Receptors Functions and Signal Transduction L1- L2

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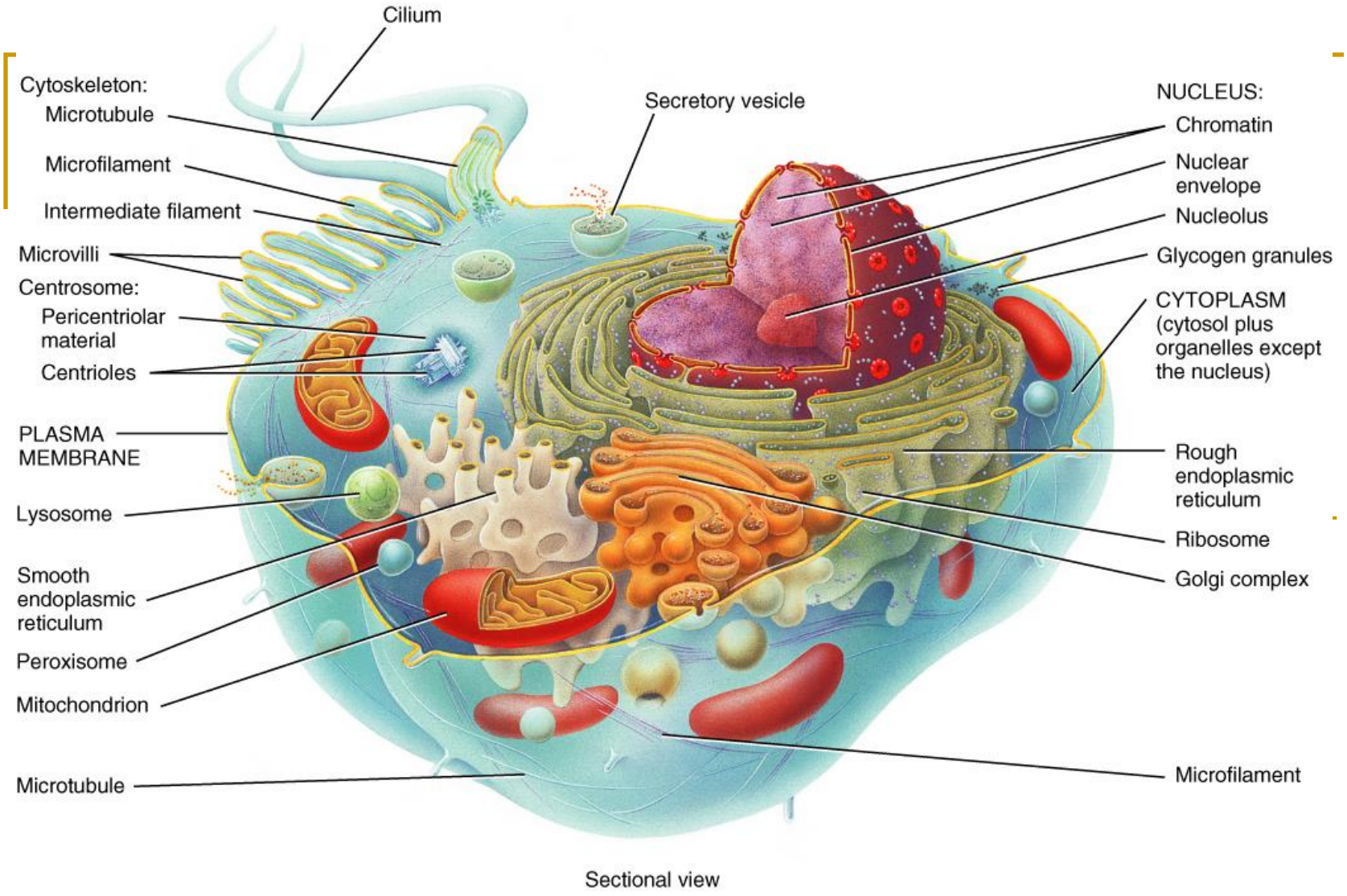
Introduction to Physiology (0501110) Spring 2026

Subject	Lecture No.	Lecturer	Pages in the 13th edition. textbook	Pages in the 14 th edition textbook
Receptors: types and adaptation - Membrane or intracellular - Ion channels - G-protein - Enzyme linked - Intracellular - Second messengers - cAMP and cGMP, Phospholipid - Calcium calmodulin and IRS		Dr. Faisal	915-927	925-935
Signal Transduction (Regulation of cellular machinery) Extracellular regulators: nervous, endocrine, paracrine and autocrine		Dr. Faisal	944-946	954-956
Steroids: Their Signal Transduction And Mechanism Of Action		Dr. Faisal	960-961 966-967	970-971 976-977

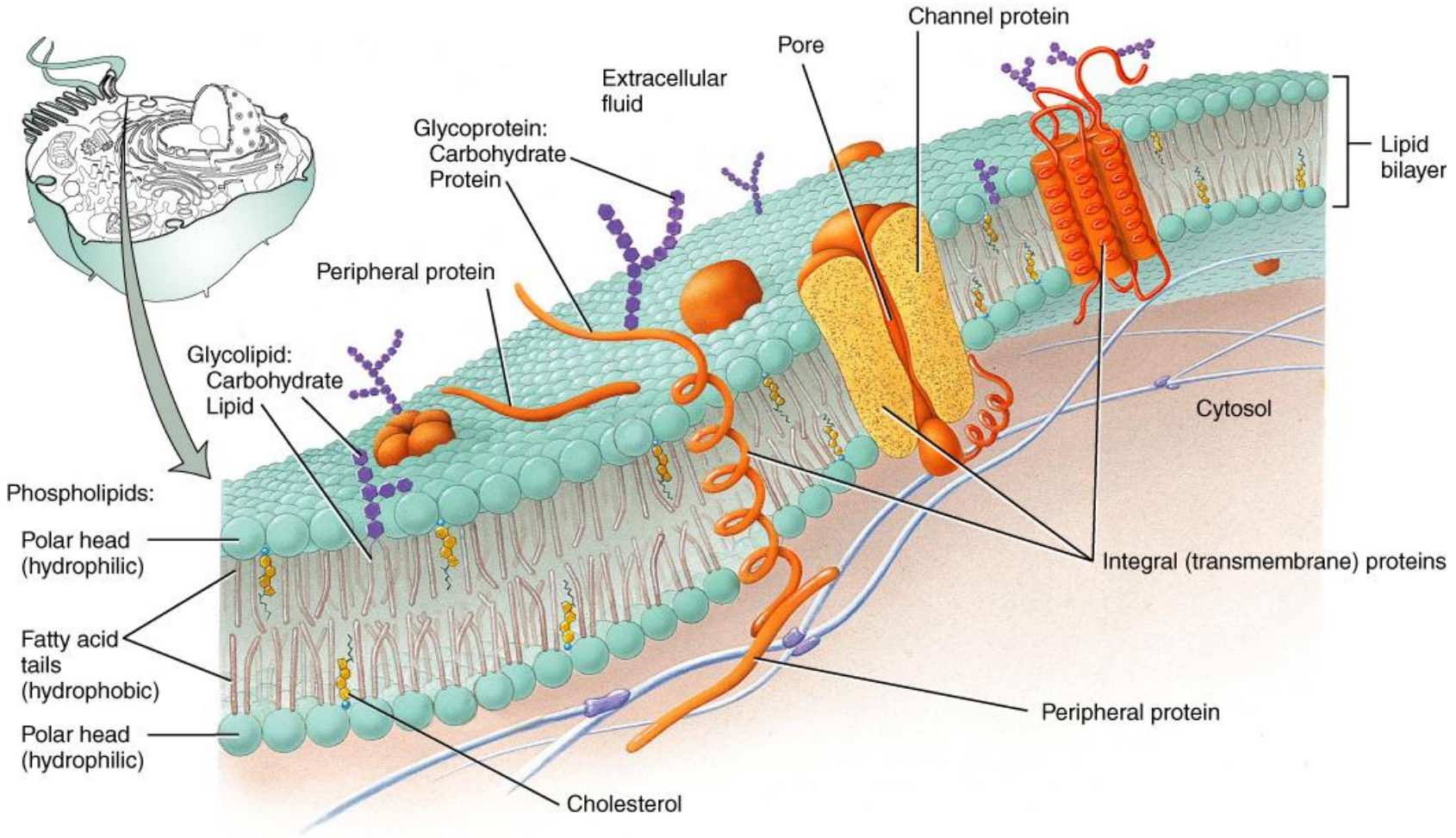
Textbook: Guyton Medical Textbook of Physiology By: Guyton and Hall 12th edition

Objectives

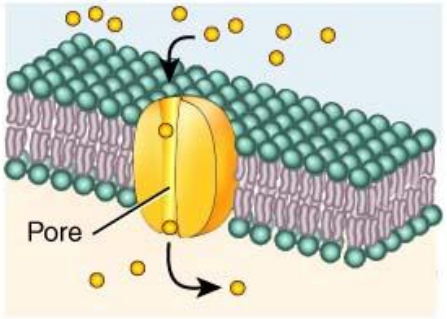
- Define first messenger (Hormones)
- List hormone types
- Describe receptor types
- Outline the hormone receptors interactions
- Describe second messenger mechanism of action
- List second messengers



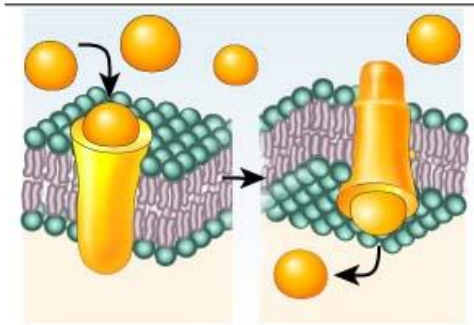
Sectional view


Channel protein
Pore
Extracellular fluid
Glycoprotein:
Carbohydrate
Protein
Lipid bilayer
Peripheral protein
Glycolipid:
Carbohydrate
Lipid
Cytosol
Phospholipids:
Polar head (hydrophilic)
Integral (transmembrane) proteins
Fatty acid tails (hydrophobic)
Peripheral protein
Polar head (hydrophilic)
Cholesterol

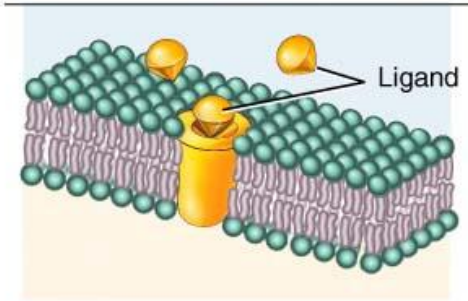
Extracellular fluid Plasma membrane Cytosol



Ion channel
Allows specific ion (●) to move through water-filled pore. Most plasma membranes include specific channels for several common ions.

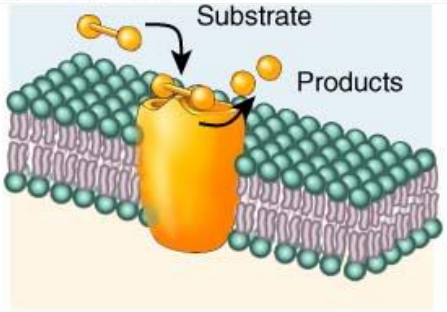


Transporter
Transporters specific substances (●) across membrane by changing shape. For example, amino acids, needed to synthesize new proteins, enter body cells via transporters.

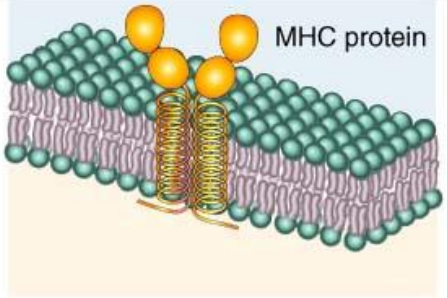


Receptor
Recognizes specific ligand (▼) and alters cell's function in some way. For example, antidiuretic hormone binds to receptors in the kidneys and changes the water permeability of certain plasma membranes.

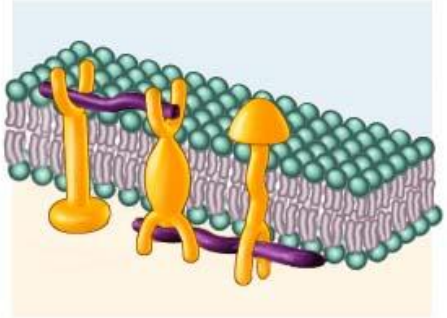
Extracellular fluid Plasma membrane Cytosol



Enzyme
Catalyzes reaction inside or outside cell (depending on which direction the active site faces). For example, lactase protruding from epithelial cells lining your small intestine splits the disaccharide lactose in the milk you drink.

