COMUNICACIÓN INTERCELULAR

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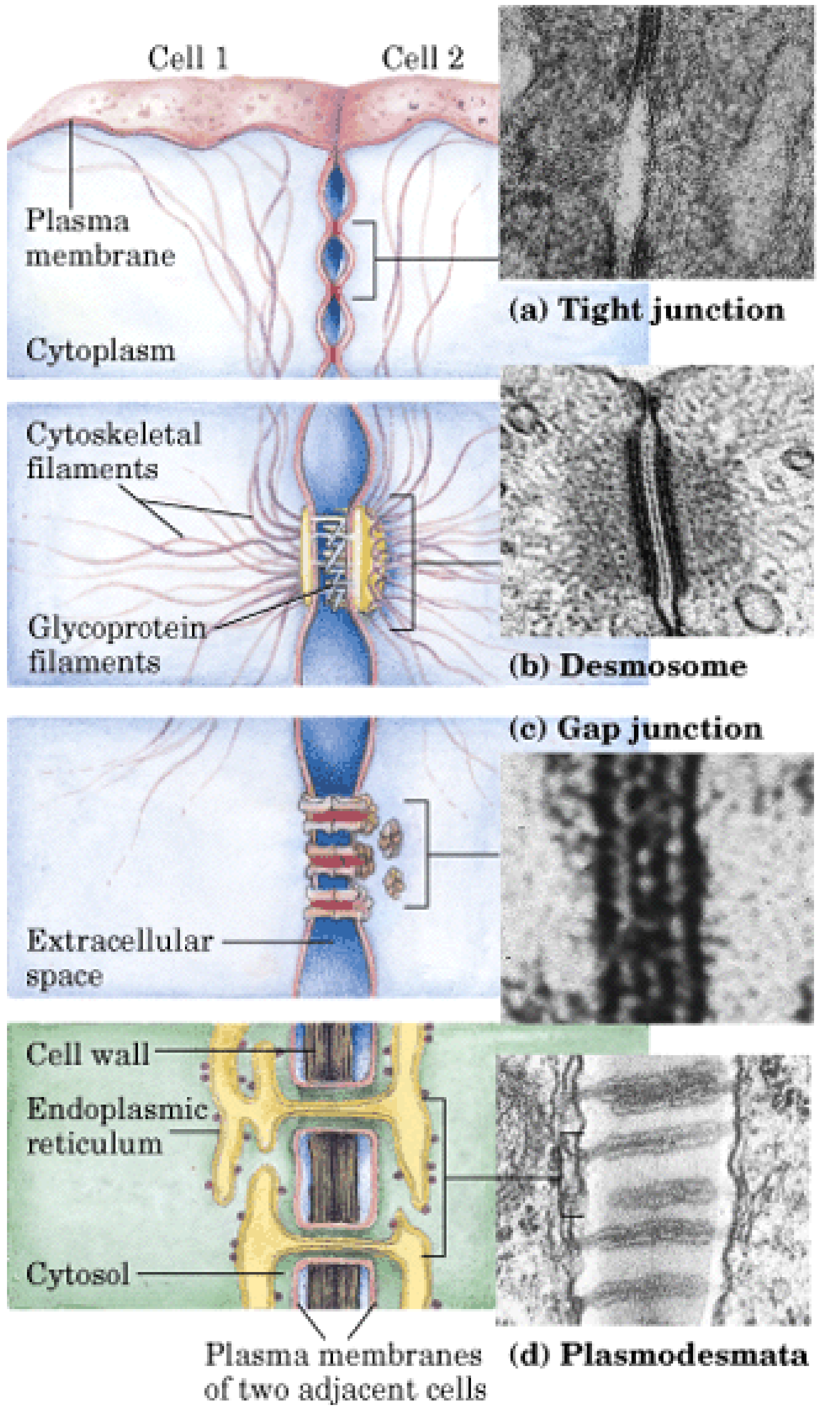
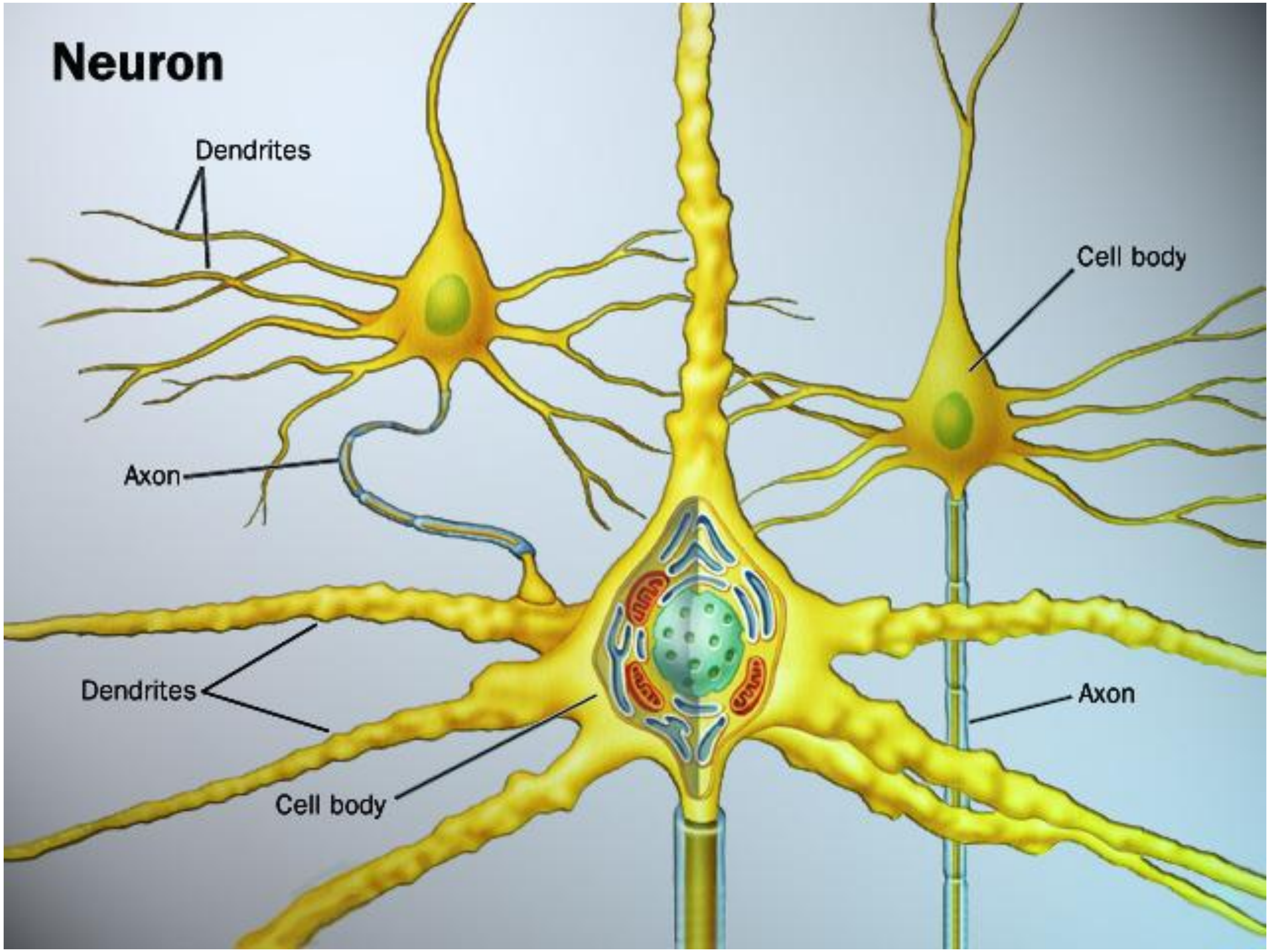
Fuentes: Lehninger 3era Ed.
Alberts B. Ed. 2002

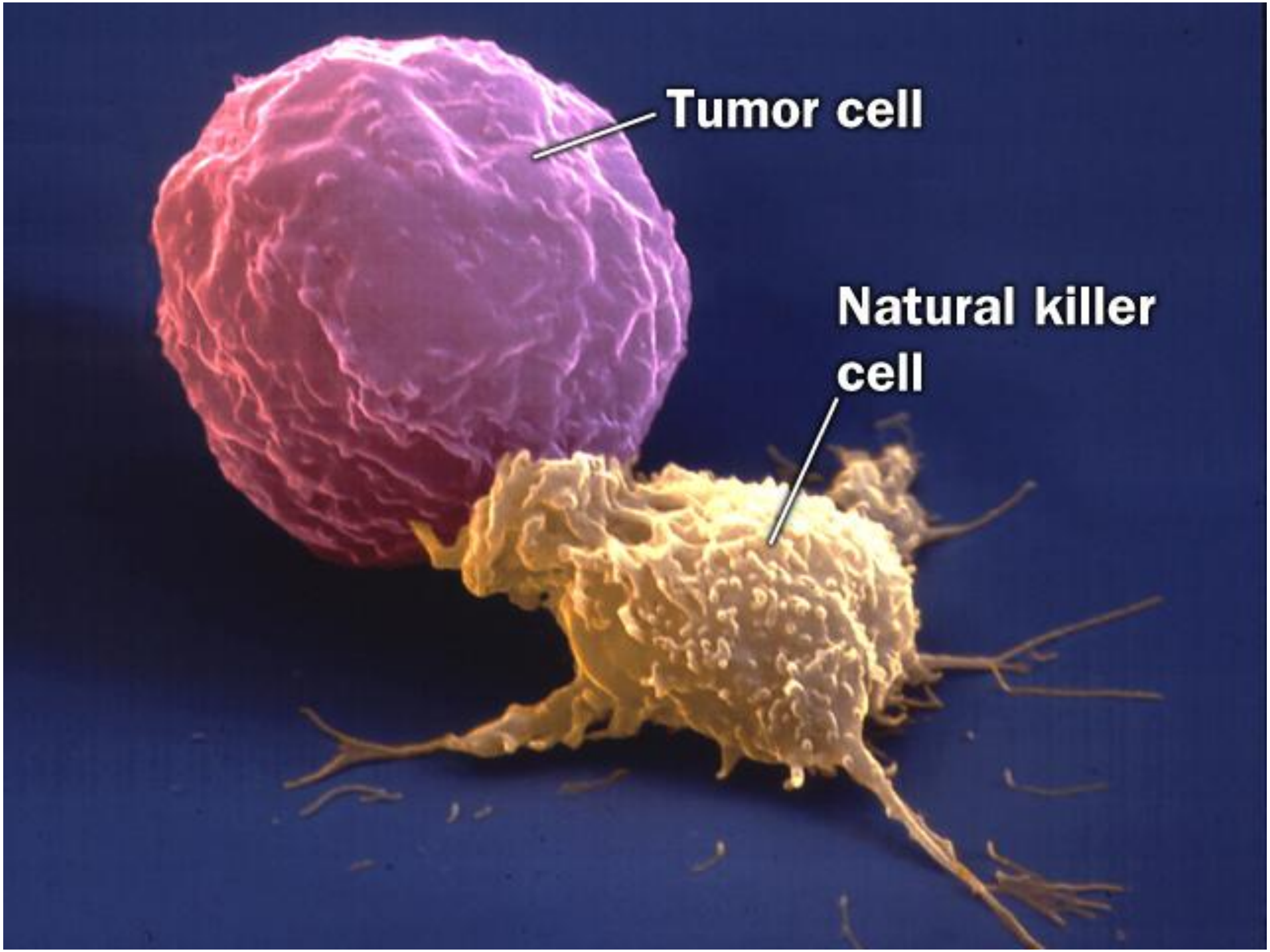


Cell 1
Cell 2
Plasma membrane
Cytoplasm
(a) Tight junction
Cytoskeletal filaments
Glycoprotein filaments
(b) Desmosome
(c) Gap junction
Extracellular space
Cell wall
Endoplasmic reticulum
Cytosol
Plasma membranes of two adjacent cells
(d) Plasmodesmata

