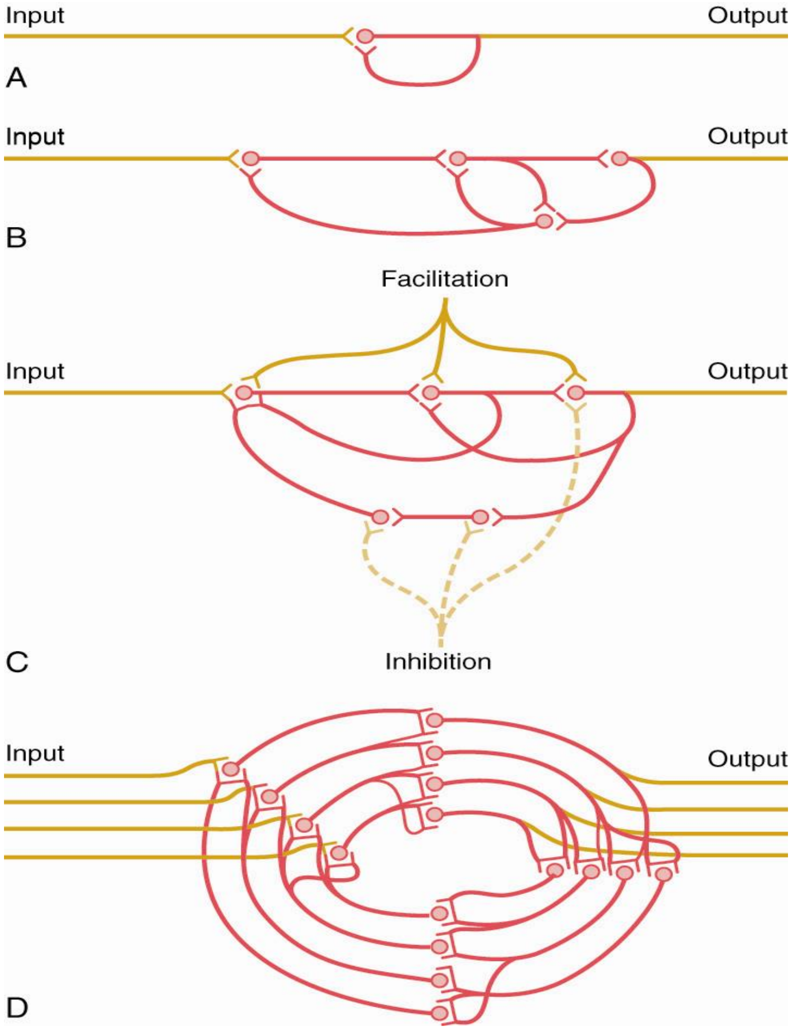
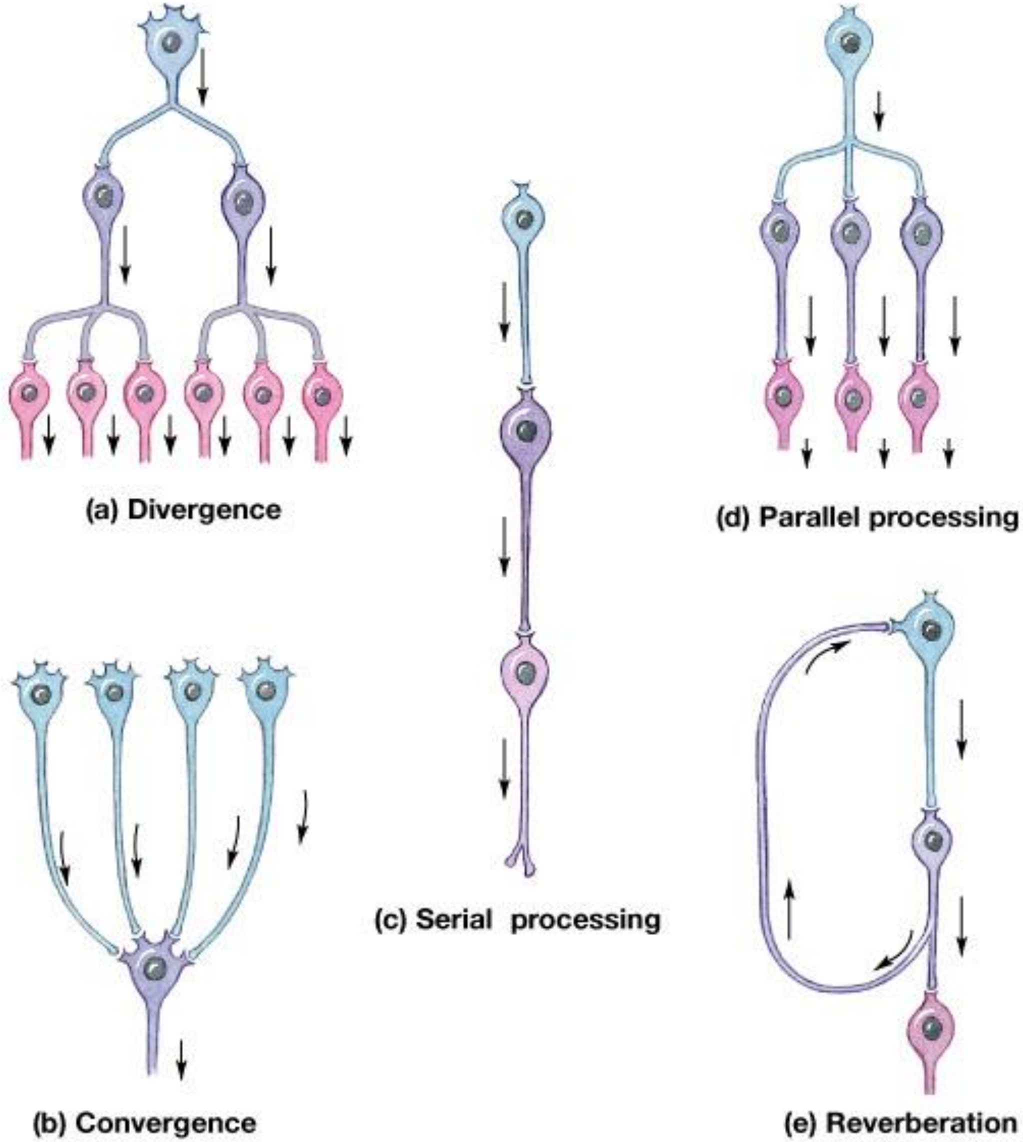
Lateral Inhibition in the sensory System as a way of sharpening of the stimulus