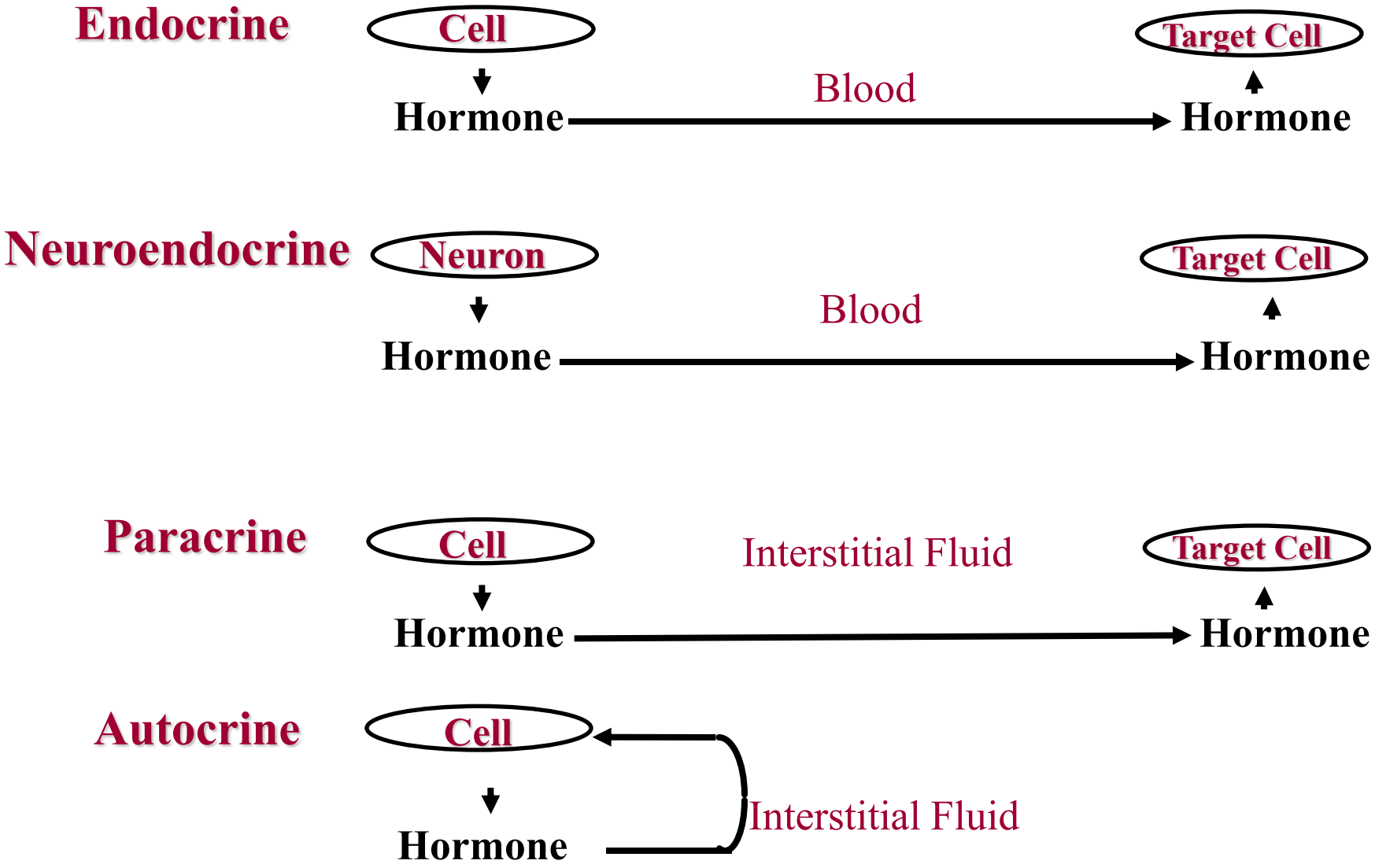


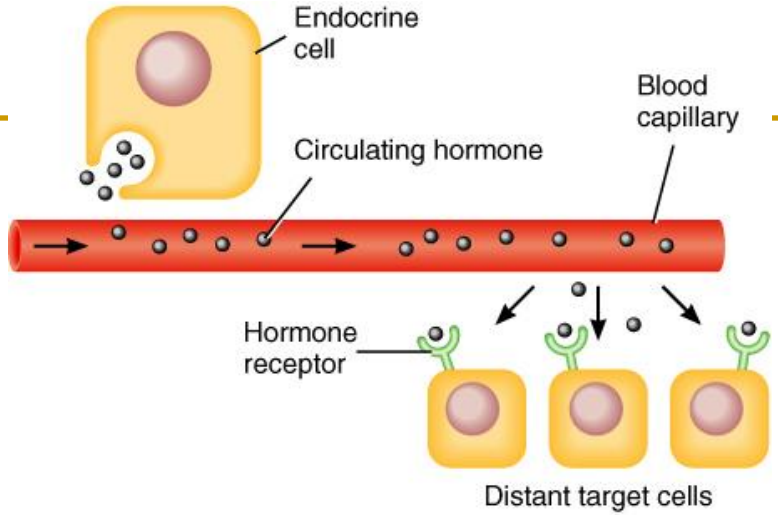
Cell Identity Marker
Distinguishes your cells from anyone else's (unless you are an identical twin). An important class of such markers are the major histocompatability (MHC) proteins.



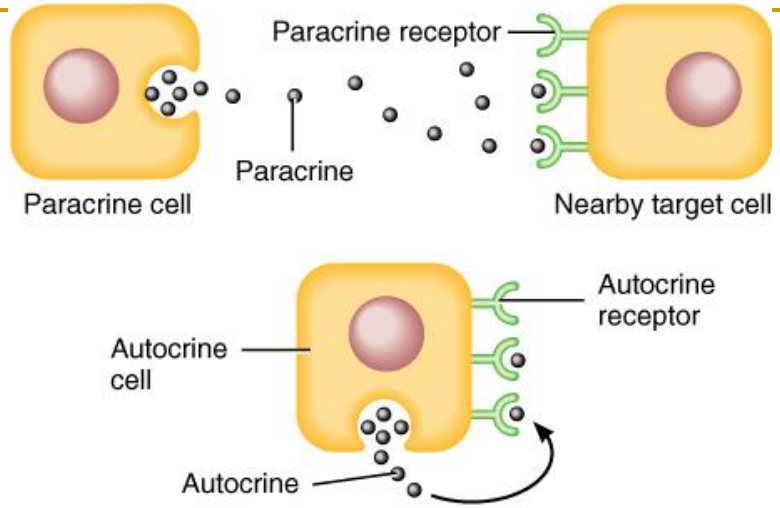
Linker
Anchors filaments inside and outside to the plasma membrane, providing structural stability and shape for the cell. May also participate in movement of the cell or link two cells together.