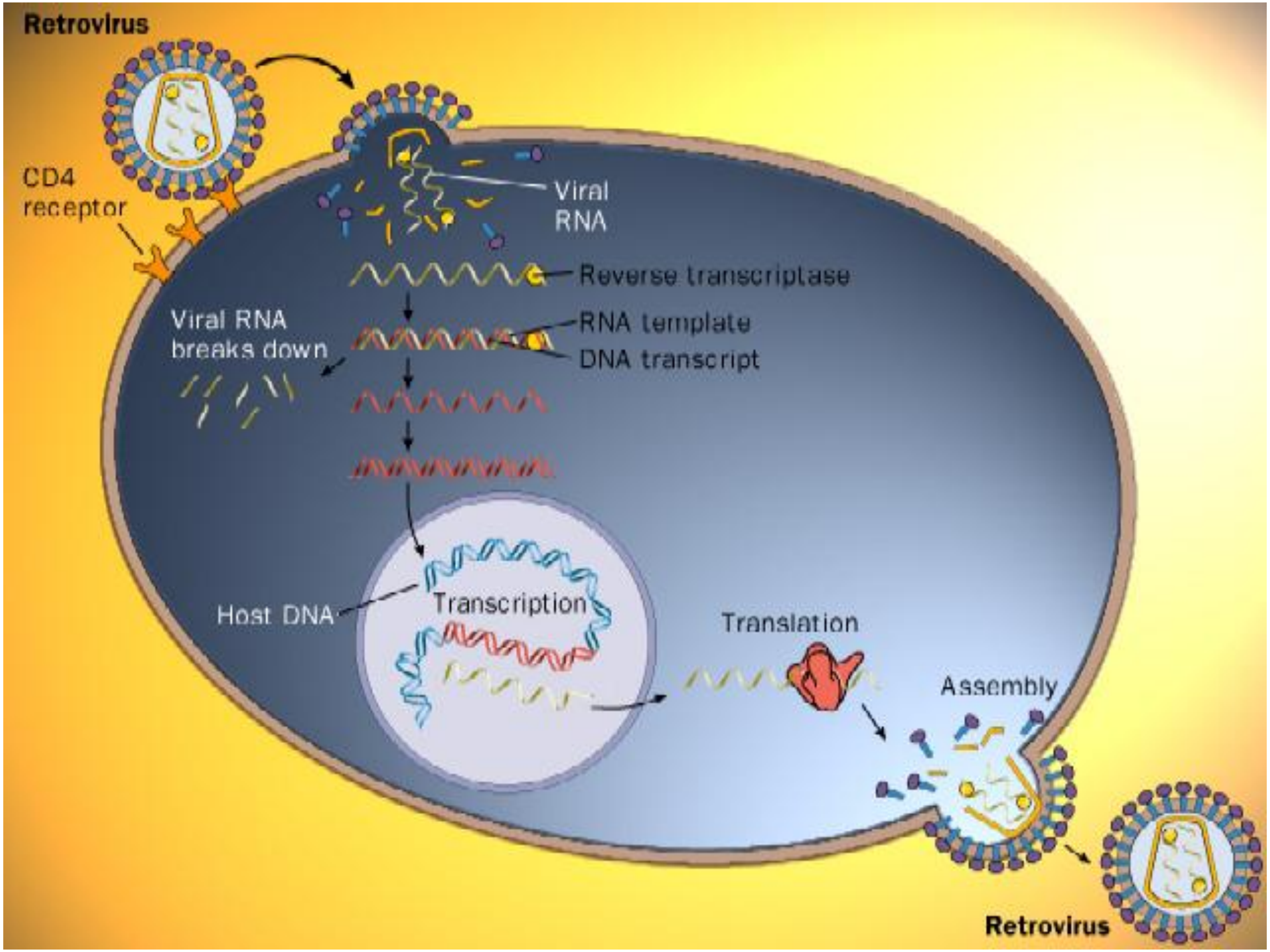
comunicación interneuronal

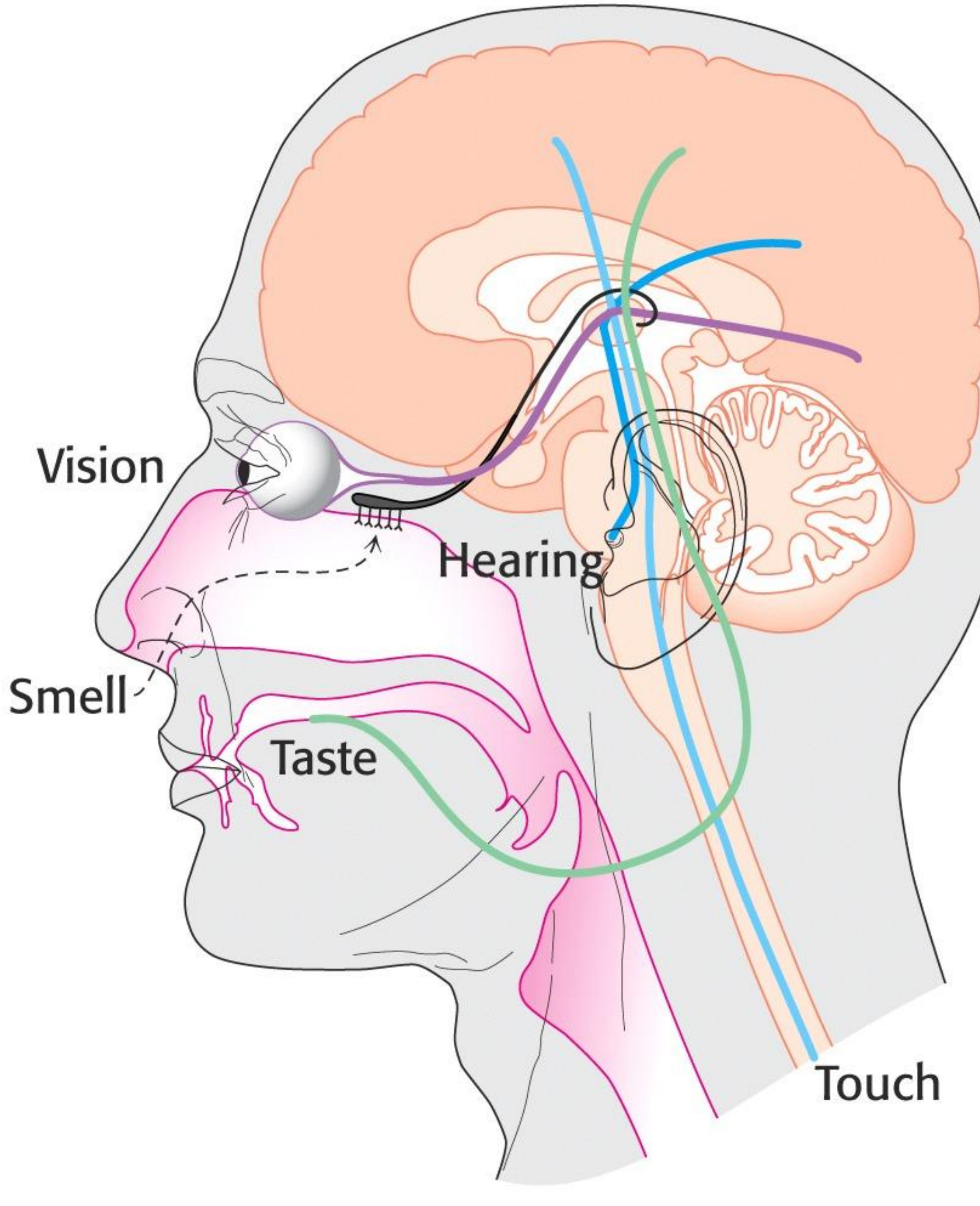


Reconocimiento célula-célula



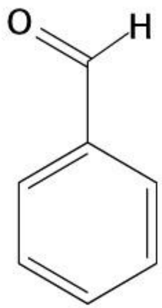
Reconocimiento célula-patógeno (infección viral)





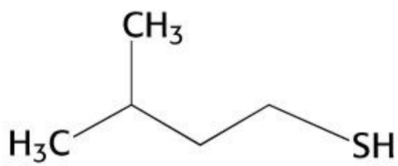
Vision
Hearing
Smell
Taste
Touch

MOLECULAS CON AROMA



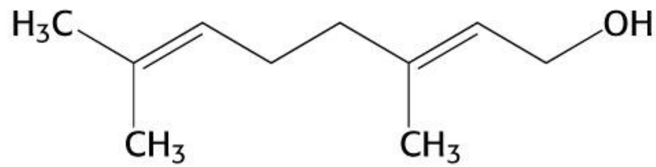
Benzaldehyde
(Almond)

Almendra



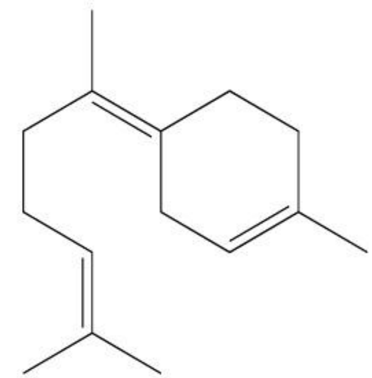
3-Methylbutane-1-thiol
(Skunk)

Mofeta



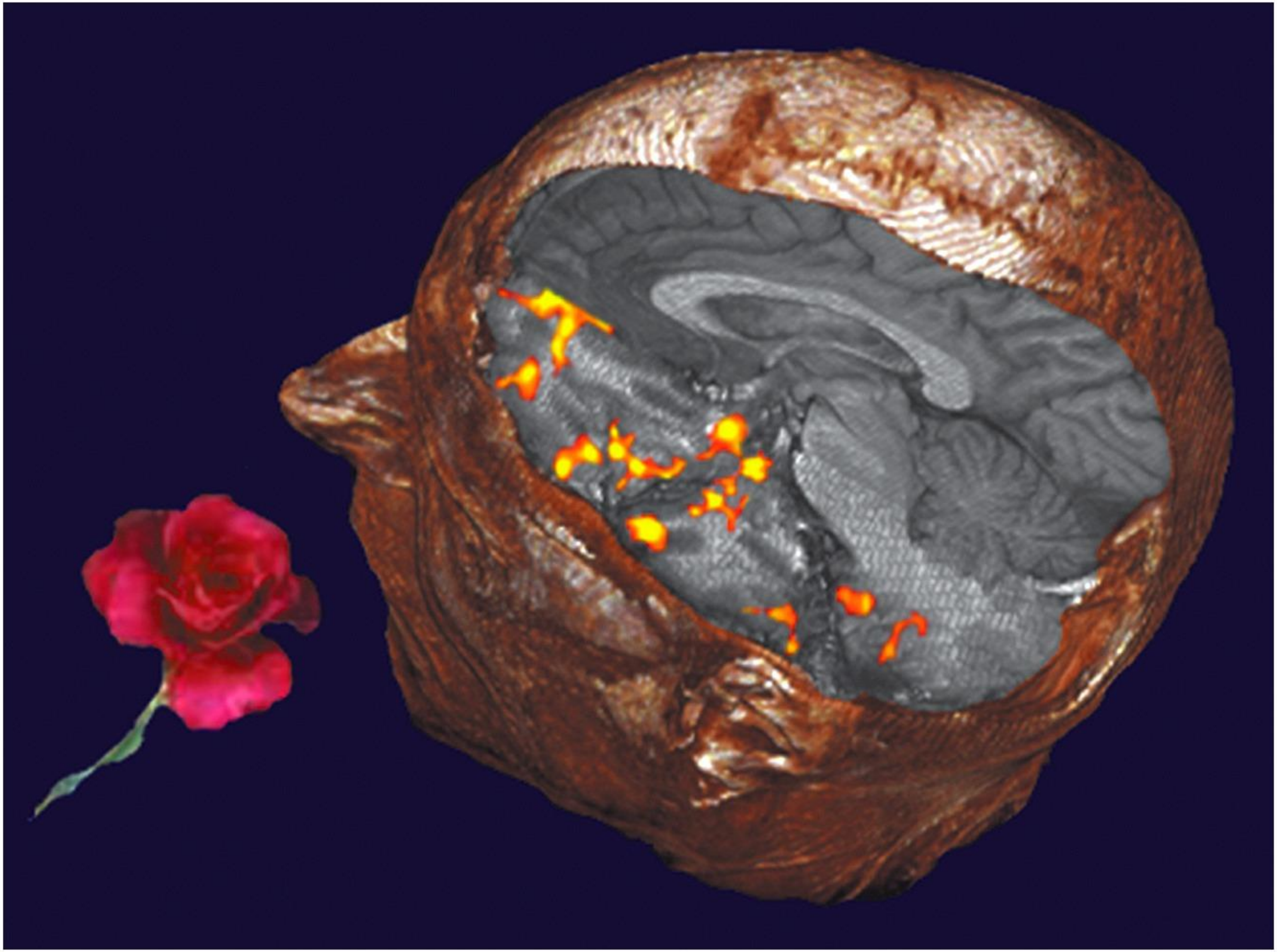
Geraniol
(Rose)

Rosa



Zingiberene
(Ginger)