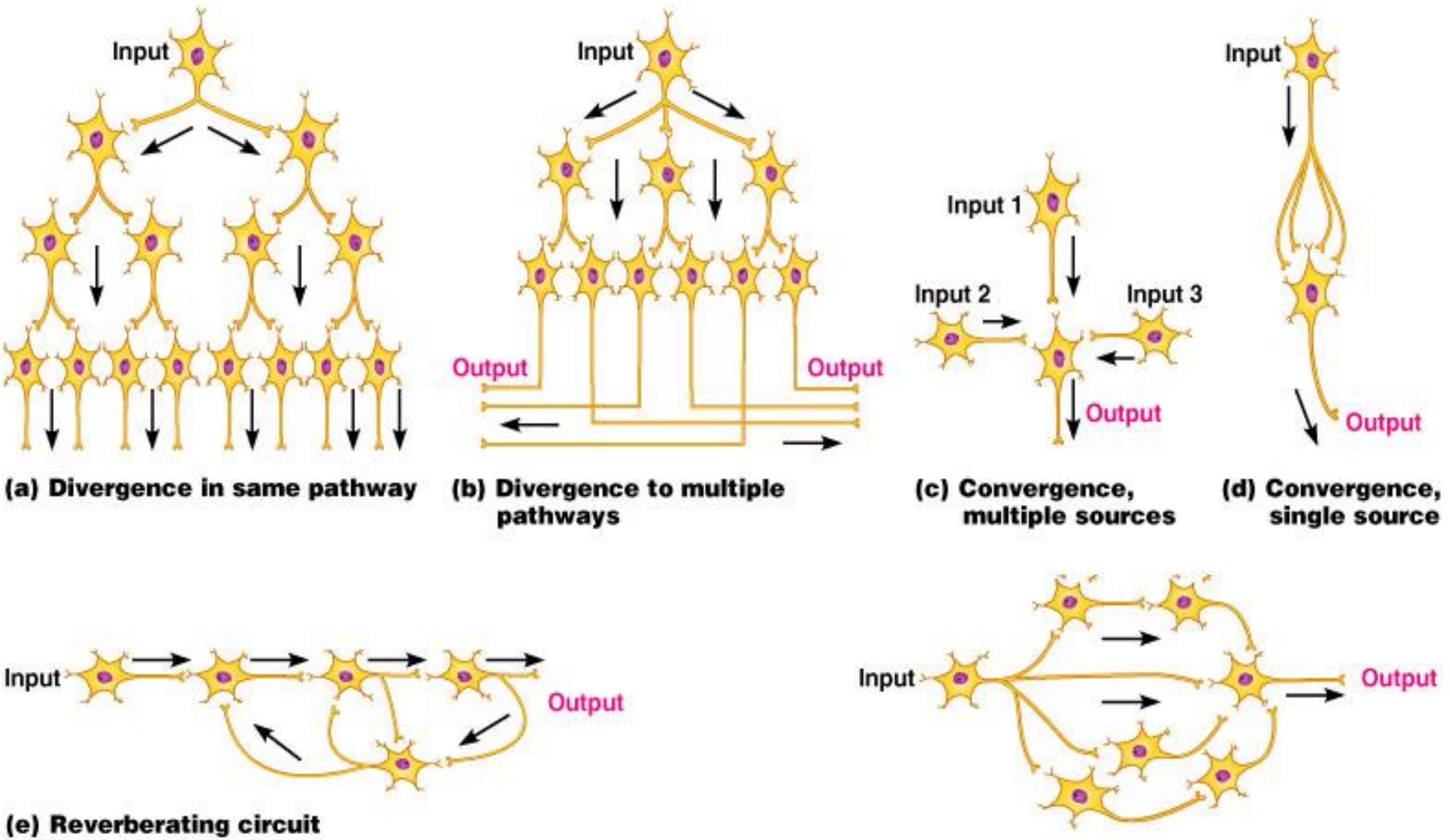
Reverberating Circuits: prolongation of Time of the signals