Intercellular Communication



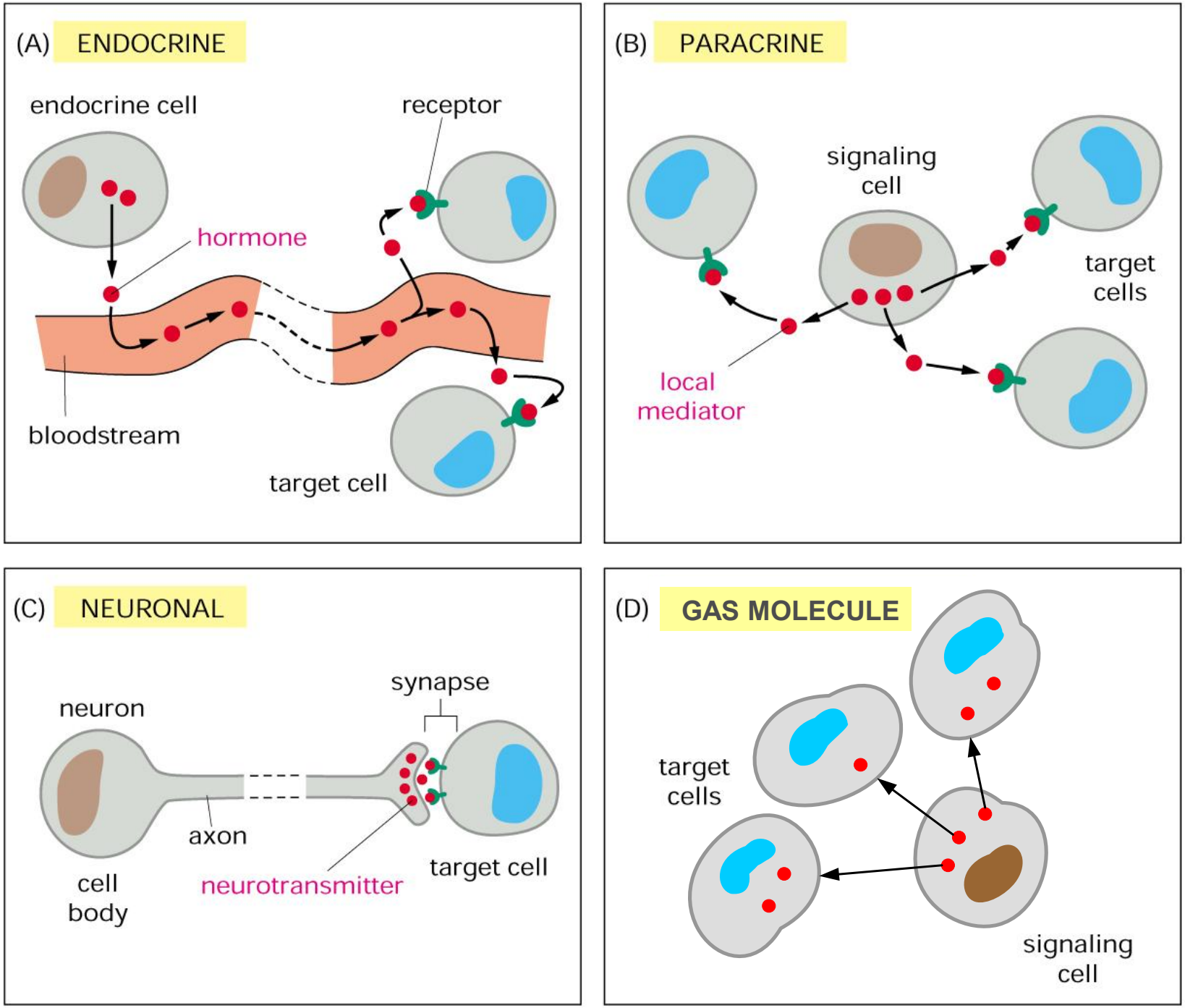


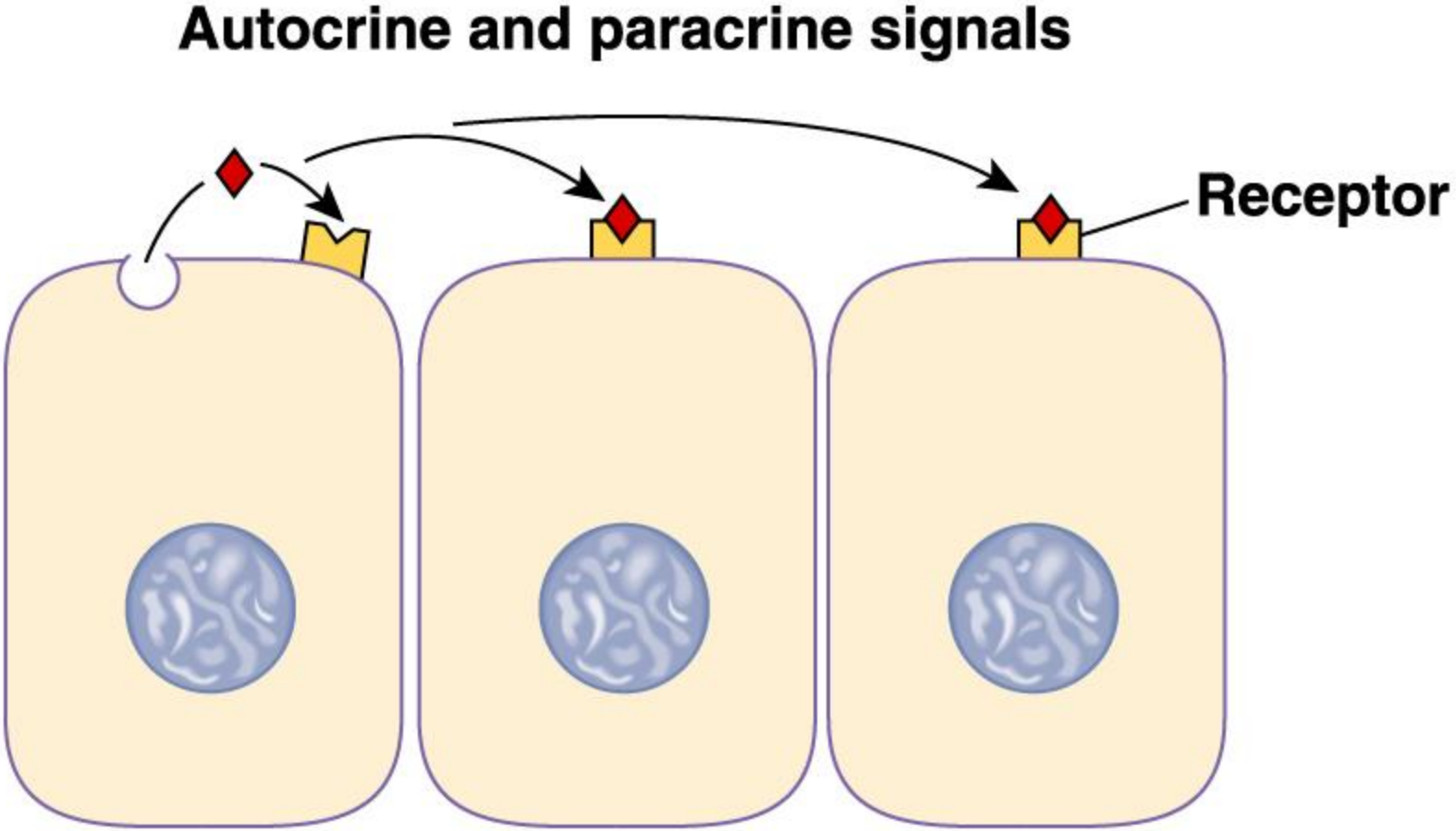
(a) Circulating hormones

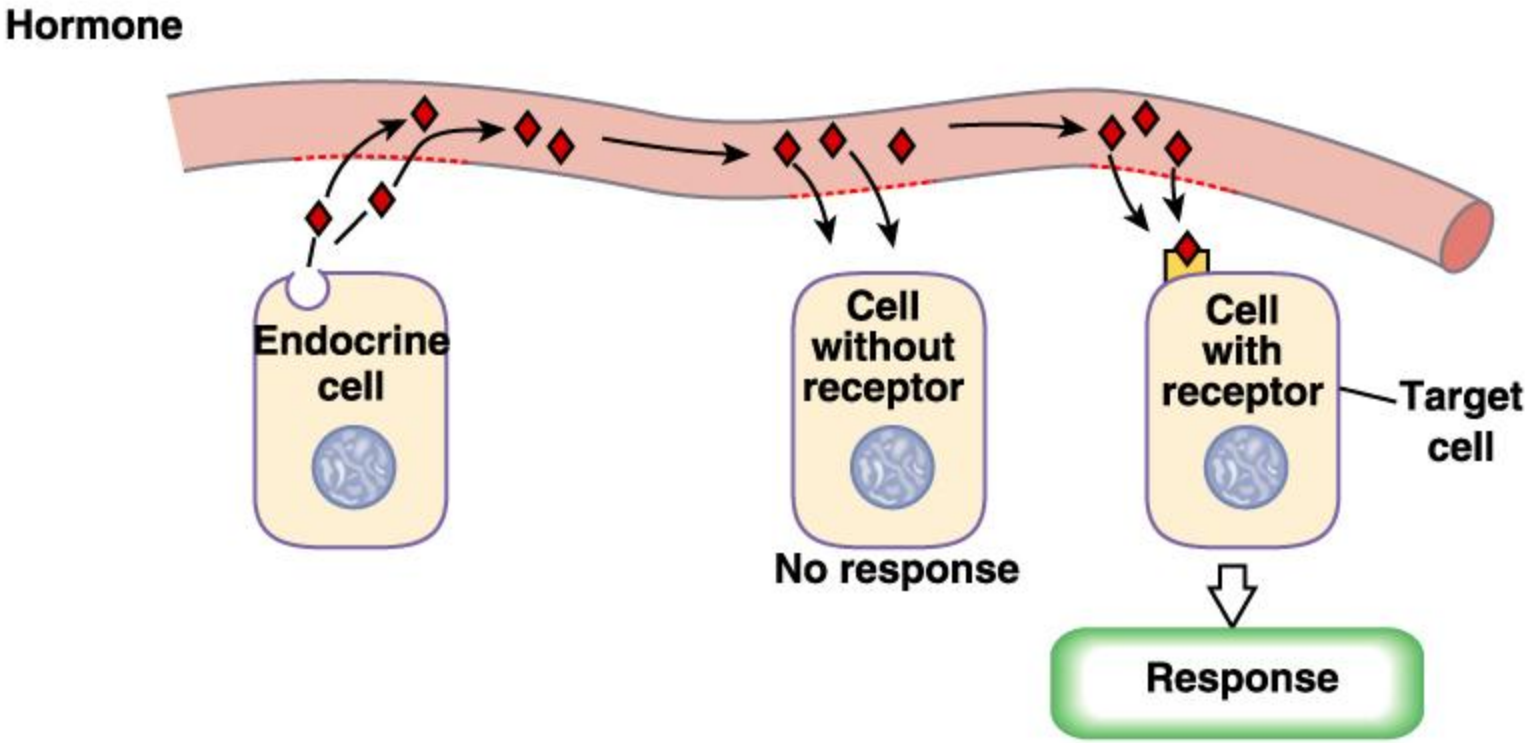


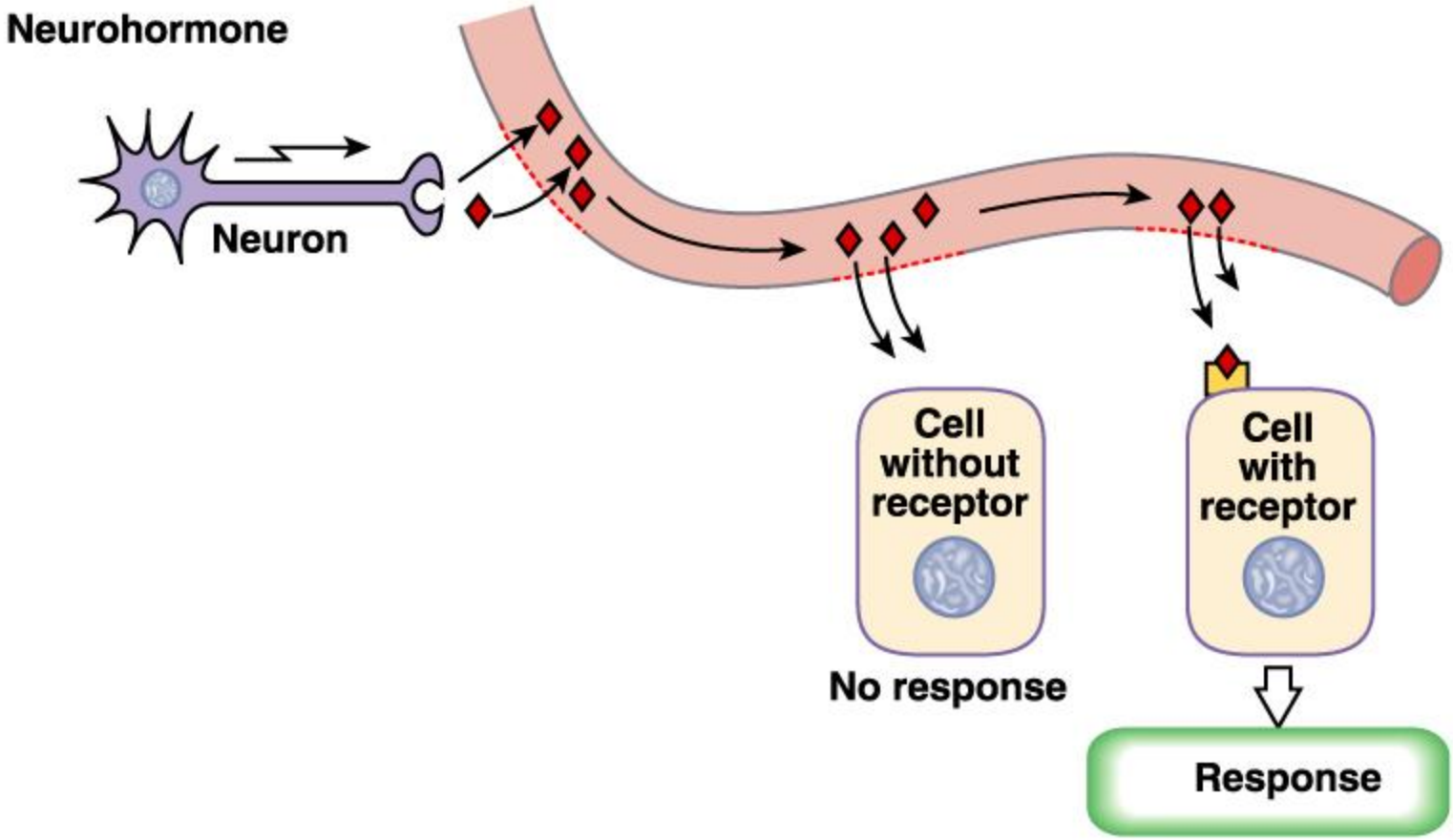
(b) Local hormones (paracrines and autocrines)

18.02


(A) ENDOCRINE
endocrine cell
receptor
hormone
bloodstream
target cell
(B) PARACRINE
signaling cell
target cells
local mediator
(C) NEURONAL
synapse
neuron
axon
cell body
neurotransmitter
target cell
(D) GAS MOLECULE
target cells
signaling cell


Autocrine and paracrine signals
Receptor


Hormone
Endocrine cell
Cell without receptor
No response
Cell with receptor
Target cell
Response


Neurohormone
Neuron
Cell without receptor
Cell with receptor
No response
Response

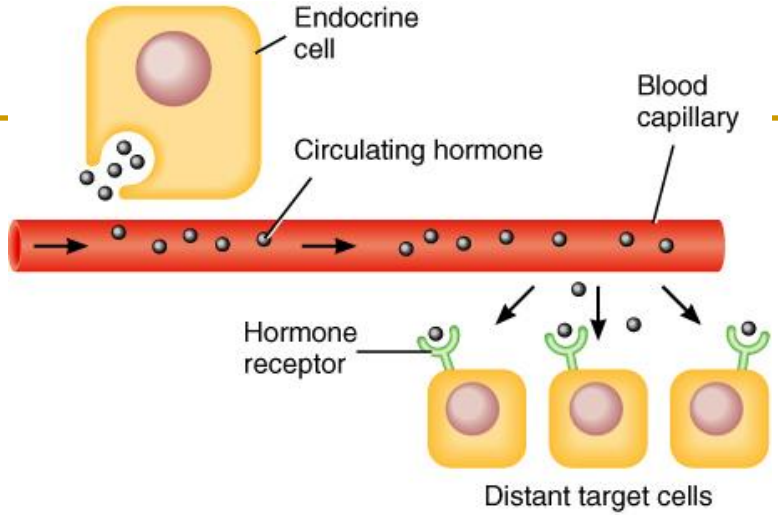
Endocrine Glands and Hormones

- Neurohormone:
  - Specialized neurons that secrete chemicals into the blood rather than synaptic cleft.
    - Chemical secreted is called neurohormone.
- Hormones:
  - Affect metabolism of target organs.
    - Help regulate total body metabolism, growth, and reproduction.