Gengibre



El dolor

Efectos por deficiencia en la hormona LEPTINA

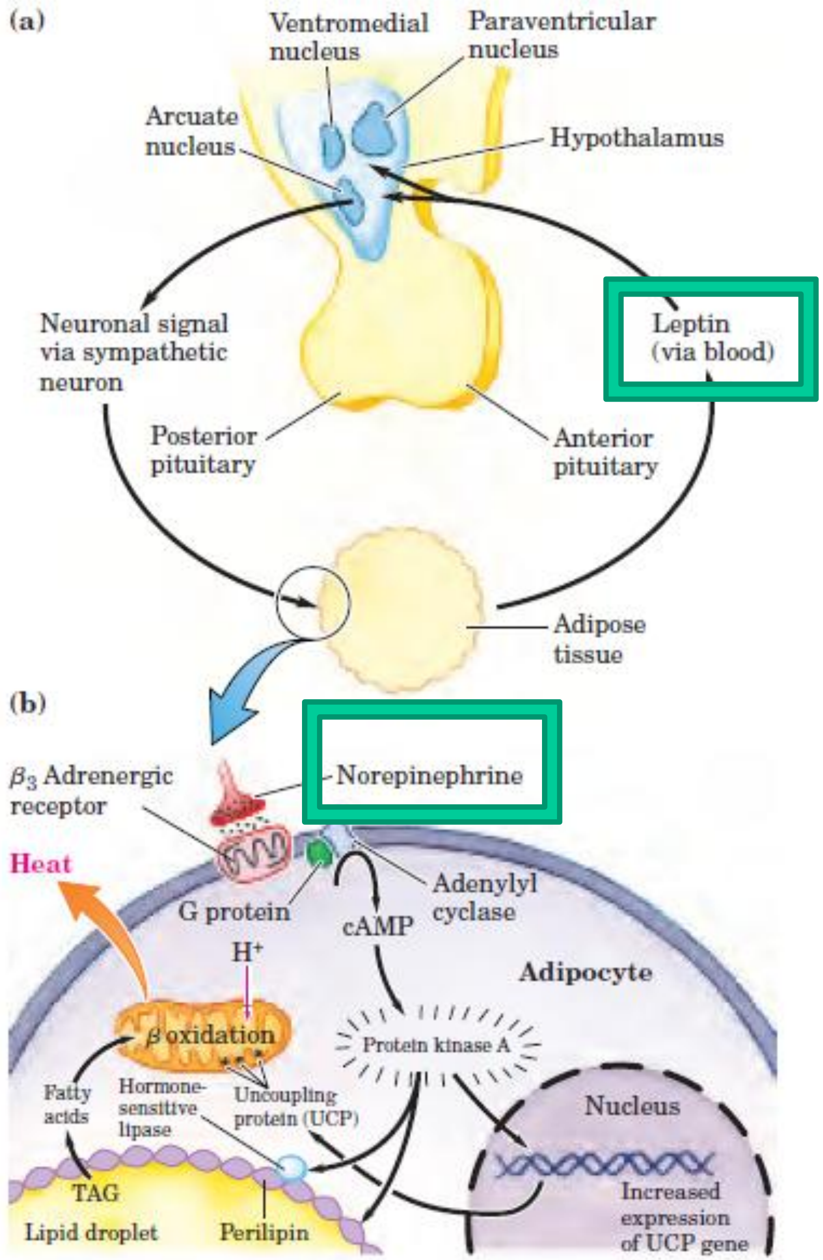
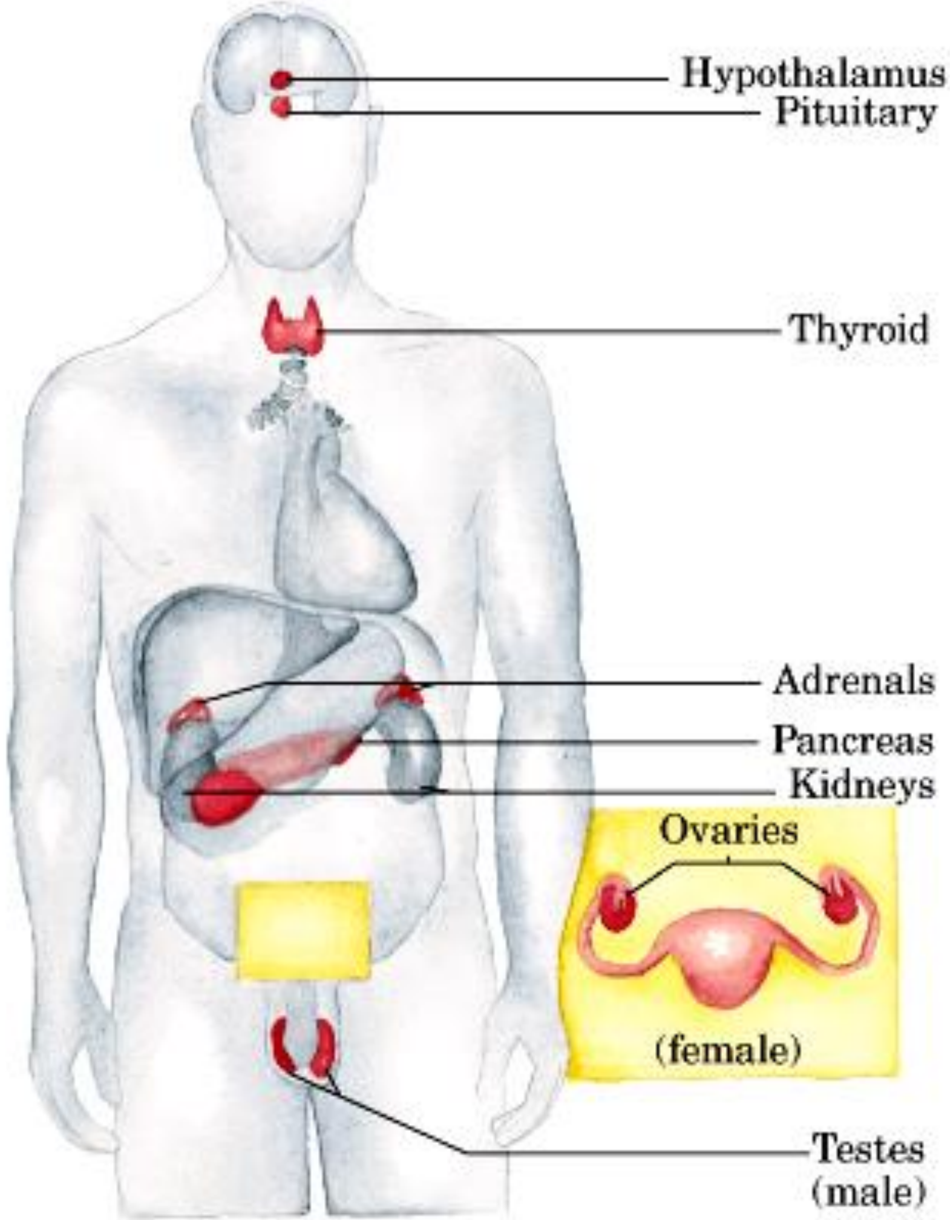
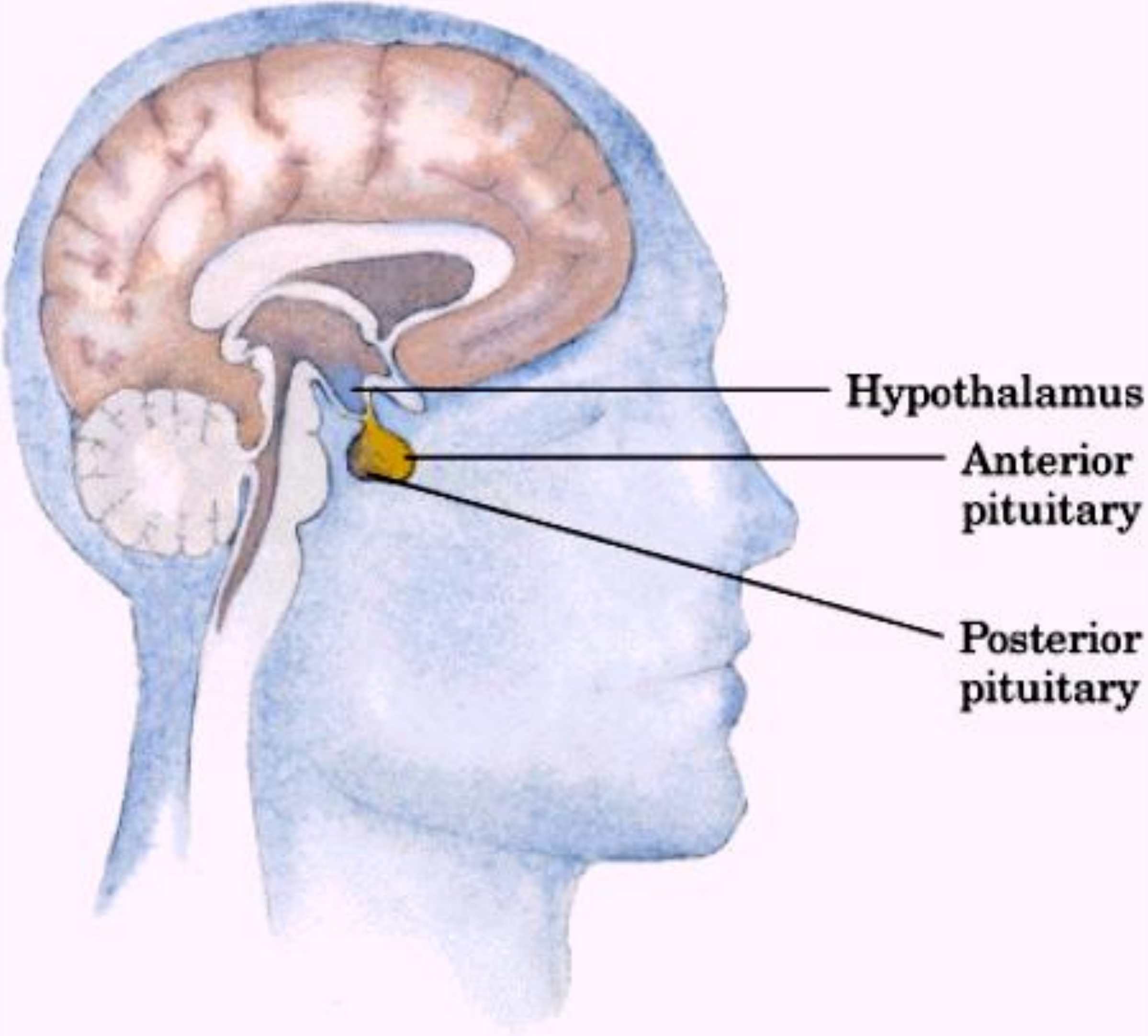
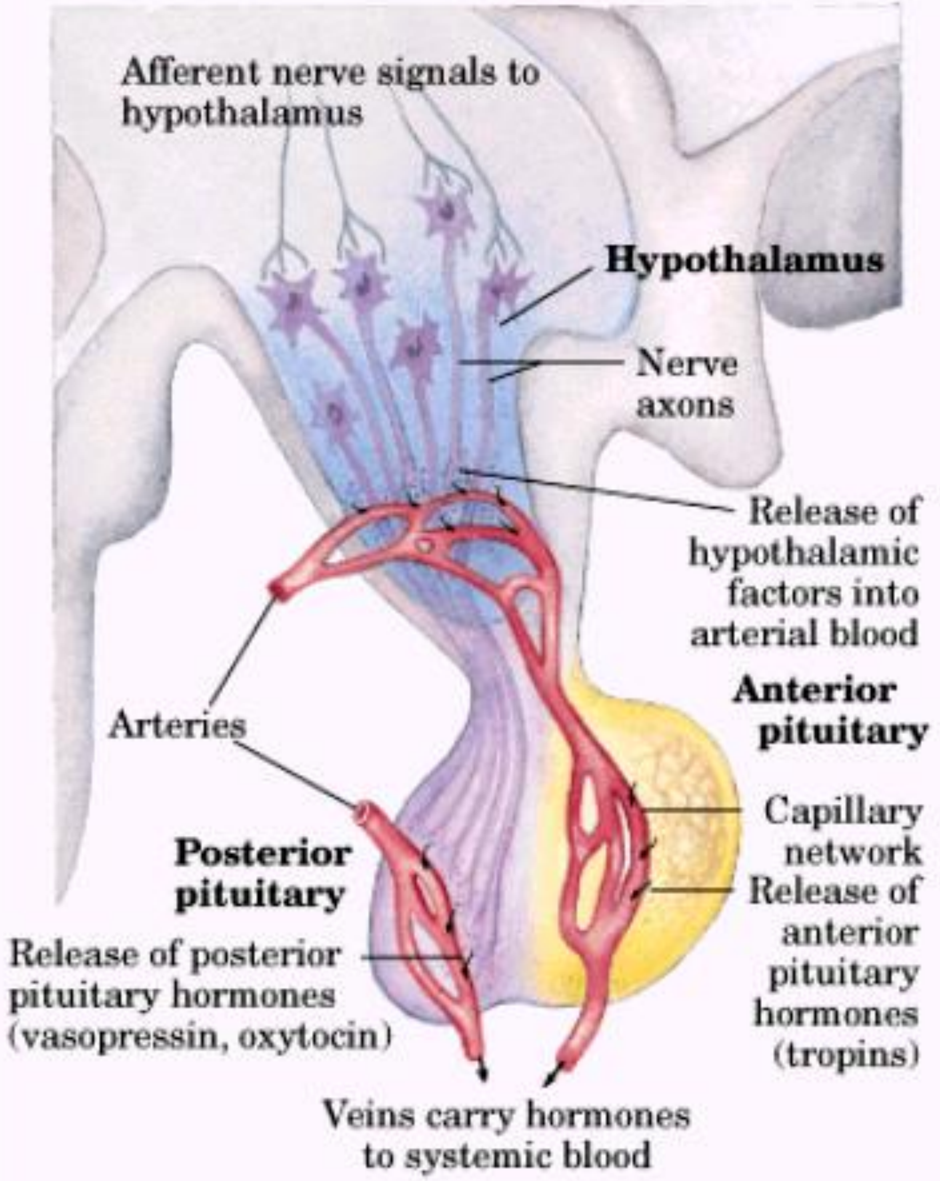


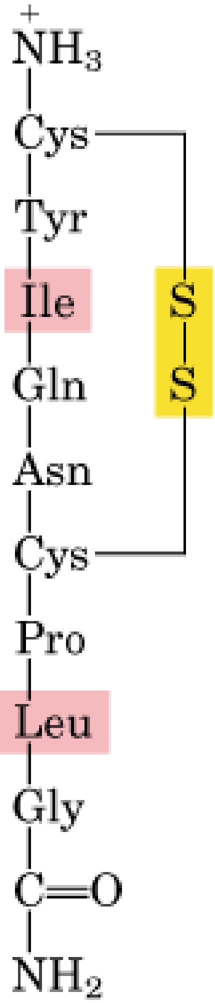
FIGURE 23–32 Hypothalamic regulation of food intake and energy expenditure. **(a)** Anatomy of the hypothalamus. **(b)** Interactions between the hypothalamus and an adipocyte, described later in text.