The Organization of Neuronal Pools

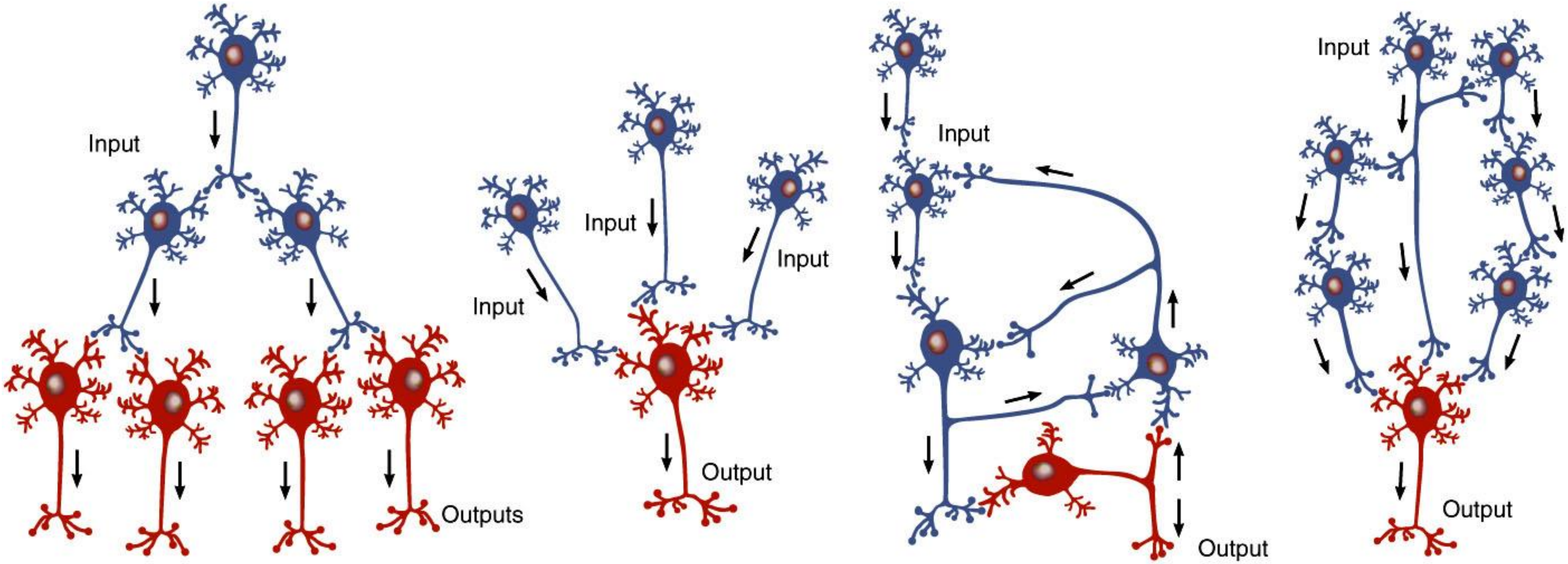


Types of Circuits in Neuronal Pools



(a) Divergence in same pathway
(b) Divergence to multiple pathways
(c) Convergence, multiple sources
(d) Convergence, single source
(e) Reverberating circuit
(f) Parallel after-discharge circuit

Neural Circuits



(a) Diverging circuit (b) Converging circuit (c) Reverberating circuit (d) Parallel after-discharge circuit

Figure 12.28 Tortora - PAP 12/e

Other mechanisms for prolongation of time

- Synaptic afterdischarge: since the time of EPSP (15-20 msec) is longer than the time of AP(0.1 – 10 msec) then more No. of AP per one EPSP
- Parallel circuits

Stabilization of neuronal discharge

- Synaptic fatigue: short term and acute adjustment of sensitivity
- Neuronal inhibitory circuits:
  - Gross inhibition –Basal ganglia inhibits muscle tone
  - Feed back inhibition-Cortico-fugal fibers from cerebral cortex descending fibers to control the intensity and sharpness
- Downregulation and upregulation- Long term stabilization through modification of the receptor availability (internalization or externalization)


THANK YOU
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We're on Track
For a Cure