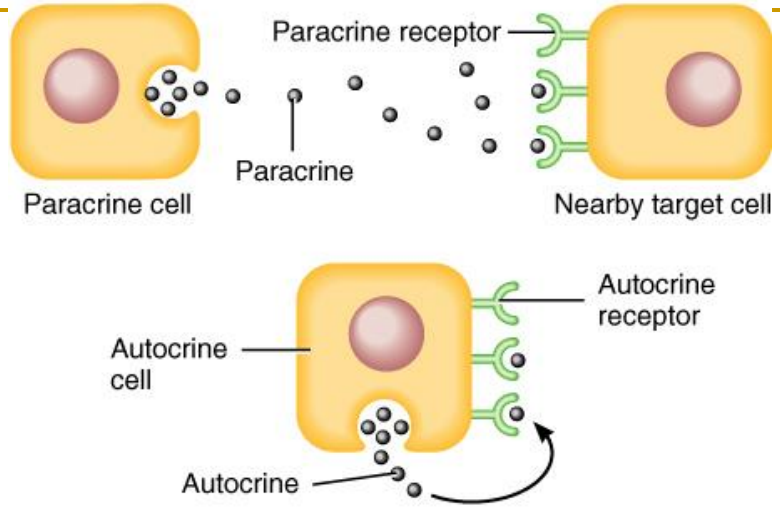
Classes of Hormones

- Peptide and Protein Hormones (amino acid chain)
- Steroid Hormones (derived from chlesterol)
- Amine Hormones (derived from amino acid e.g tyrosin)
- Gas – Nitric Oxide (NO)

- Hormone types
  - Circulating – circulate in blood throughout body
  - Local hormones – act locally
    - Paracrine – act on neighboring cells
    - Autocrine – act on the same cell that secreted them



(a) Circulating hormones



(b) Local hormones (paracrines and autocrines)

18.02

Chemical classes of hormones

- Lipid-soluble hormones- use transport proteins in the plasma
  - Steroid: Lipids derived from cholesterol.
    - Are lipophilic hormones.
      - Testosterone.
      - Estradiol.
      - Cortisol.
      - Progesterone.
  - Thyroid (amine but lipid soluble)
  - Nitric oxide (NO)

Chemical classes of hormones …cont

- Water-soluble – circulate in "free" form in the plasma
  - Amines:
    - Hormones derived from tyrosine and tryptophan.
  - Polypeptides and proteins:
    - Polypeptides:
      - Chains of < 100 amino acids in length.
        - ADH.
    - Protein hormones:
      - Polypeptide chains with > 100 amino acids.
      - Growth hormone.
  - Eicosanoid (prostaglandins) derived from arachidonic acid (20 carbon 4 double bonds)

Chemical Classification of Hormones …cont

- Glycoproteins:
  - Long polypeptides (>100) bound to 1 or more carbohydrate (CHO) groups.
    - FSH and LH, TSH and hCG (human chorionic gonadotropin)

      They have α and β subunits (α is common and β is specific)
- Hormones can also be divided into:
  - Polar:
    - H_20 soluble.
  - Nonpolar (lipophilic):
    - H_20 insoluble.
      - Can gain entry into target cells.
      - Steroid hormones and T_4 (thyrxine –tetraiodothyronine))

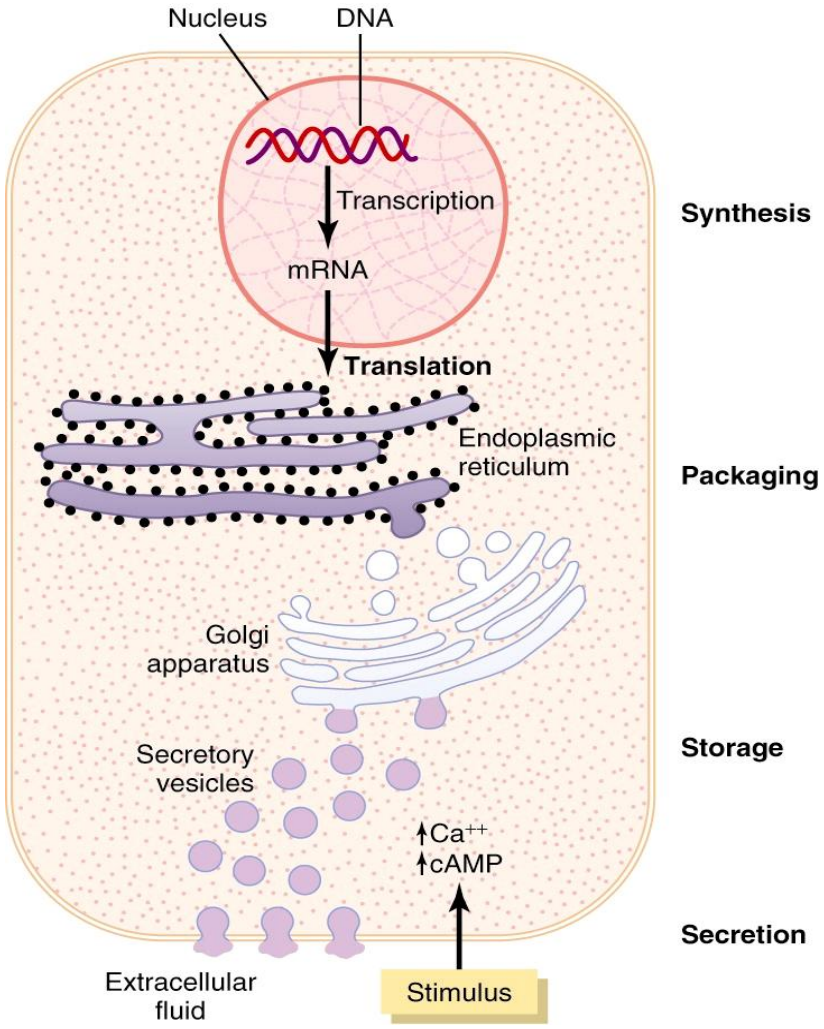
Prohormones and Prehormones

- Prohormone:
  - Precursor is a longer chained polypeptide that is cut and spliced together to make the hormone.
    - Proinsulin – gives insulin
- Preprohormone:
  - Prohormone derived from larger precursor molecule.
    - Preproinsulin.
- Prehormone:
  - Molecules secreted by endocrine glands that are inactive until changed into hormones by target cells.
    - T_4 converted to T_3 (tri-iodothyronin).

Peptide & Protein Hormones

Gland/Tissue	Hormones	Gland/Tissue	Hormones
Hypothalamus	▪ TRH, GnRH, CRH GHRH, Somatostatin,	Placenta	▪ HCG, HCS or HPL
Anterior pituitary	▪ ACTH, TSH, FSH, LH, PRL, GH	Kidney	▪ Renin
Posterior pituitary	▪ Oxytocin, ADH	Heart	▪ ANP
Thyroid	▪ Calcitonin	G.I. tract	▪ Gastrin, CCK, Secretin, GIP, Somatostatin
Pancreas	▪ Insulin,Glucagon, Somatostatin		
Liver	▪ Somatomedin C (IGF-1)	Adipocyte	▪ Leptin
Parathyroid	▪ PTH	Adrenal medulla	▪ Norepinephrine, epinephrine

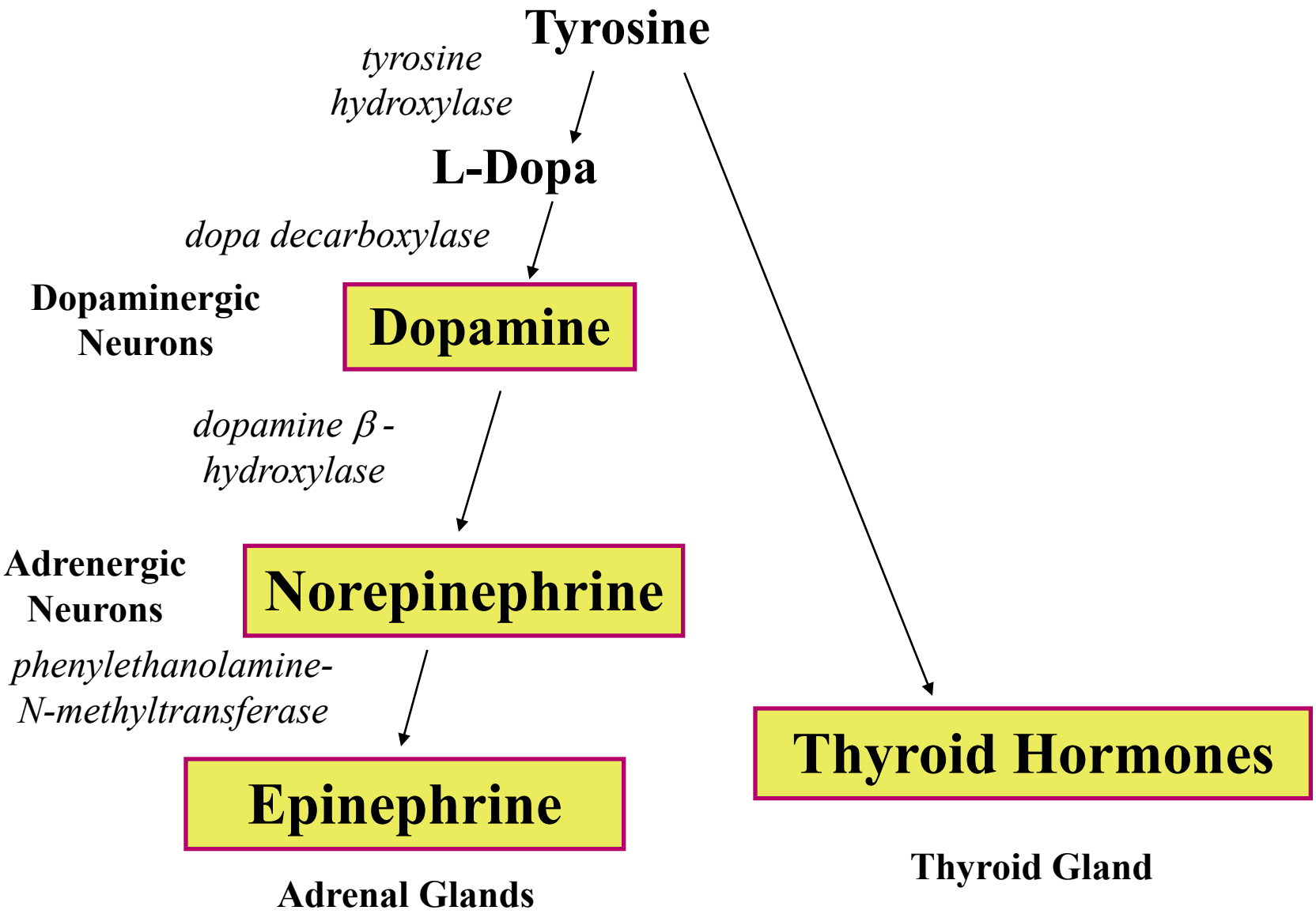
Synthesis and secretion of peptide hormones



Amine Hormones

Gland/Tissue	Hormones
Hypothalamus	▪ Dopamine
Thyroid	▪ T_3, T_4
Adrenal medulla	▪ Epinephrine and Norepinephrine (NE, EPI)

Synthesis of Amine Hormones



Steroid Hormones

Gland/Tissue	Hormones
Adrenal Cortex	▪ Cortisol, Aldosterone, Androgens
Testes	▪ Testosterone
Ovaries	▪ Estrogens, Progesterone
Corpus Luteum	▪ Estrogens, Progesterone
Placenta	▪ Estrogens, Progesterone
Kidney	▪ 1,25-Dihydroxycholecalciferol (calcitriol)