Hypothalamus
Pituitary
Thyroid
Adrenals
Pancreas
Kidneys
Ovaries
(female)
Testes
(male)

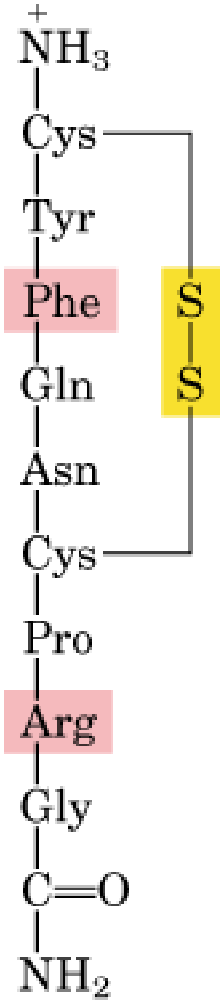


(a)

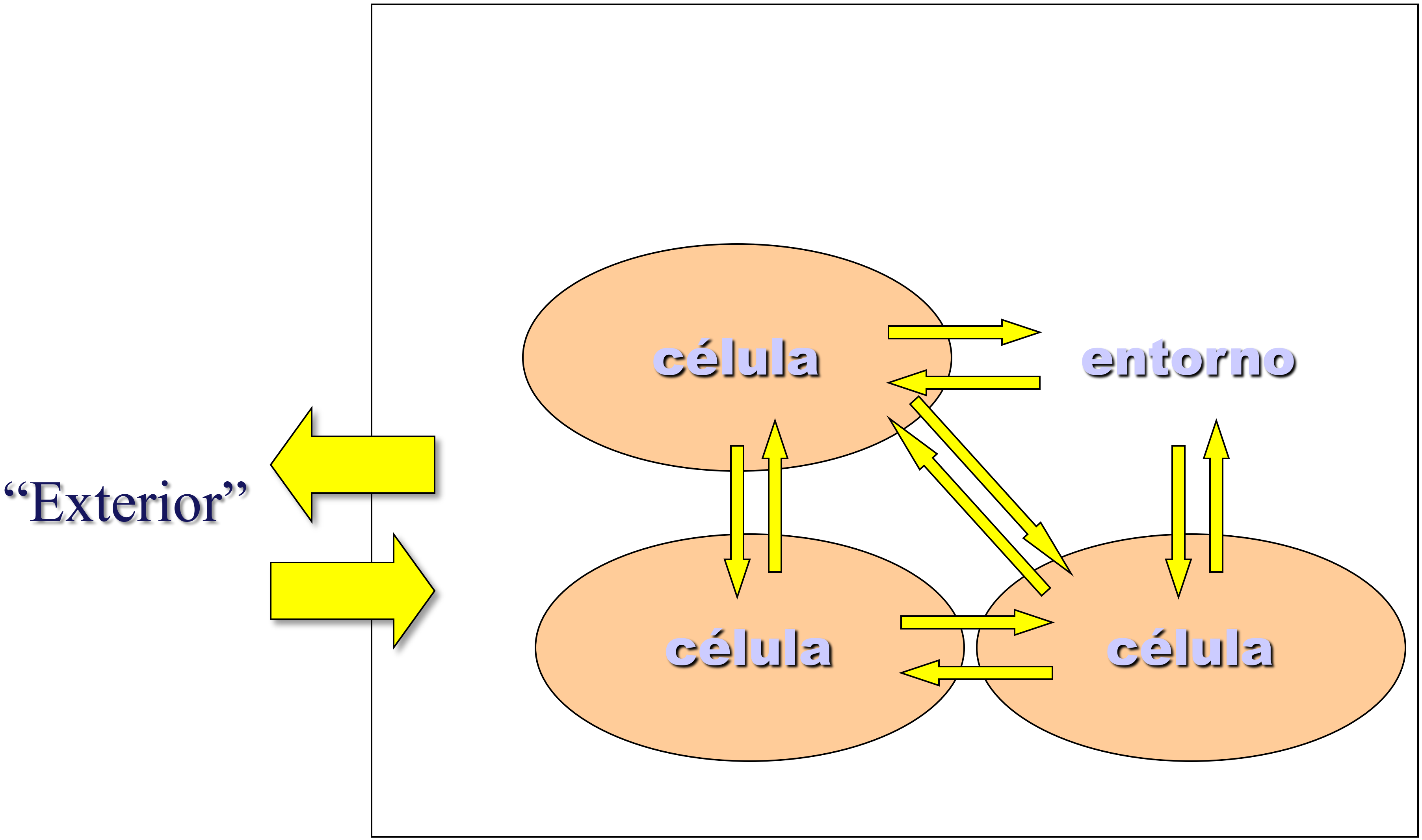

Afferent nerve signals to hypothalamus
Hypothalamus
Nerve axons
Release of hypothalamic factors into arterial blood
Anterior pituitary
Arteries
Capillary network
Release of anterior pituitary hormones (tropins)
Posterior pituitary
Release of posterior pituitary hormones (vasopressin, oxytocin)
Veins carry hormones to systemic blood
(b)

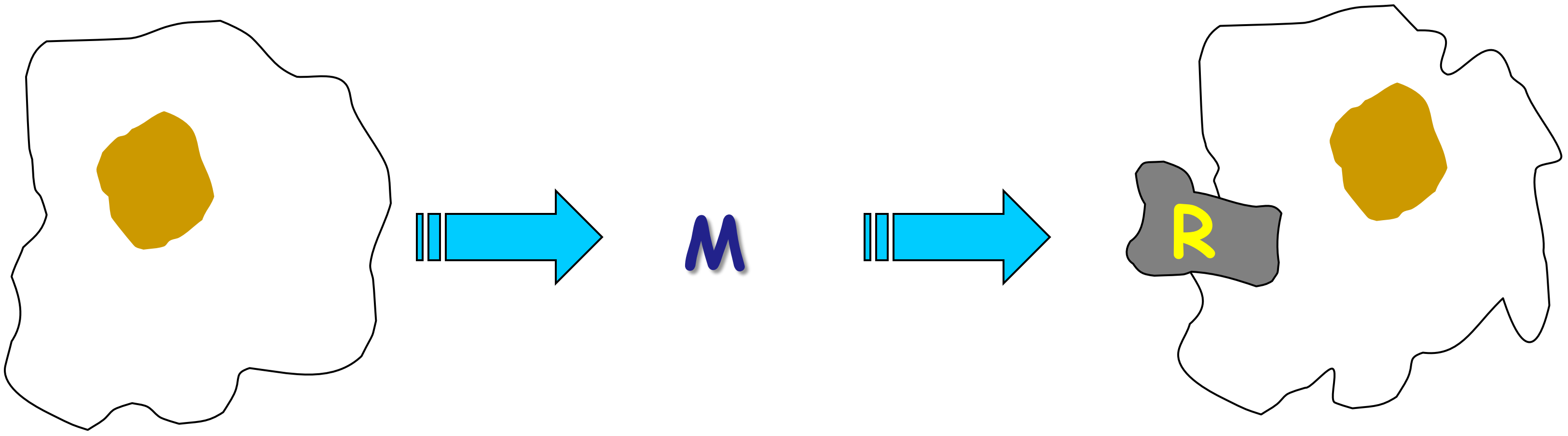


Human oxytocin



Human vasopressin
(antidiuretic hormone)

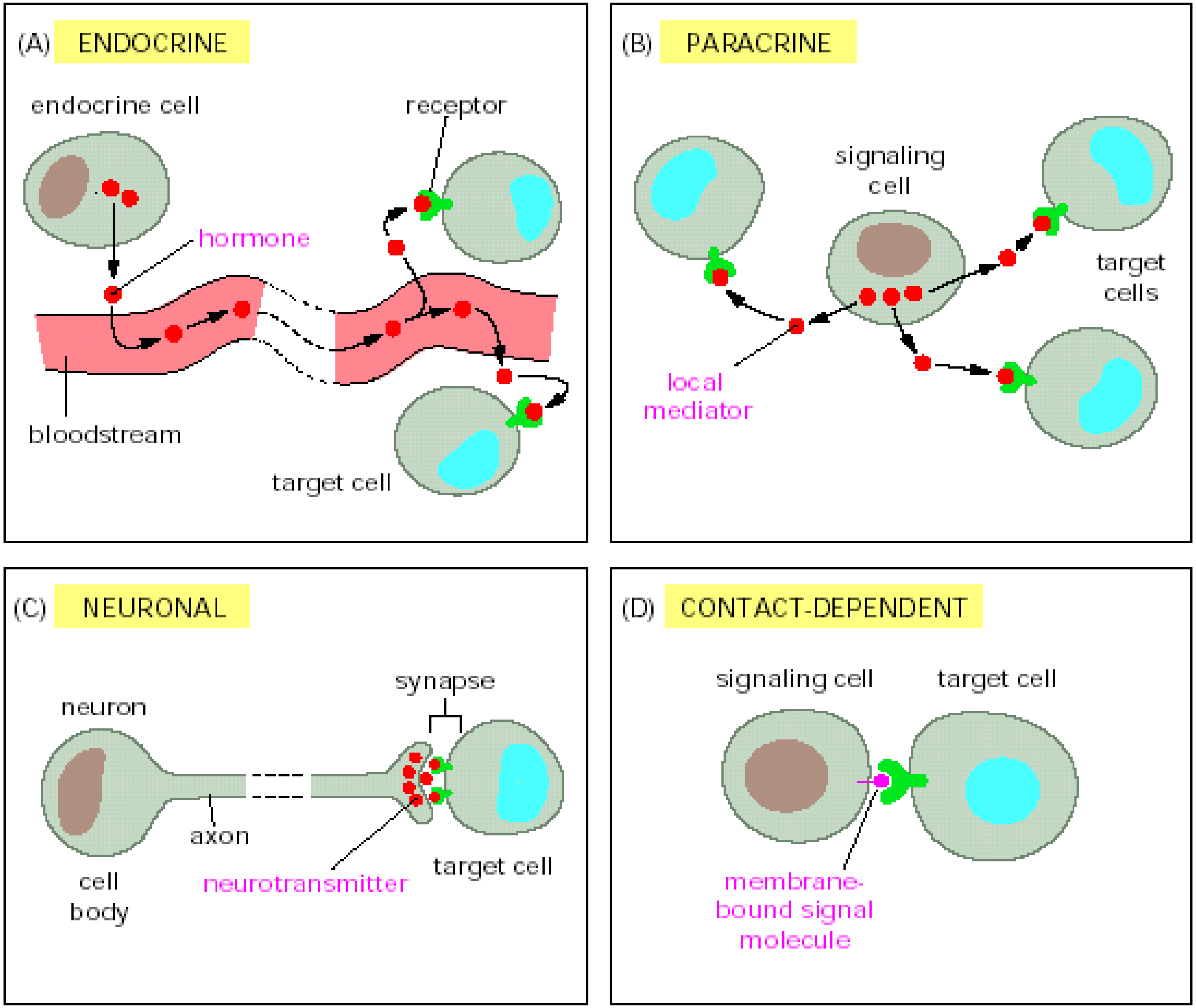

célula
entorno
"Exterior"
célula
célula


M
R

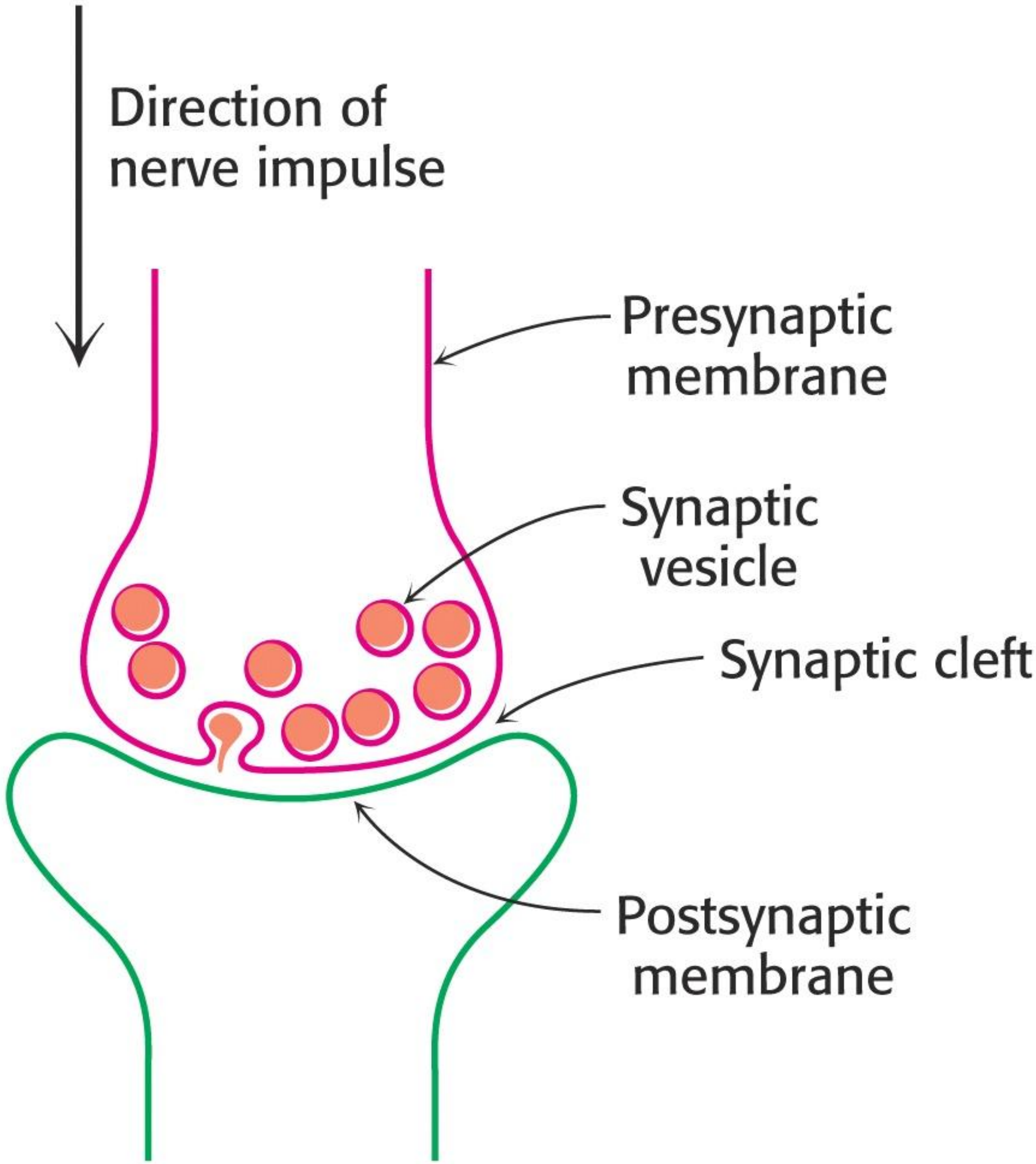

M
R

Modos de señal según la distancia entre la célula emisora y la célula blanco:

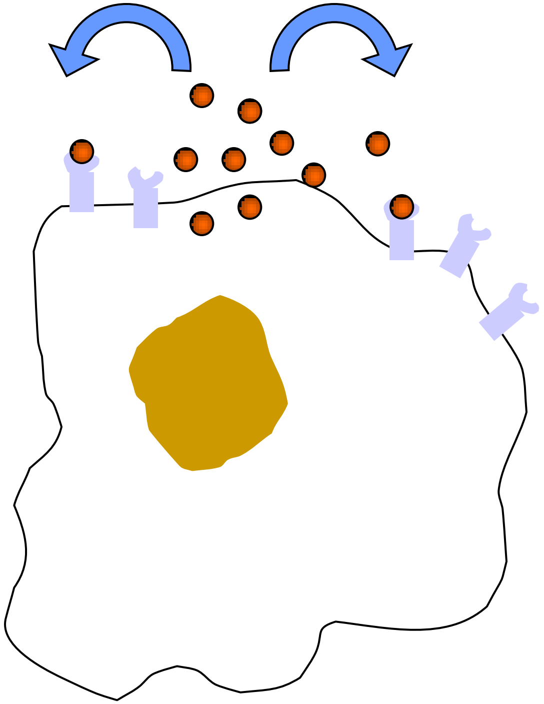
- **ENDOCRINA**
- **PARACRINA**
- **AUTOCRINA**
- **YUXTACRINA**
- **NEURONAL**



(A) ENDOCRINE
endocrine cell
receptor
hormone
bloodstream
target cell
(B) PARACRINE
signaling cell
target cells
local mediator
(C) NEURONAL
neuron
synapse
axon
cell body
neurotransmitter
target cell
(D) CONTACT-DEPENDENT
signaling cell
target cell
membrane-bound signal molecule


Direction of
nerve impulse
Presynaptic
membrane
Synaptic
vesicle
Synaptic cleft
Postsynaptic
membrane

COMUNICACIÓN AUTOCRINA



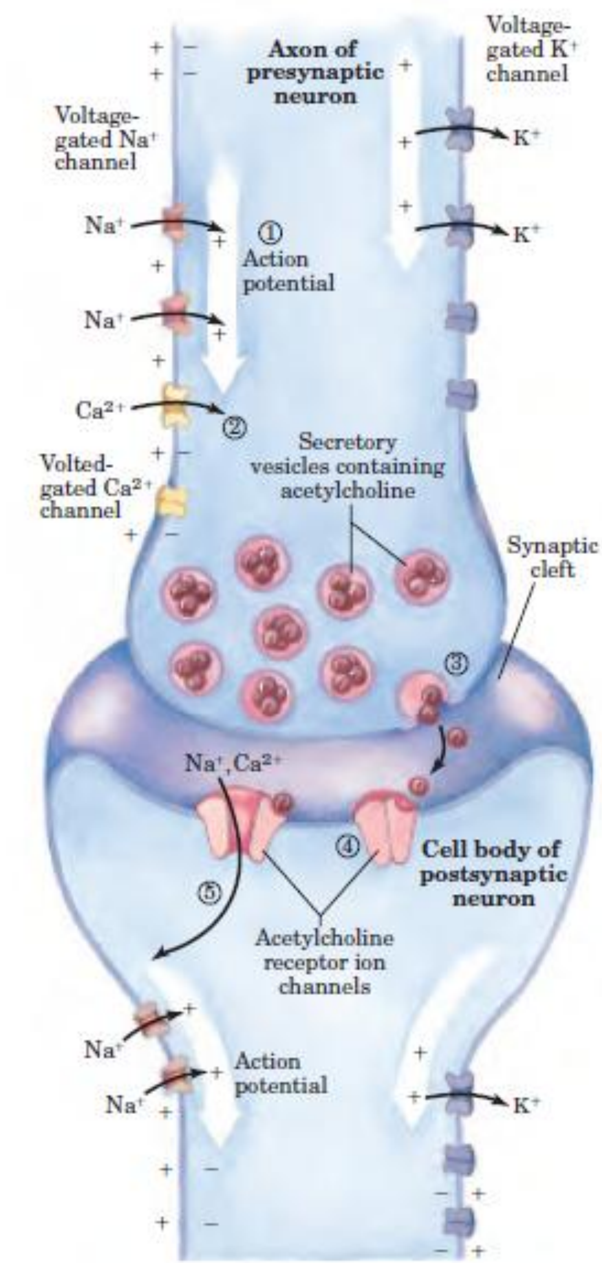


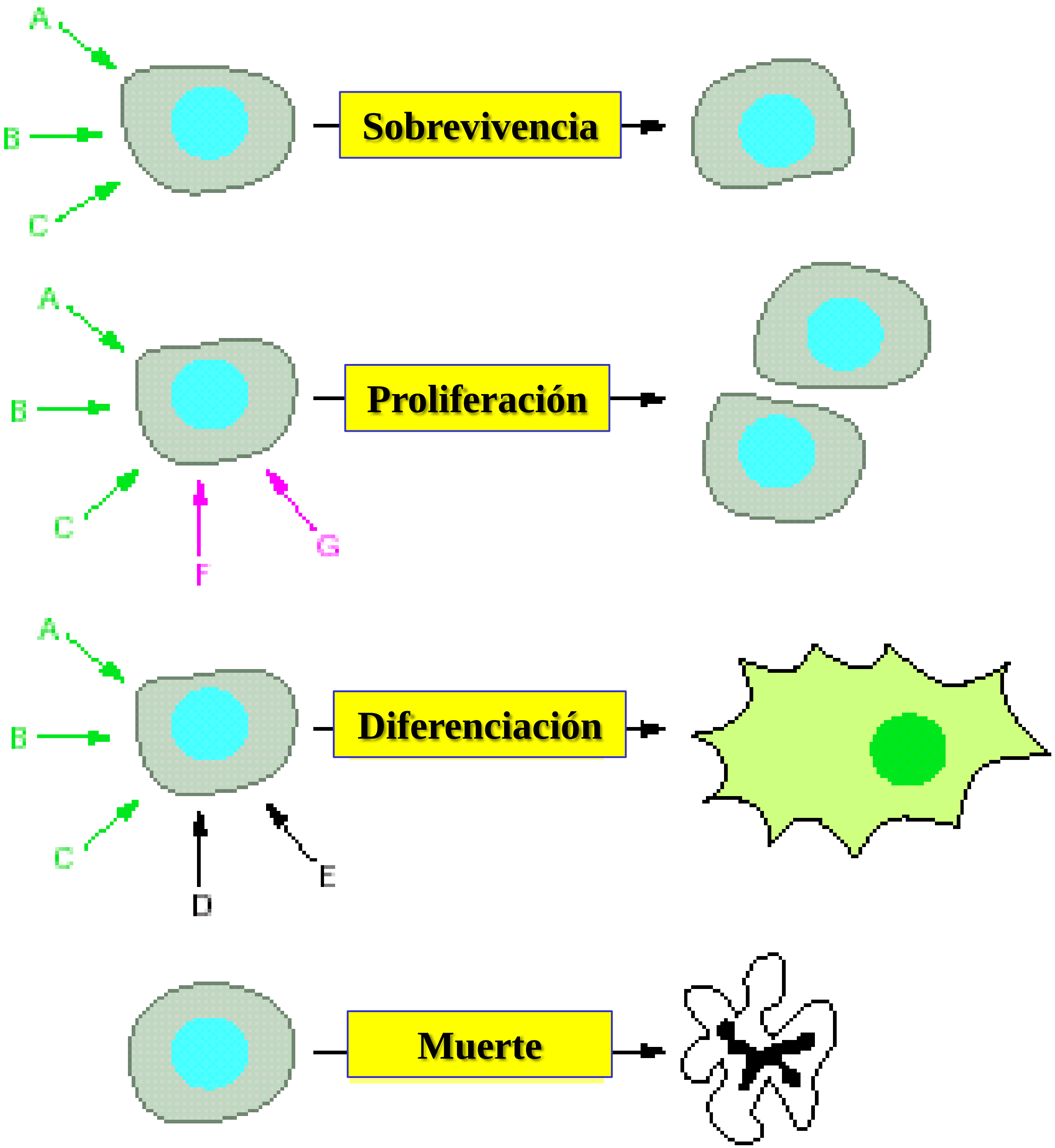
FIGURE 12-5 Role of voltage-gated and ligand-gated ion channels in neural transmission. Initially, the plasma membrane of the presynaptic neuron is polarized (inside negative) through the action of the electrogenic Na^+K^+ ATPase, which pumps 3 Na^+ out for every 2 K^+ pumped into the neuron (see Fig. 12–3). ① A stimulus to this neuron causes an action potential to move along the axon (white arrow), away from the cell body. The opening of one voltage-gated Na^+ channel allows Na^+ entry, and the resulting local depolarization causes the adjacent Na^+ channel to open, and so on. The directionality of movement of the action potential is ensured by the brief refractory period that follows the opening of each voltage-gated Na^+ channel. ② When the wave of depolarization reaches the axon tip, voltage-gated Ca^{2+} channels open, allowing Ca^{2+} entry into the presynaptic neuron. ③ The resulting increase in internal [Ca^{2+}] triggers exocytic release of the neurotransmitter acetylcholine into the synaptic cleft. ④ Acetylcholine binds to a receptor on the postsynaptic neuron, causing its ligand-gated ion channel to open. ⑤ Extracellular Na^+ and Ca^{2+} enter through this channel, depolarizing the postsynaptic cell. The electrical signal has thus passed to the cell body of the postsynaptic neuron and will move along its axon to a third neuron by this same sequence of events.

Sistemas de TRANSDUCCIÓN DE SEÑALES

Parte de este material fue tomado del Lenhinger 3ª Ed y del Stryer 5ª Ed.

table 13–1

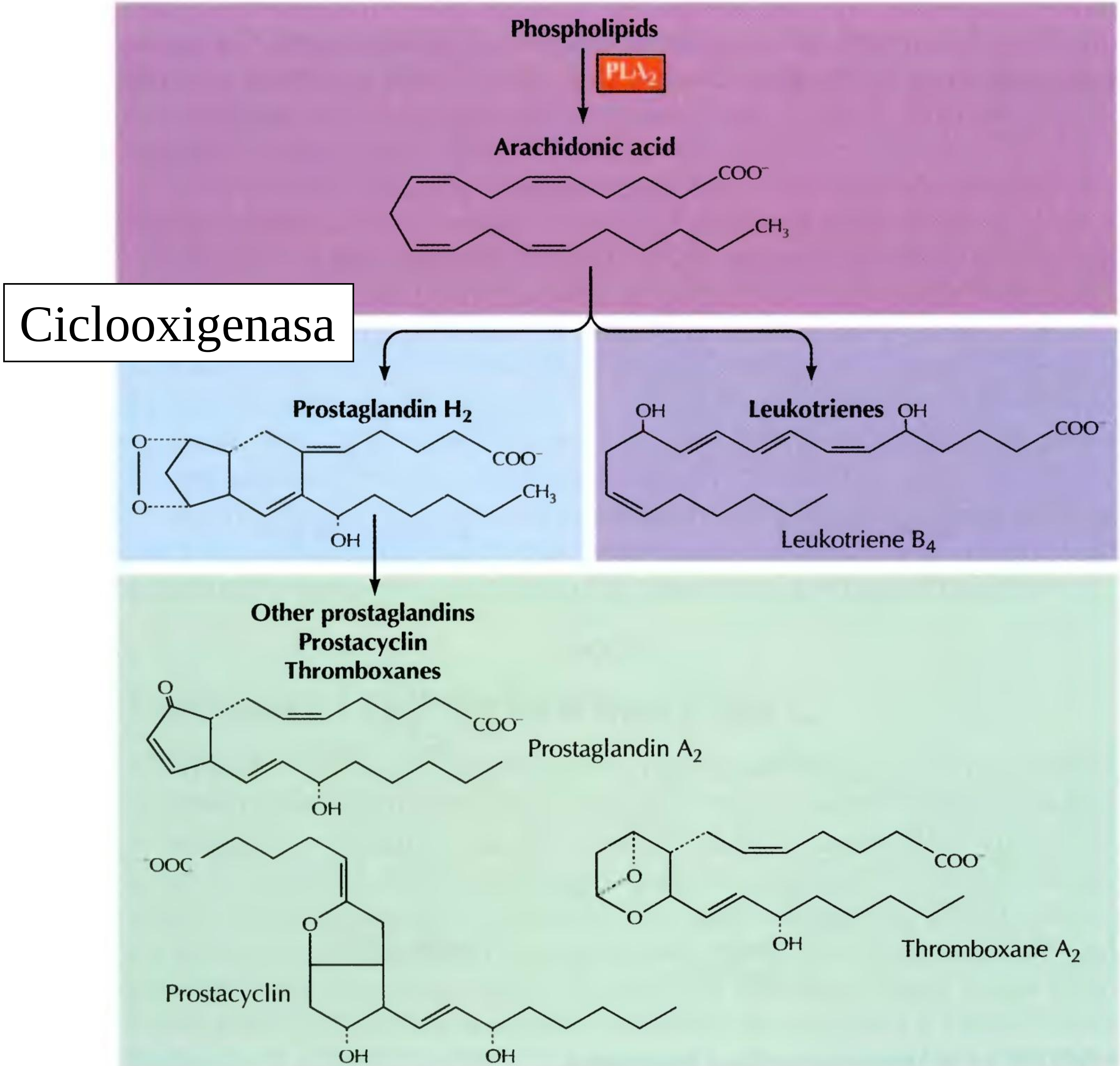
Some Signals to Which Cells Respond
Antigens
Cell surface glycoproteins/oligosaccharides
Developmental signals
Extracellular matrix components
Growth factors
Hormones
Light
Mechanical touch
Neurotransmitters
Odorants
Pheromones
Tastants