Thank you

Hormone Activity

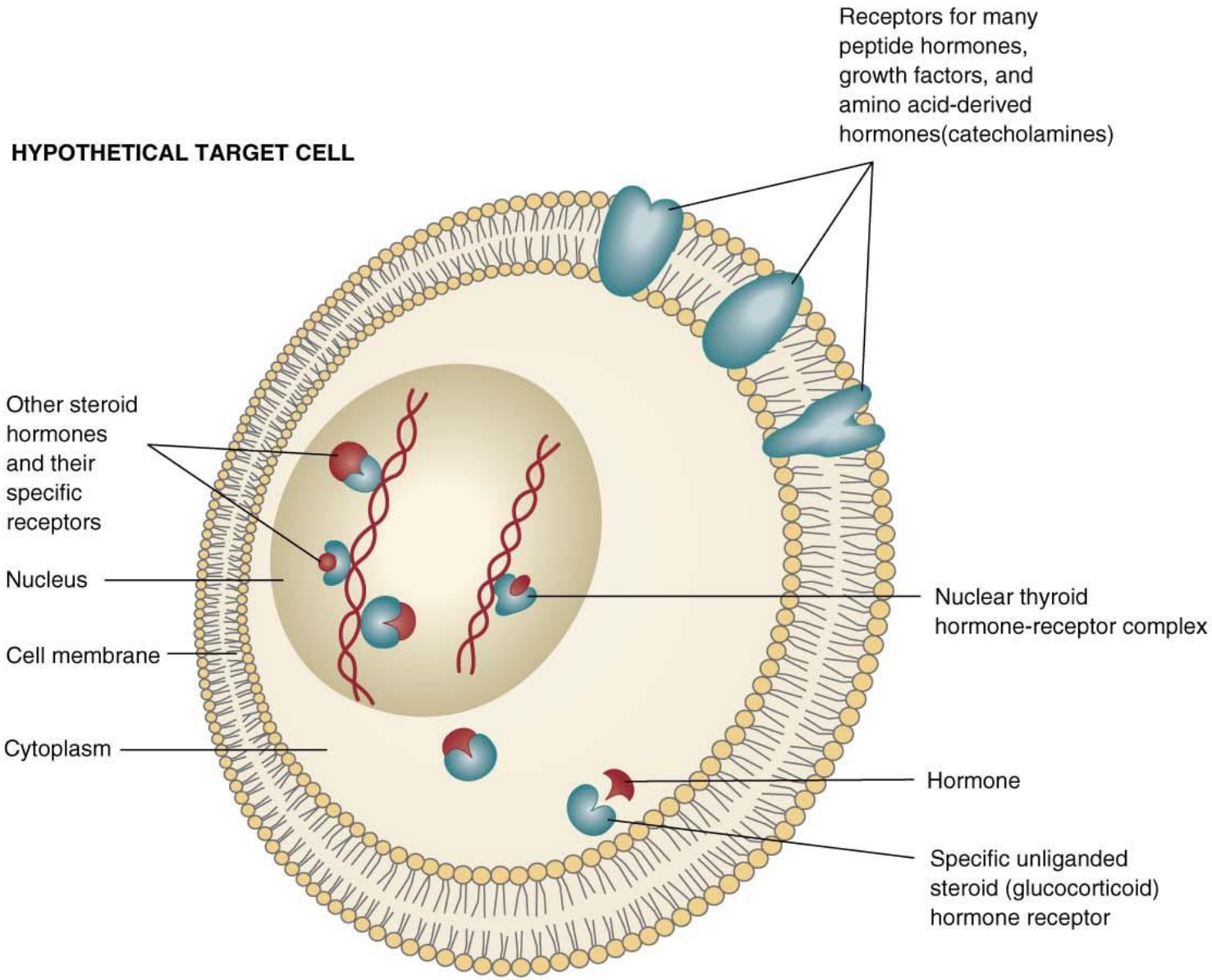
- Hormones affect only specific target tissues with specific receptors
- Receptors are dynamic and constantly synthesized and broken down
  - Down-regulation- decrease in receptor number or esponse
  - Up-regulation- increase in receptor number or activity

Effects of [Hormone] on Tissue Response

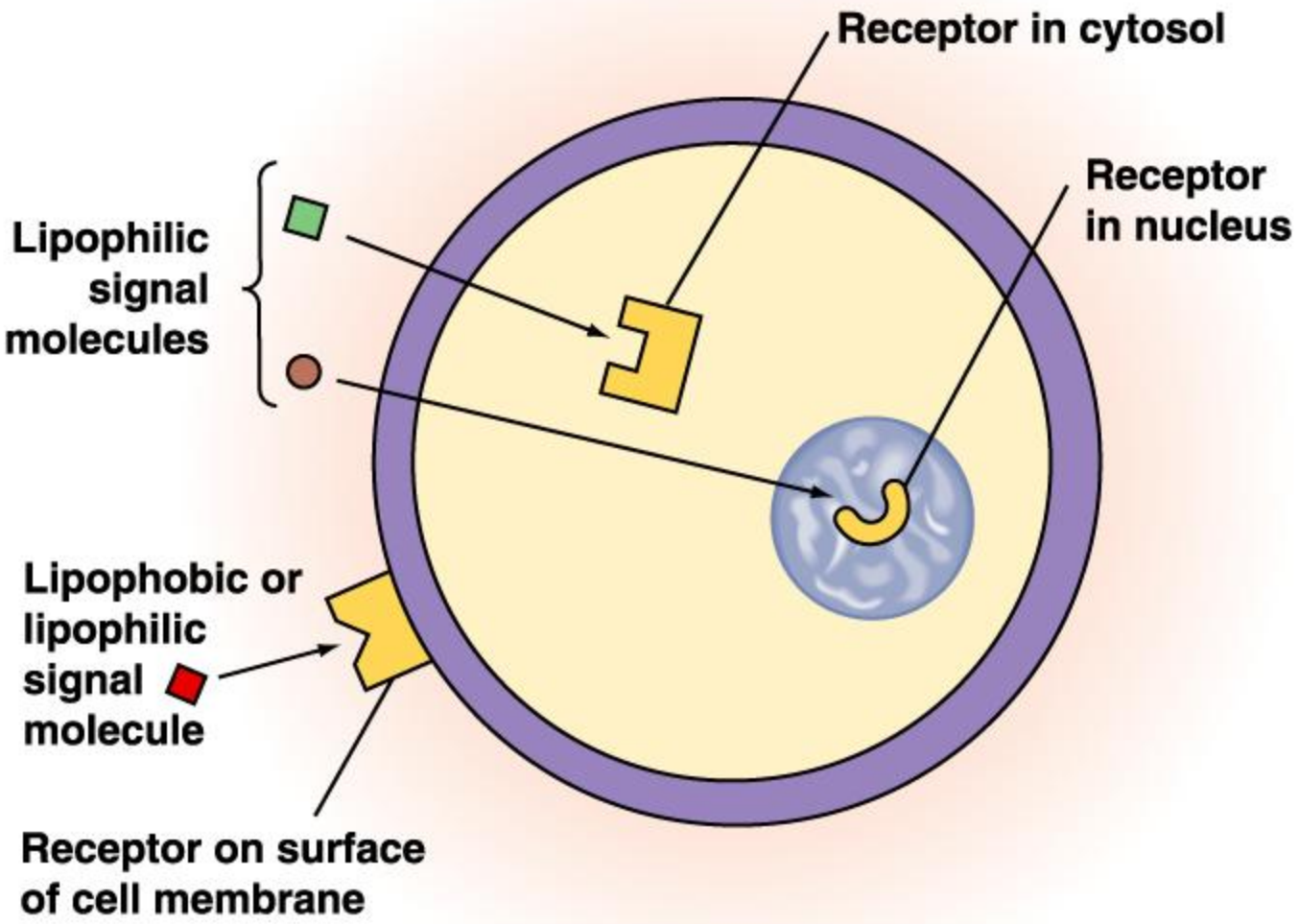
- Priming effect (upregulation):
  - Increase number of receptors formed on target cells in response to particular hormone.
  - Greater response by the target cell.
- Desensitization (downregulation):
  - Prolonged exposure to high [polypeptide hormone].
    - Subsequent exposure to the same [hormone] produces less response.
      - Decrease in number of receptors on target cells.
        - Insulin in adipose cells.
  - Pulsatile secretion may prevent downregulation.

Effects of hormone concentration on Tissue Response

- [Hormone] in blood reflects the rate of secretion.
- Half-life:
  - Time required for the blood [hormone] to be reduced to ½ reference level.
    - Minutes to days.
- Normal tissue responses are produced only when [hormone] are present within physiological range.
- Varying [hormone] within normal, physiological range can affect the responsiveness of target cells.



. Diagram showing the different locations of classes of hormone receptors expressed by a target cell.


Receptor in cytosol
Receptor in nucleus
Lipophilic signal molecules
Lipophobic or lipophilic signal molecule
Receptor on surface of cell membrane

Mechanisms of Hormone Action

- Hormones of same chemical class have similar mechanisms of action.
  - Similarities include:
    - Location of cellular receptor proteins depends on the chemical nature of the hormone.
    - Events that occur in the target cells.
- To respond to a hormone:
  - Target cell must have specific receptors for that hormone (specificity).
    - Hormones exhibit:
      - Affinity (bind to receptors with high bond strength).
      - Saturation (low capacity of receptors).

Mechanisms of Hormone Action

- Response depends on both hormone and target cell
- Lipid-soluble hormones bind to receptors inside target cells
- Water-soluble hormones bind to receptors on the plasma membrane
  - Activates second messenger system
  - Amplification of original small signal
- Responsiveness of target cell depends on
  - Hormone's concentration
  - Abundance of target cell receptors

Receptor

Receptors are specific membrane proteins, which are able to recognize and bind to corresponding ligand molecules, become activated, and transduce signal to next signaling molecules.

Glycoprotein or Lipoprotein

ligand

A small molecule that binds specifically to a larger one; for example, a hormone is the ligand for its specific protein receptor.

- **Membrane receptors**

  Membrane Glycoprotein

- **Intracellular receptors**

  Cytosol or nuclei

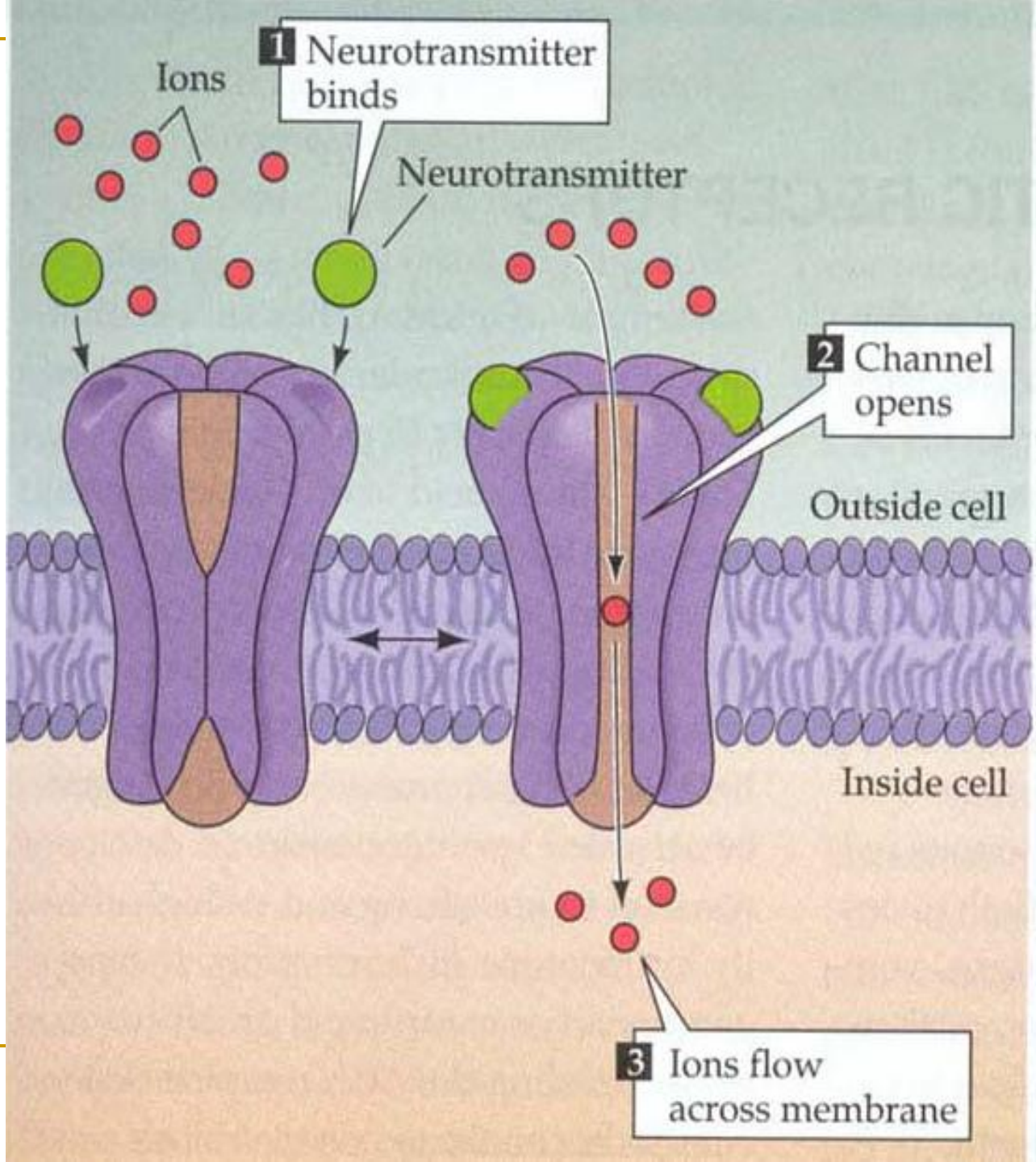
  DNA binding protein

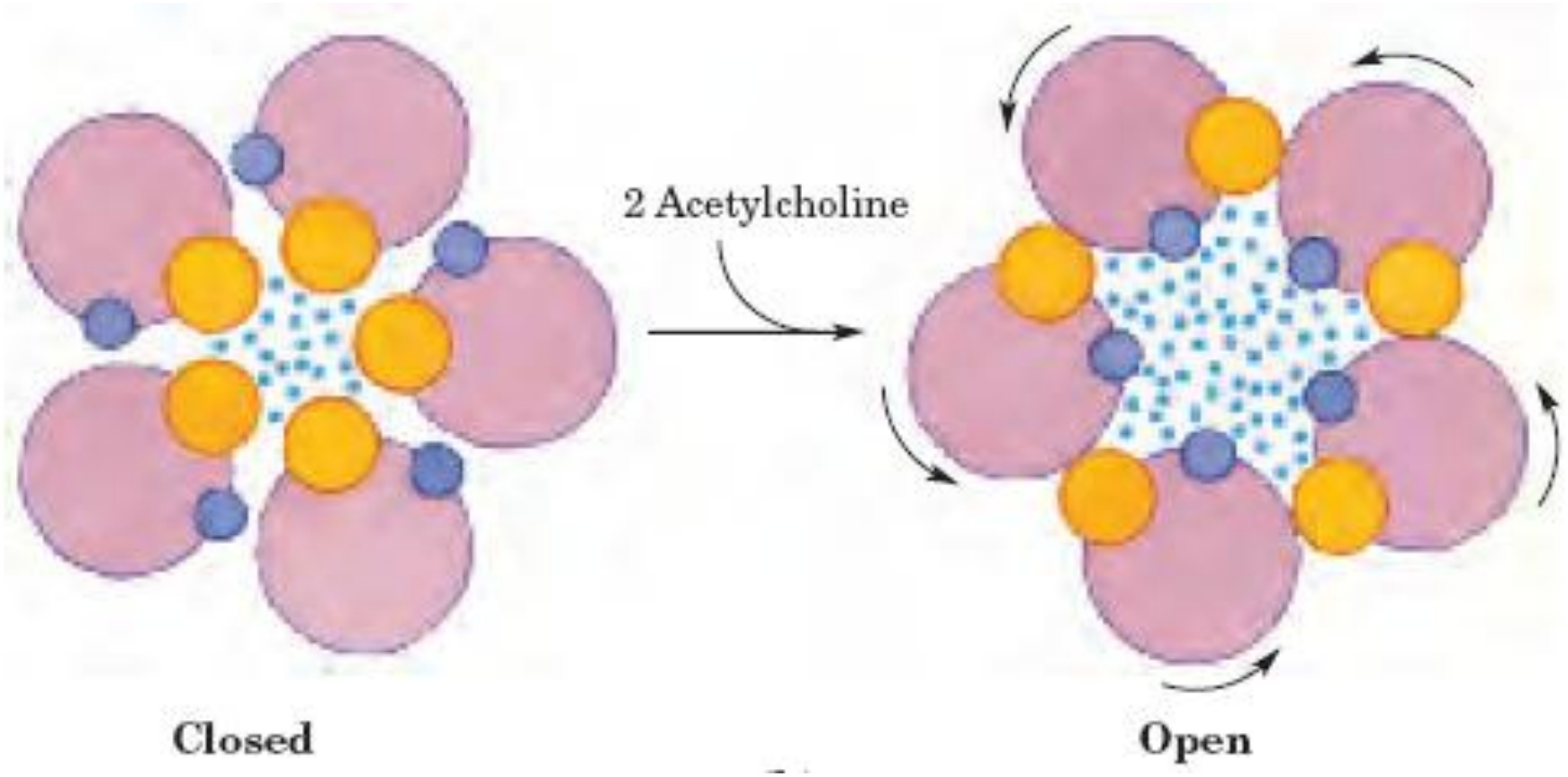
1. membrane receptors

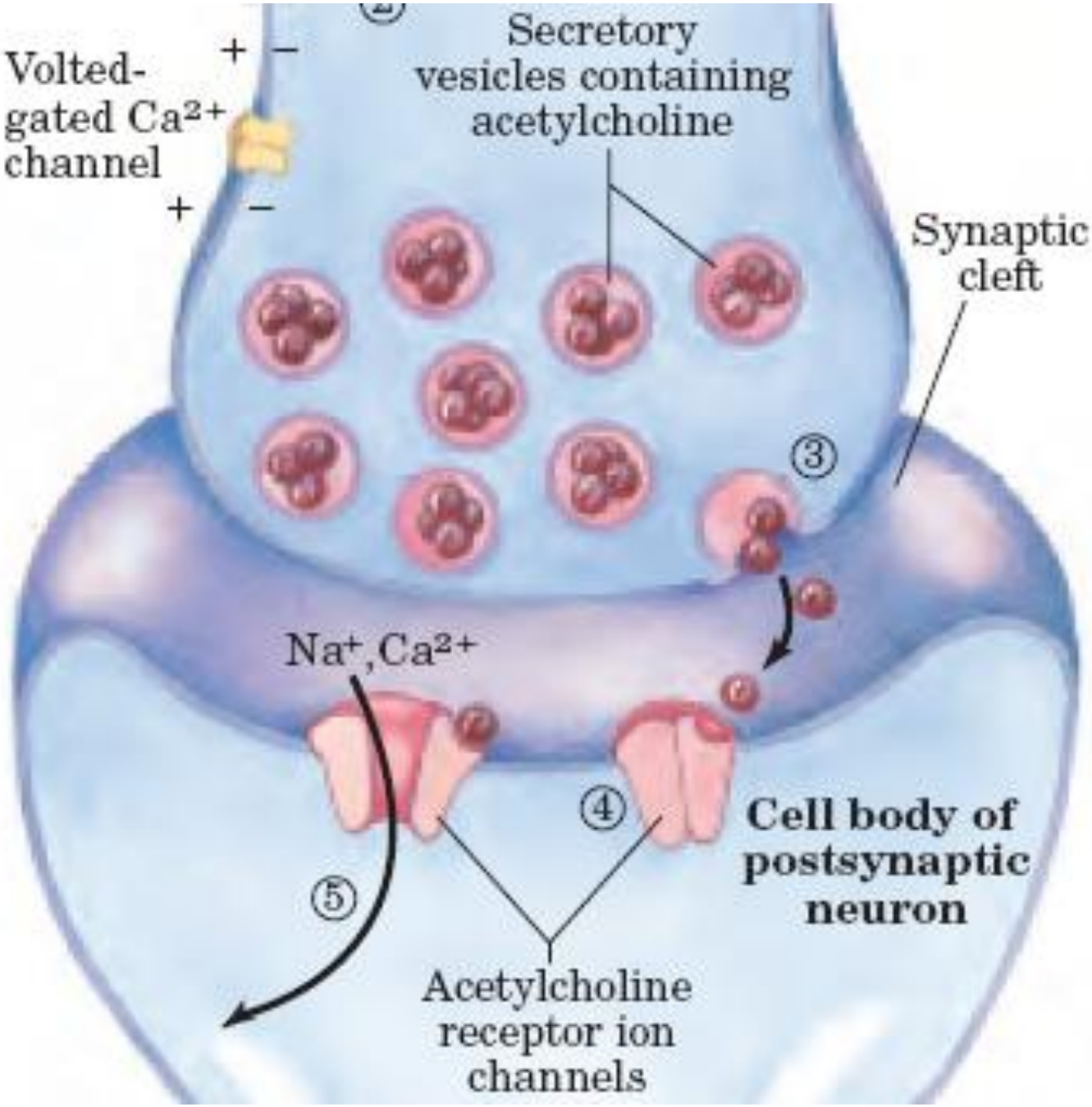
1- Ligand-gate ion channels type

(cyclic receptor)

ligand→receptor→ion channel open or close

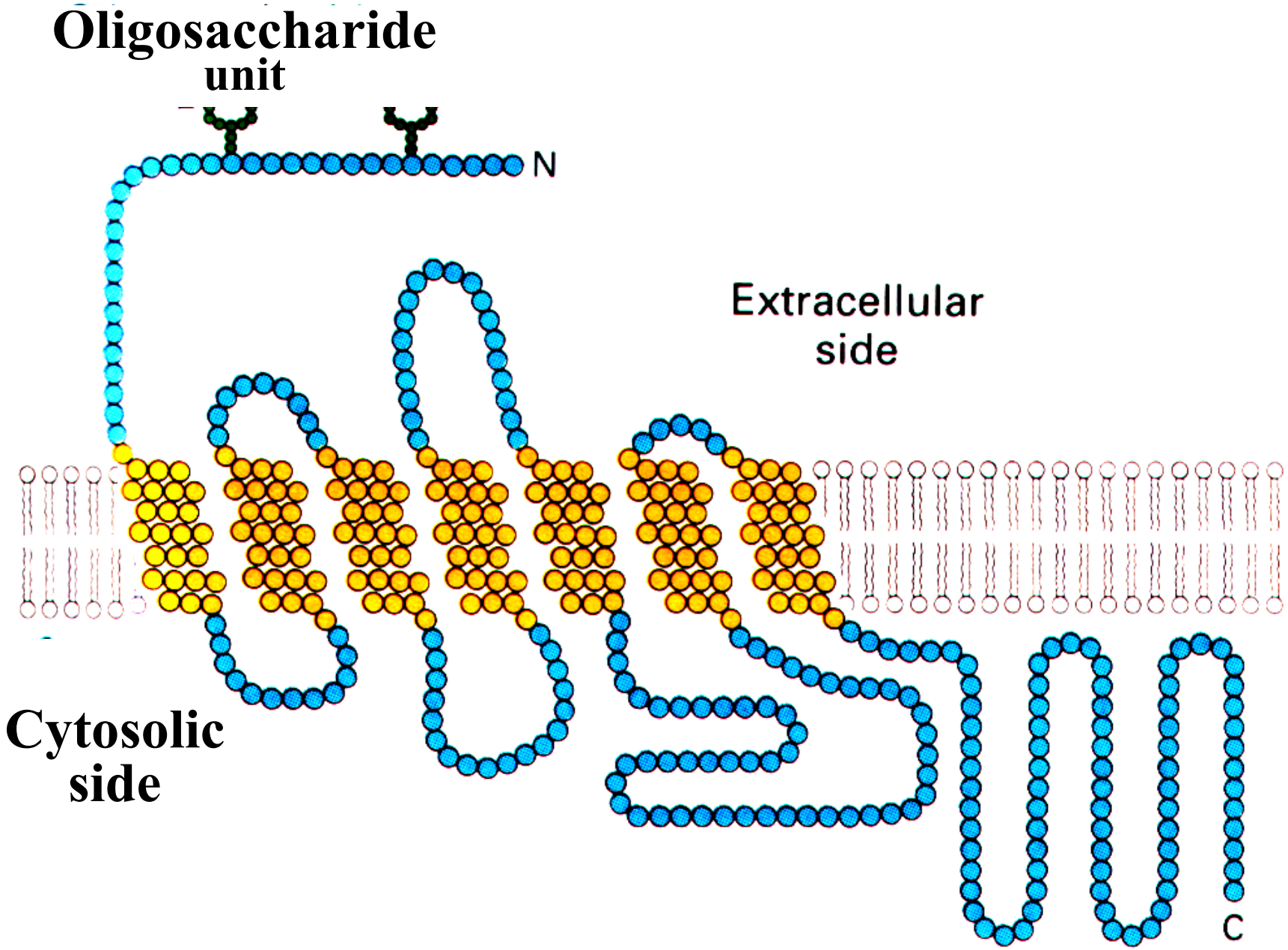

Ions
1 Neurotransmitter binds
Neurotransmitter
2 Channel opens
Outside cell
Inside cell
3 Ions flow across membrane


2 Acetylcholine
Closed
Open


Volted-gated Ca^{2+} channel
+ −
+ −
Secretory vesicles containing acetylcholine
Synaptic cleft
③
Na^+, Ca^{2+}
④
Cell body of postsynaptic neuron
⑤
Acetylcholine receptor ion channels