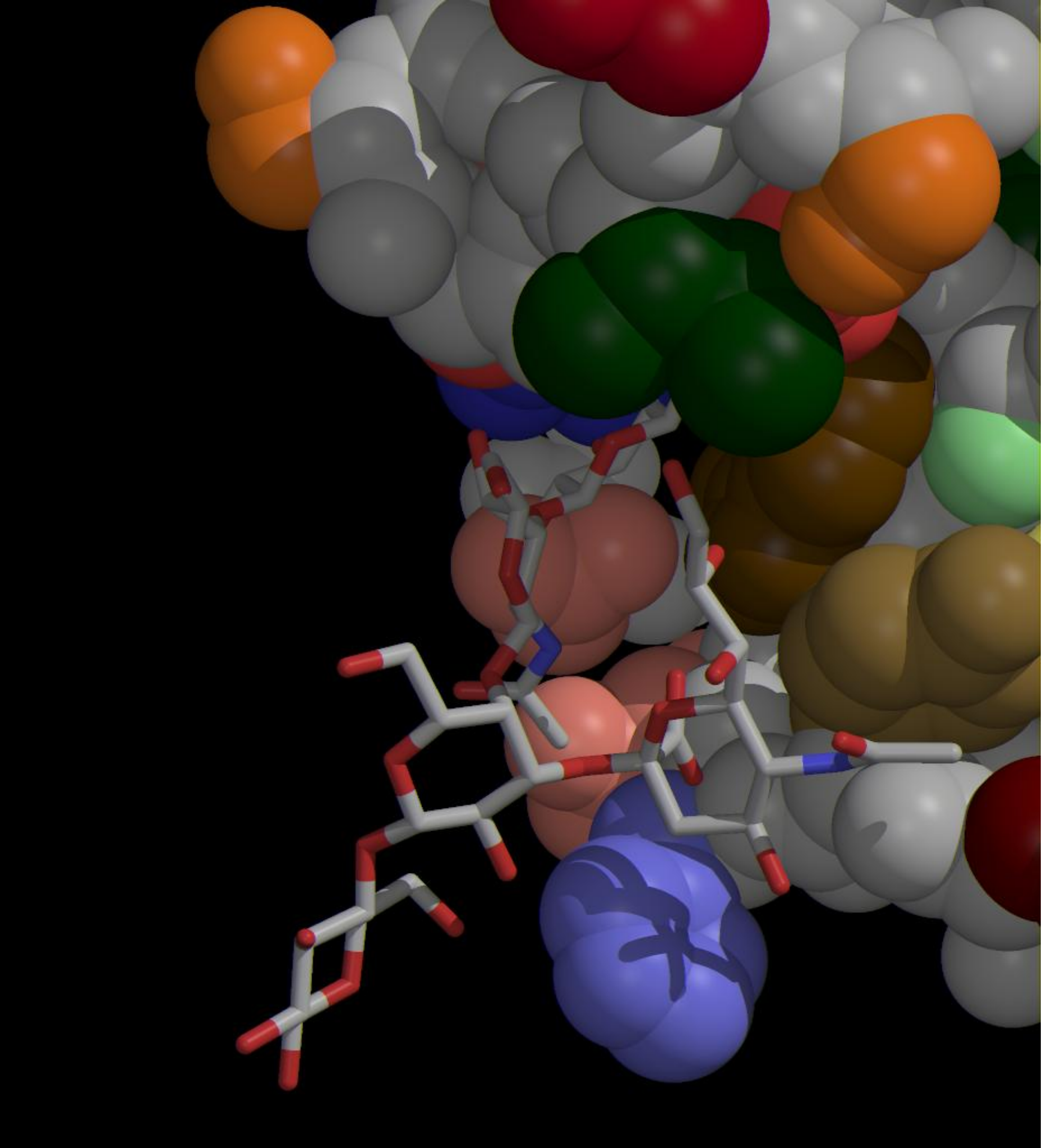

A
B
C
Sobrevivencia
A
B
C
F
G
Proliferación
A
B
C
D
E
Diferenciación
Muerte

Apoptosis

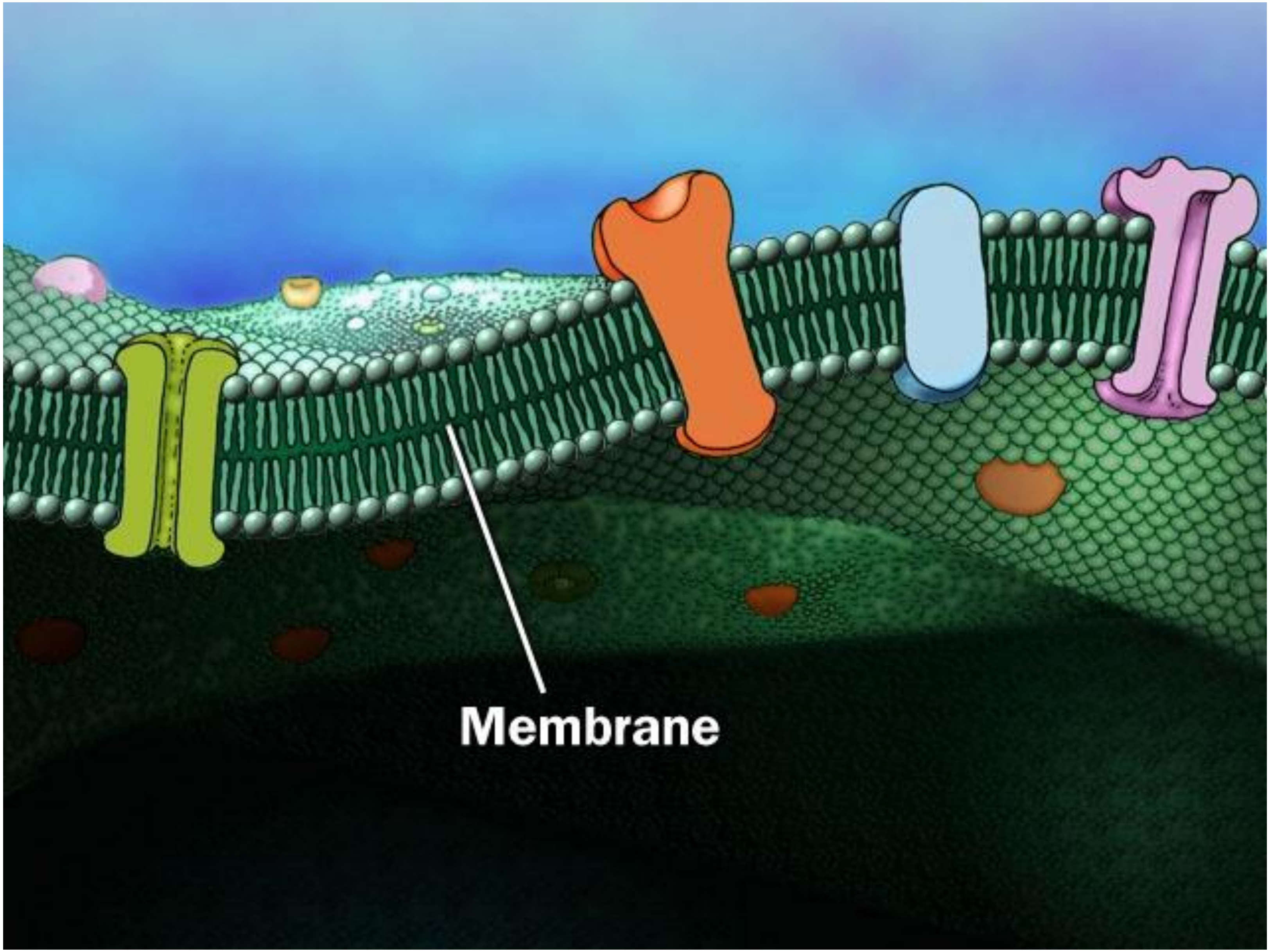
En las células eucariontes los primeros mensajeros pueden ser:

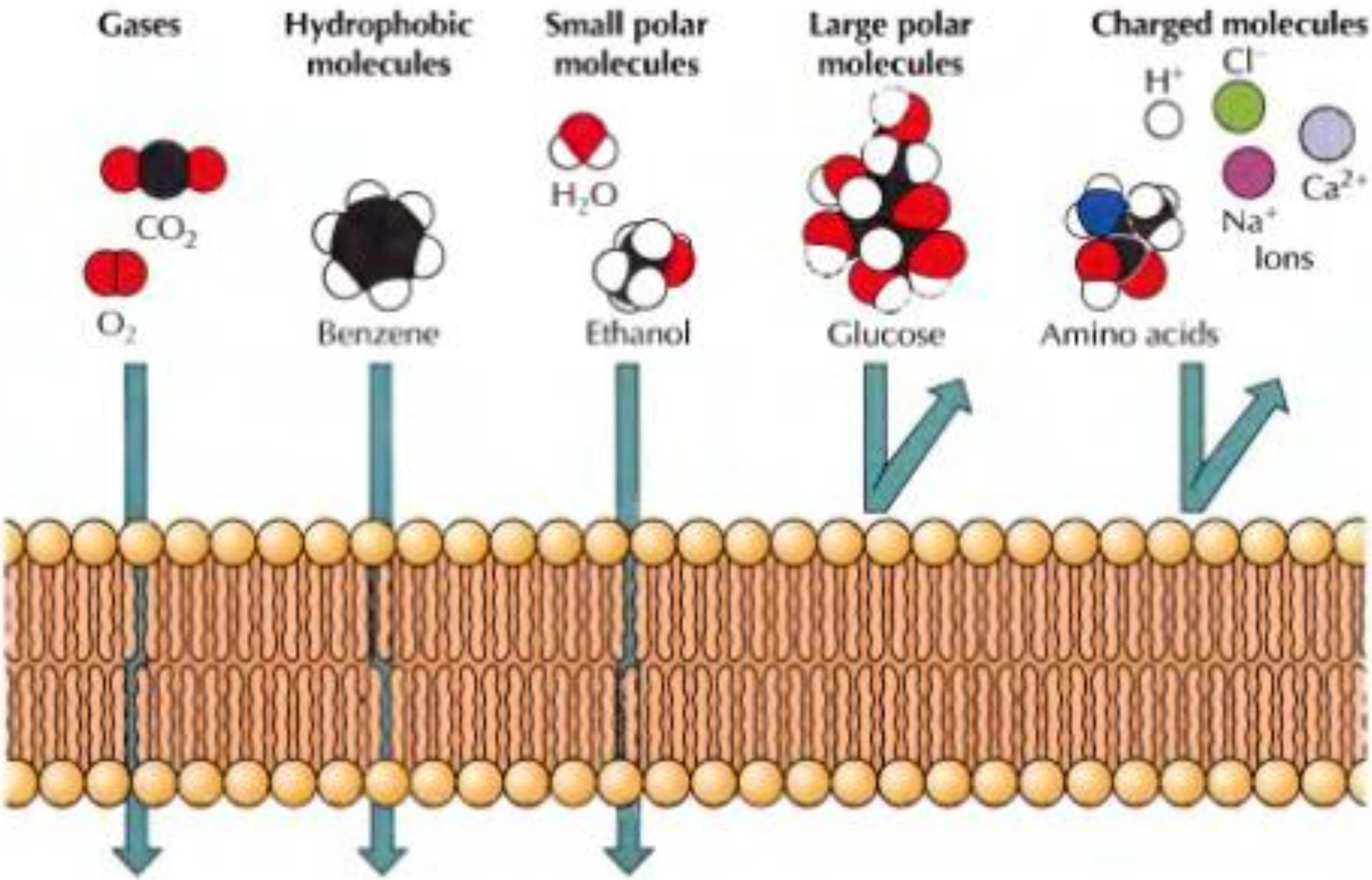
- **Proteínas.** (insulina, hormona de crecimiento, prolactina, factores de crecimiento, etc)
- **Pequeños péptidos** (ocitocina, vasopresina, encefalinas, sustancia P, etc.)
- **Aminoácidos o sus derivados** (glutamato, glicina, serotonina, histamina, dopamina, adrenalina)
- **Nucleótidos** (ATP)
- **Esteroides** (cortisol, estradiol, testosterona)
- **Retinoides** (ácido retinoico)
- **Derivados de ácidos grasos** (Prostaglandinas, leucotrienos y tromboxanos)
- **Gases disueltos** (NO y CO)

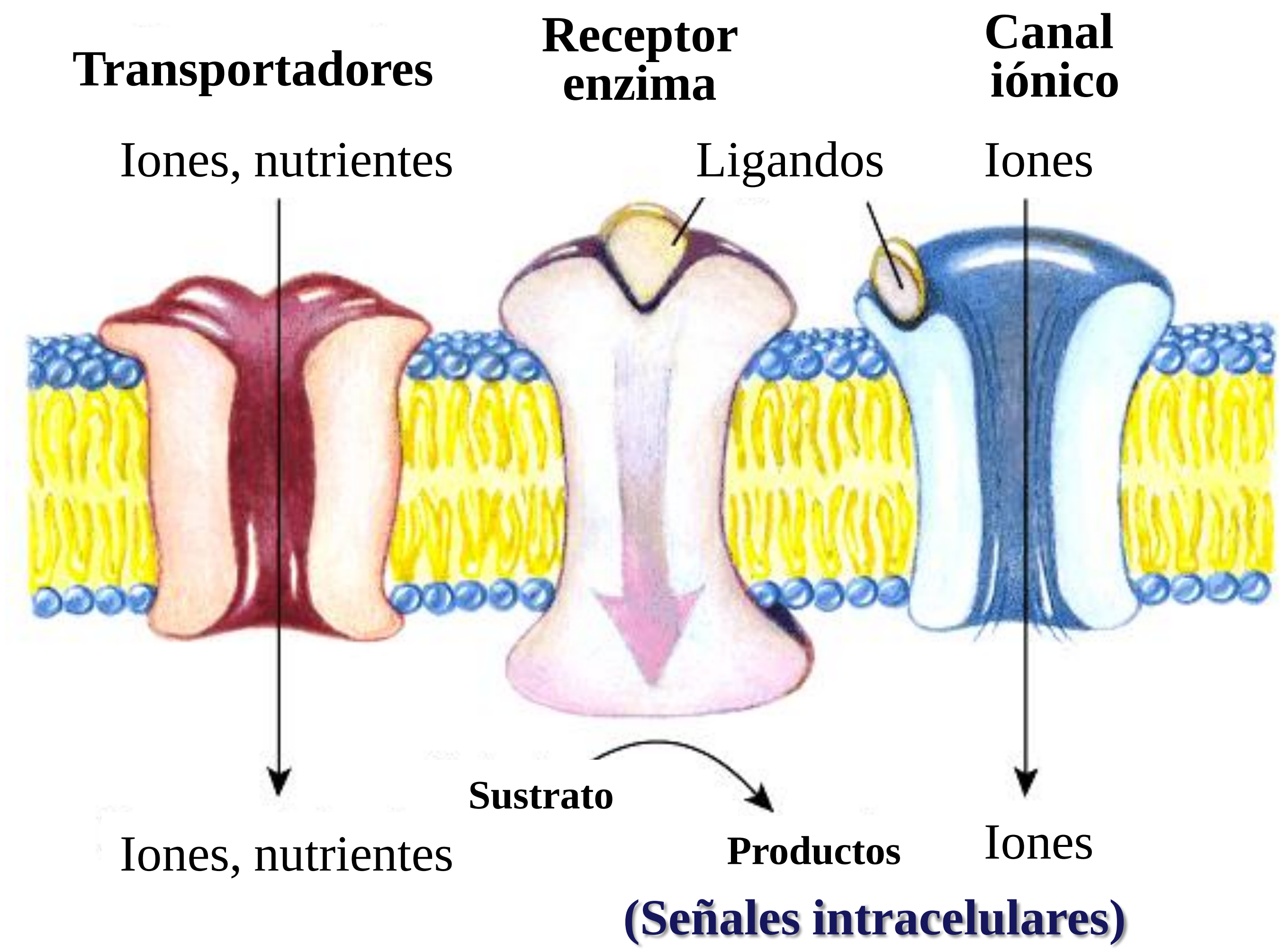

Phospholipids
PLA2
Arachidonic acid
COO⁻
CH3
Ciclooxigenasa
Prostaglandin H2
O
O
COO⁻
CH3
OH
Leukotrienes
OH
OH
COO⁻
Leukotriene B4
Other prostaglandins
Prostacyclin
Thromboxanes
O
COO⁻
OH
Prostaglandin A2
⁻OOC
O
Prostacyclin
OH
OH
O
O
COO⁻
OH
Thromboxane A2

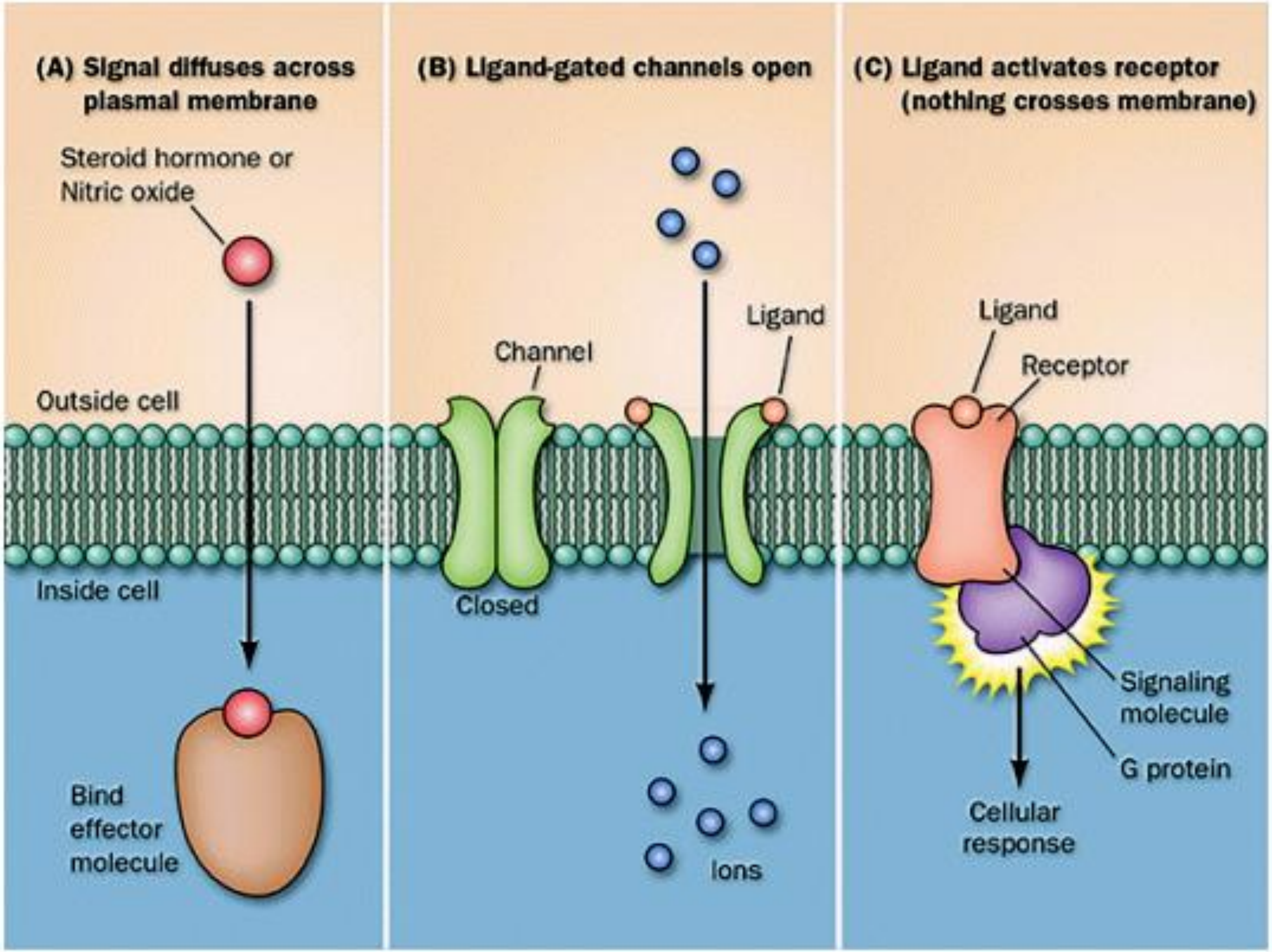


Interacción a nivel molecular


Membrane


Gases
Hydrophobic molecules
Small polar molecules
Large polar molecules
Charged molecules
CO_2
O_2
Benzene
H_2O
Ethanol
Glucose
Amino acids
H^+
Cl^-
Na^+
Ca^{2+}
Ions


Transportadores
Receptor enzima
Canal iónico
Iones, nutrientes
Ligandos
Iones
Sustrato
Productos
Iones, nutrientes
Iones
(Señales intracelulares)



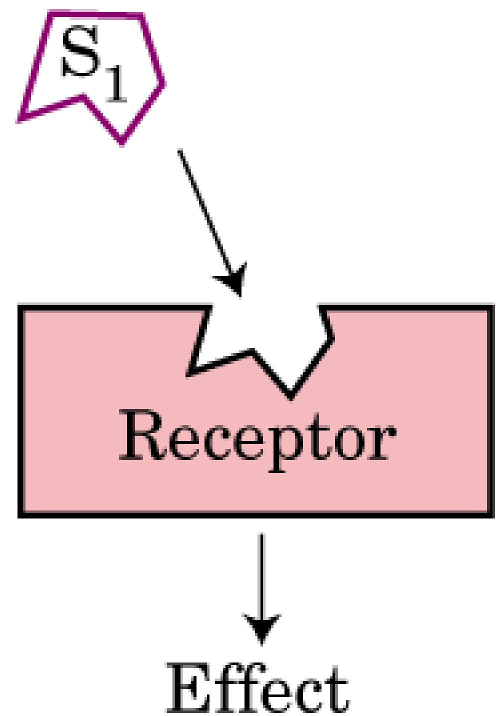
(A) Signal diffuses across plasmal membrane
Steroid hormone or Nitric oxide
Outside cell
Inside cell
Bind effector molecule
(B) Ligand-gated channels open
Channel
Ligand
Closed
Ions
(C) Ligand activates receptor (nothing crosses membrane)
Ligand
Receptor
Signaling molecule
G protein
Cellular response

La respuesta celular ante un mensajero externo tiene cuatro características:

- **Es específica**
- **Se amplifica la señal**
- **Se produce adaptación**
- **Se puede integrar con otras señales**

(a) Specificity

Signal molecule fits binding site on its complementary receptor; other signals do not fit.



(a) Specificity

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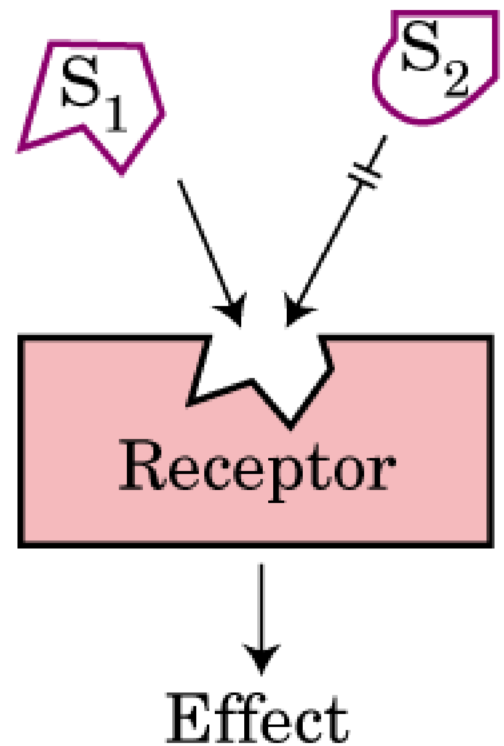
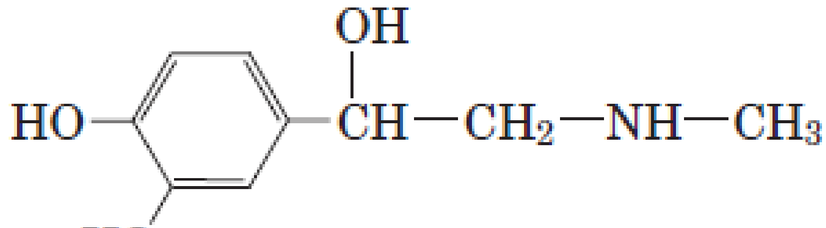
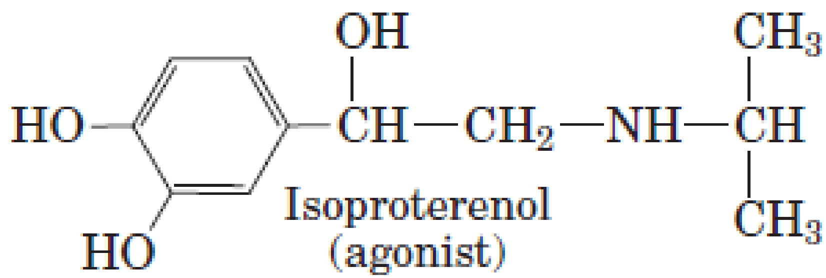