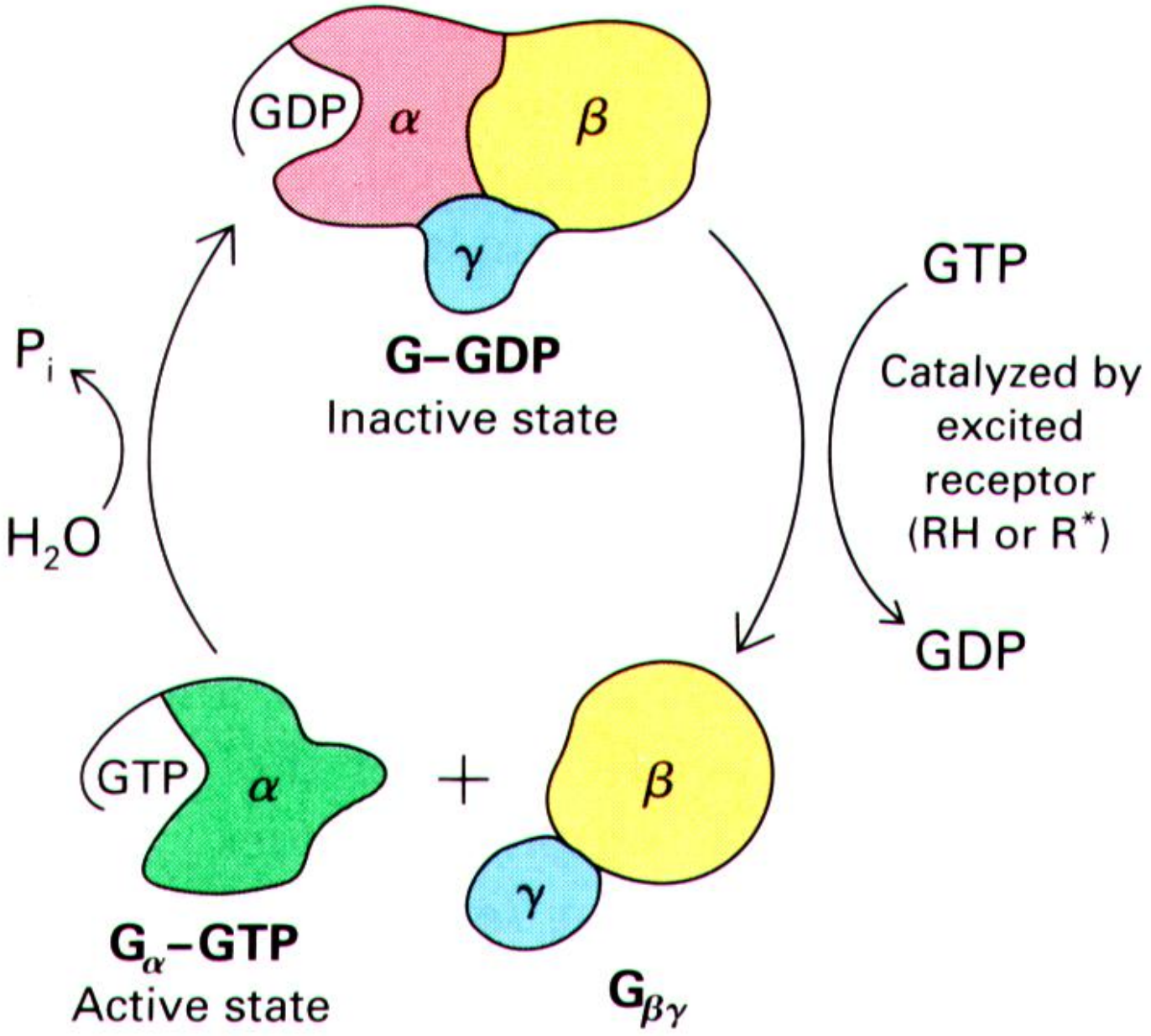
2- G Protein-Coupled Receptors

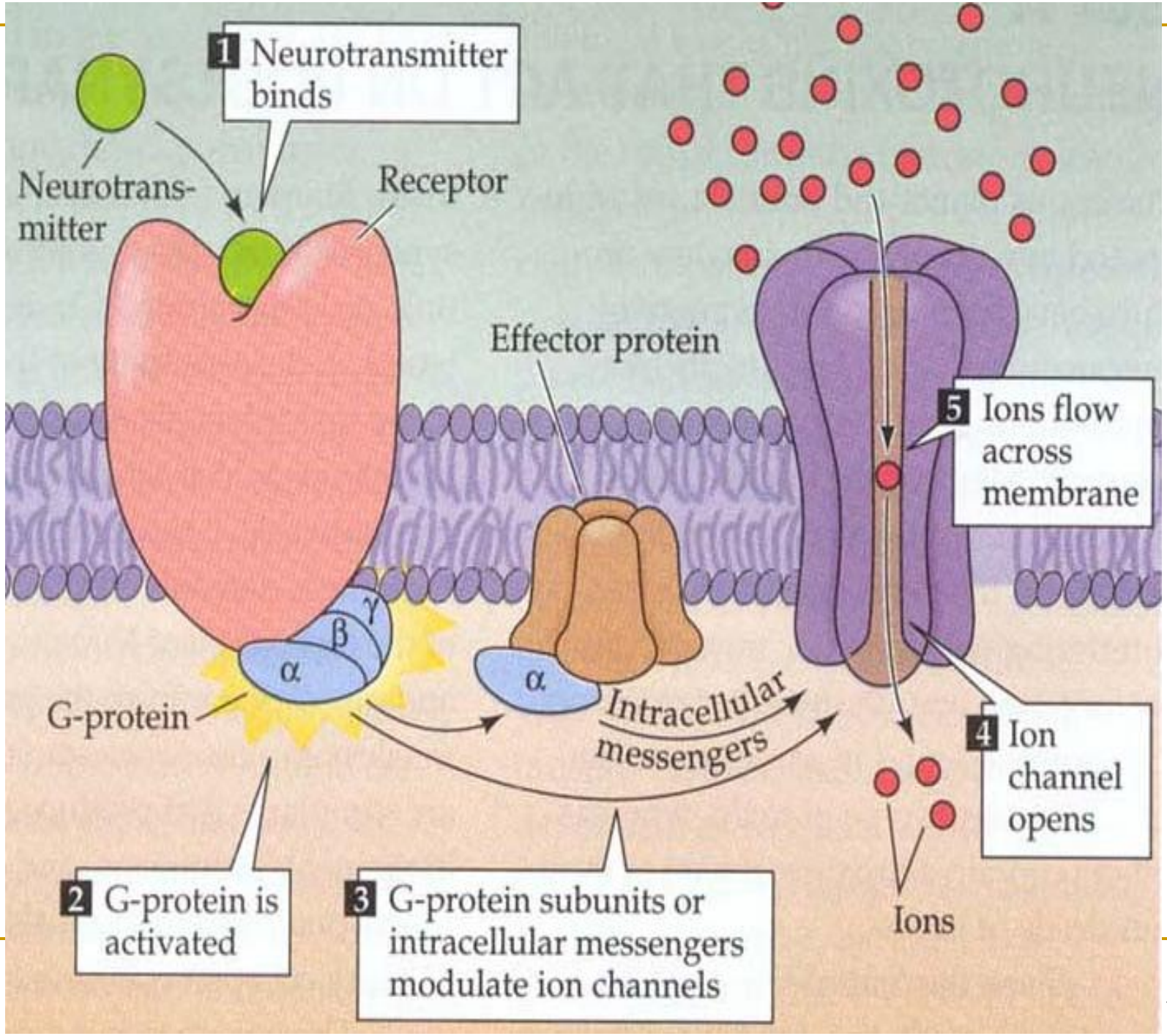
I- 7-helices transmembrane receptor

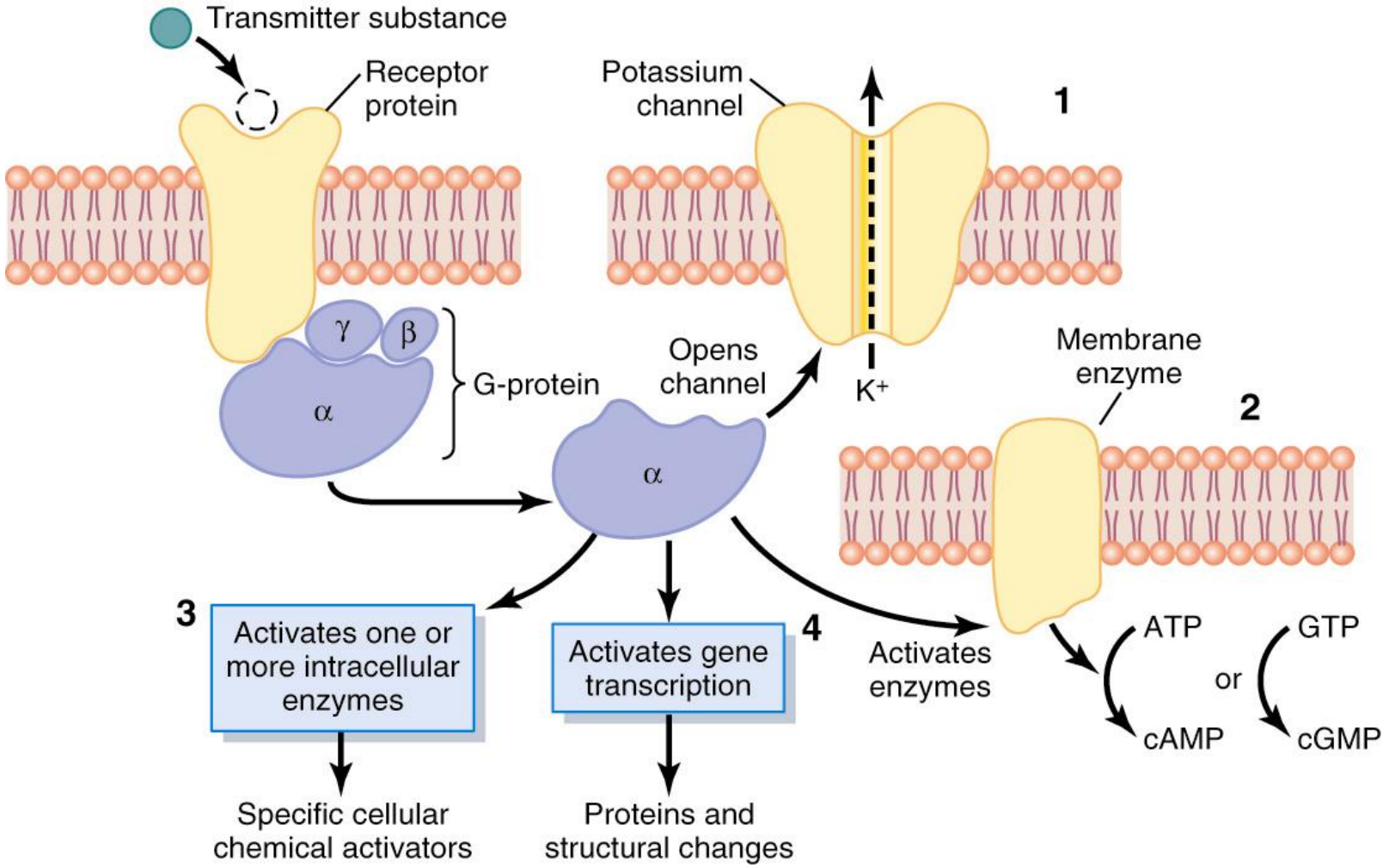

Oligosaccharide unit
N
Extracellular side
Cytosolic side
C

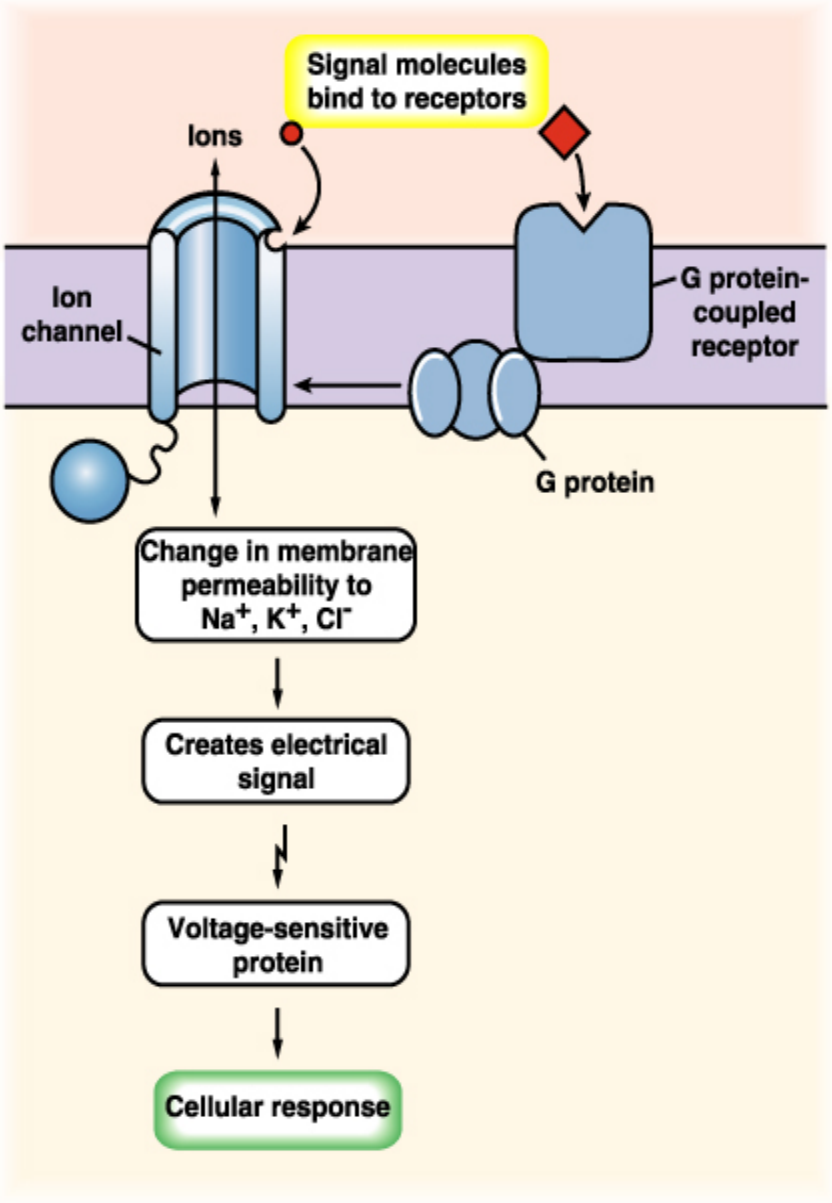
2) G protein (Guanylate binding protein)

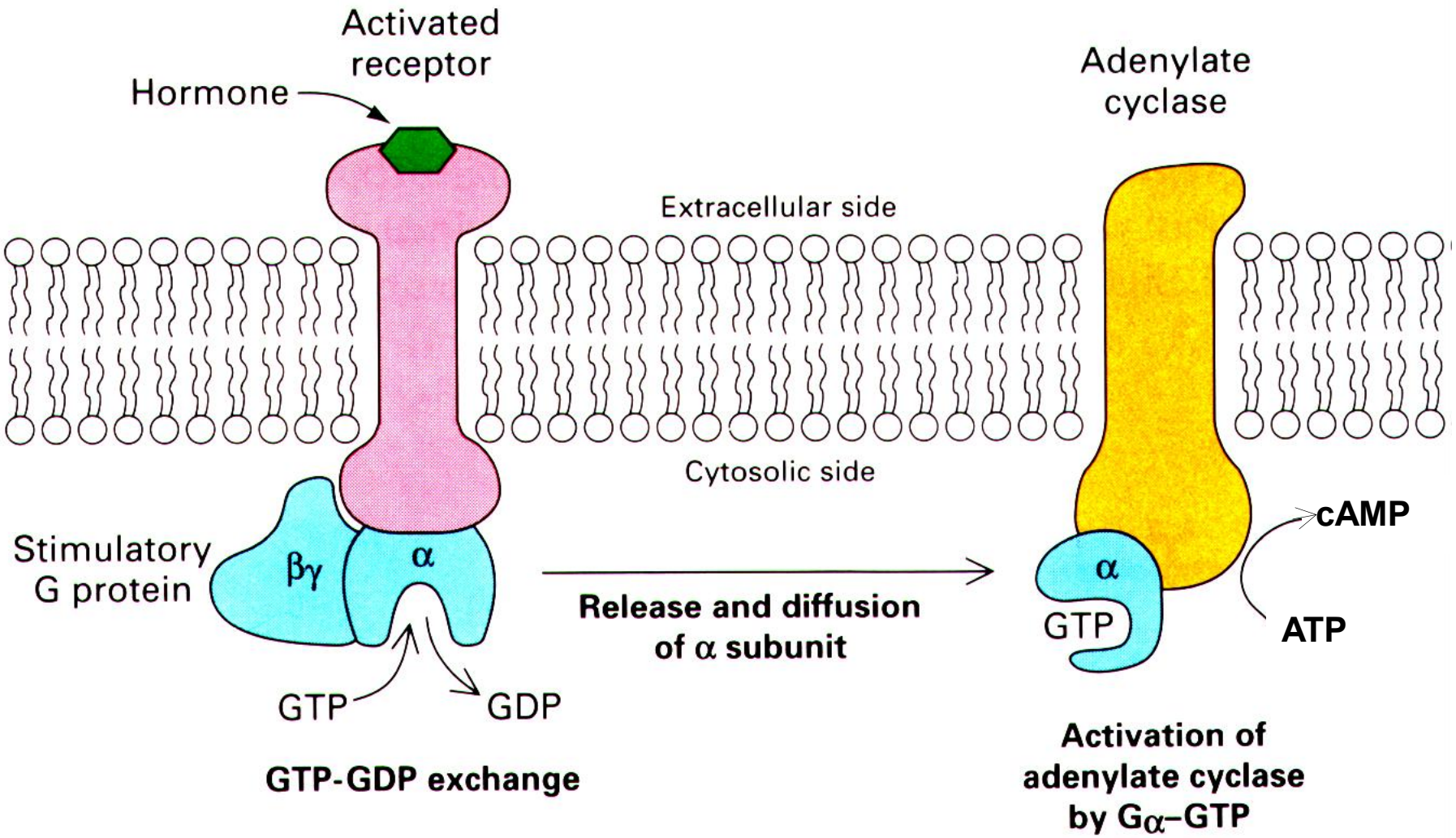
- G protein refers to any protein which binds to GDP or GTP and act as signal transduction.
- G proteins consist of three different subunits (α, β, γ-subunit) bound to GDP when exchanged to GTP activate α-subunit
- α-subunit carries GTPase activity, binding and hydrolysis of GTP.


GDP
α
β
γ
G–GDP
Inactive state
GTP
Catalyzed by
excited
receptor
(RH or R*)
GDP
Pi
H2O
GTP
α
β
γ
Gα–GTP
Active state
Gβγ

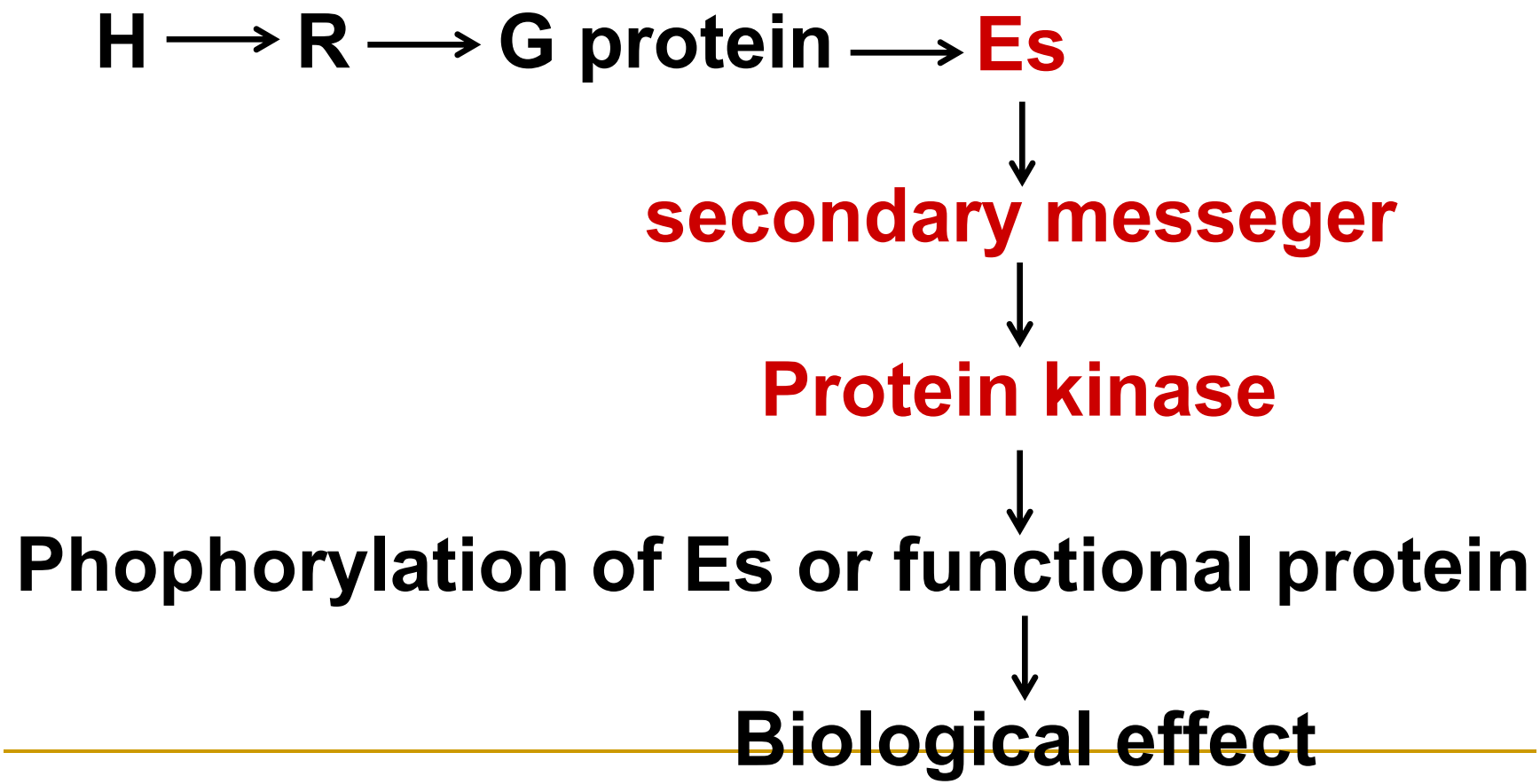

1 Neurotransmitter binds
Neurotrans-
mitter
Receptor
Effector protein
5 Ions flow across membrane
γ
β
α
α
G-protein
Intracellular messengers
4 Ion channel opens
2 G-protein is activated
3 G-protein subunits or intracellular messengers modulate ion channels
Ions


Transmitter substance
Receptor protein
Potassium channel
1
γ
β
α
G-protein
Opens channel
K+
Membrane enzyme
2
α
3
Activates one or more intracellular enzymes
Specific cellular chemical activators
4
Activates gene transcription
Proteins and structural changes
Activates enzymes
ATP
GTP
or
cAMP
cGMP


Signal molecules bind to receptors
Ions
Ion channel
G protein-coupled receptor
G protein
Change in membrane permeability to Na^+, K^+, Cl^-
Creates electrical signal
Voltage-sensitive protein
Cellular response


Activated
receptor
Hormone
Adenylate
cyclase
Extracellular side
Cytosolic side
Stimulatory
G protein
βγ
α
GTP
GDP
GTP-GDP exchange
Release and diffusion
of α subunit
α
GTP
cAMP
ATP
Activation of
adenylate cyclase
by Gα–GTP

- Pathway of G protein linked receptor



Properties of binding of H and R

- high specificity
- high affinity
- saturation
- reversible binding
- special function model

Receptor Types

- Channel-linked receptors
  - Ionotropic
- Enzyme-linked receptors
  - Protein kinases → phosphorylation
  - Neurotrophins
- G-protein-coupled receptors
  - Metabotropic
- Intracellular receptors
  - Activation by cell-permeant signals ~


T
THANK YOU
.com
WELLS FARGO
THE WALK TO CURE DIABETES
JDRF 2005
We're on Track
For a Cure