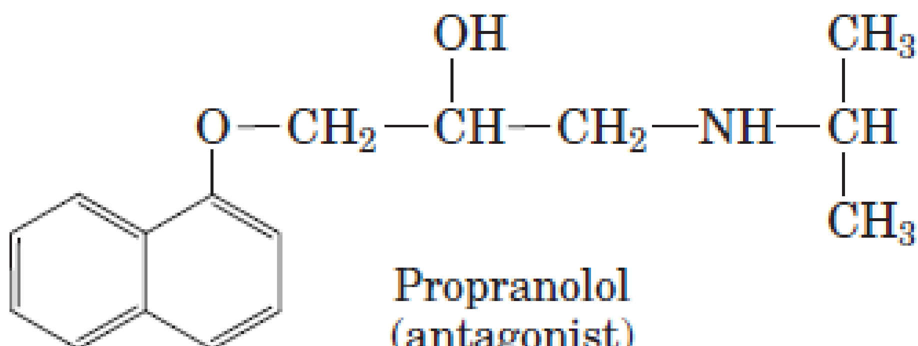
k_d (μM)



Epinephrine — 5



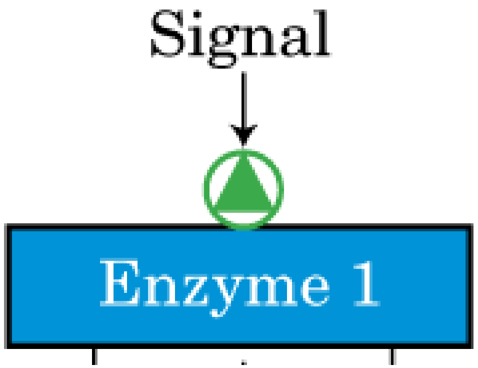
Isoproterenol (agonist) — 0.4



Propranolol (antagonist) — 0.0046

(b) Amplification

When enzymes activate enzymes, the number of affected molecules increases geometrically in an enzyme cascade.



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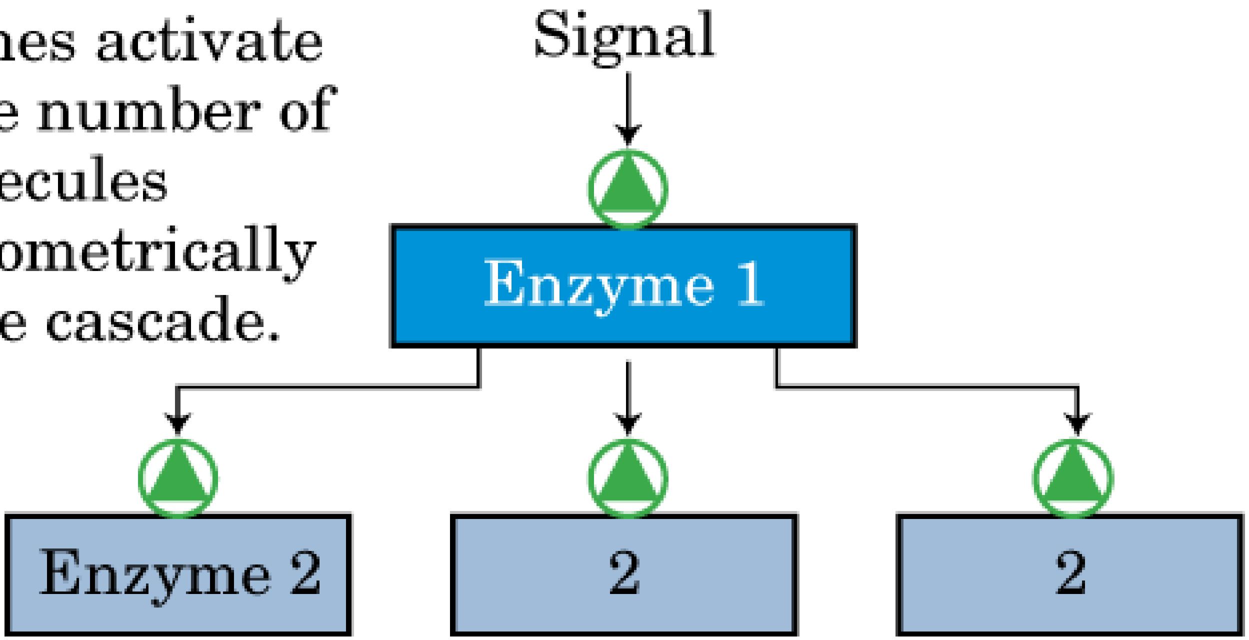

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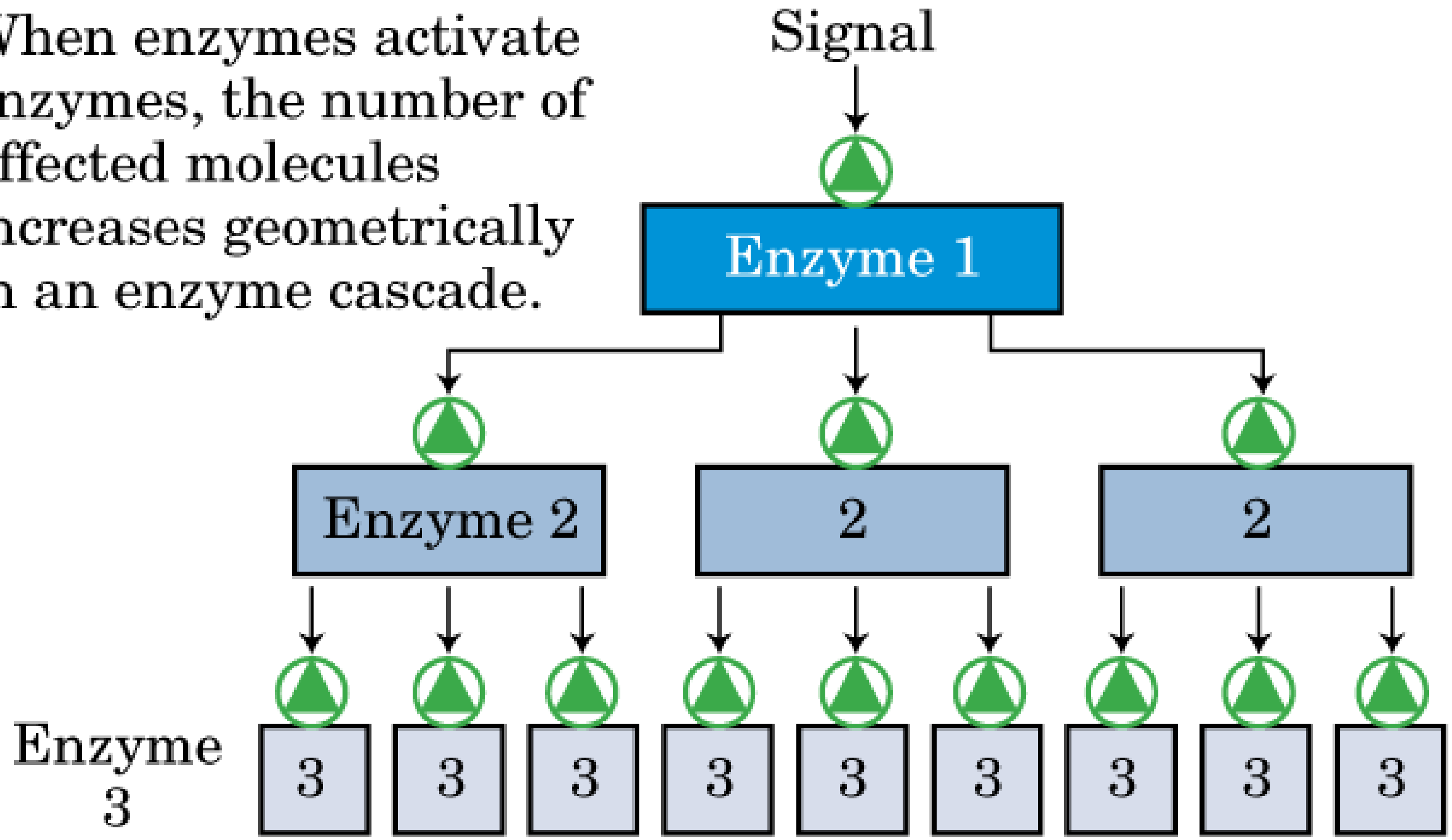
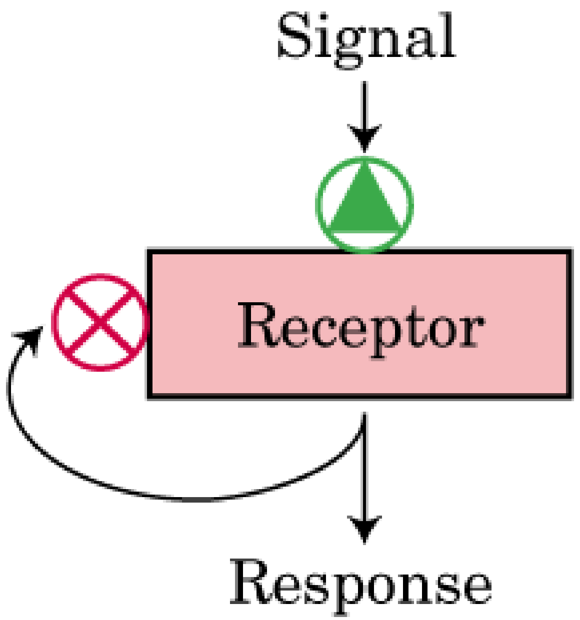


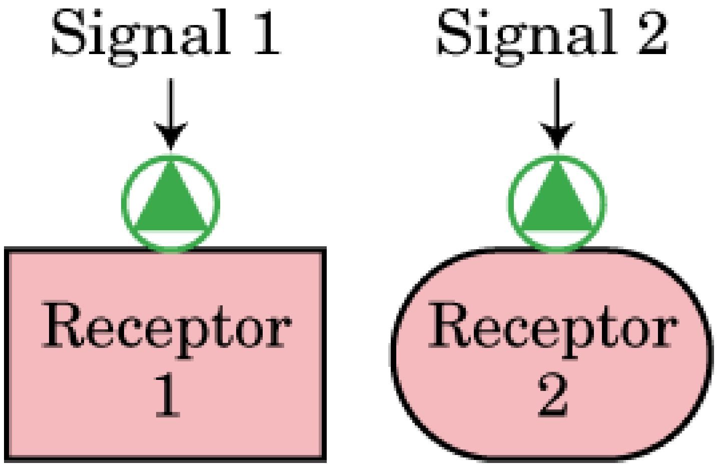
(c) Desensitization/Adaptation

Receptor activation triggers a feedback circuit that shuts off the receptor or removes it from the cell surface.



(d) Integration

When two signals have opposite effects on a metabolic characteristic such as the concentration of a second messenger X, or the membrane potential V_m, the regulatory outcome results from the integrated input from both receptors.



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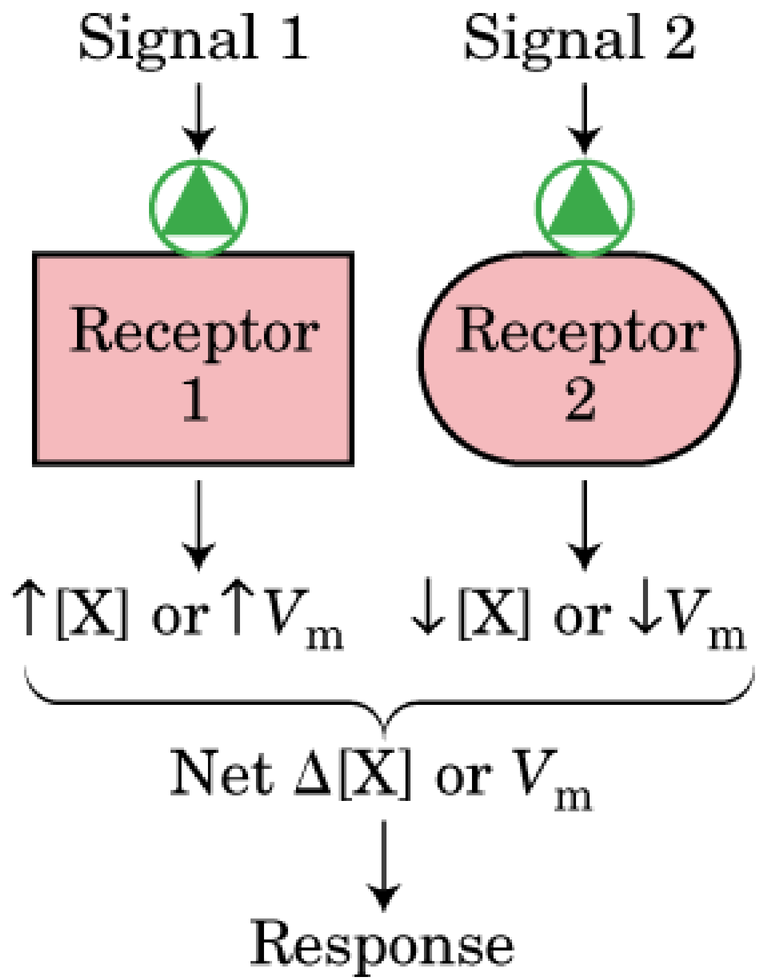
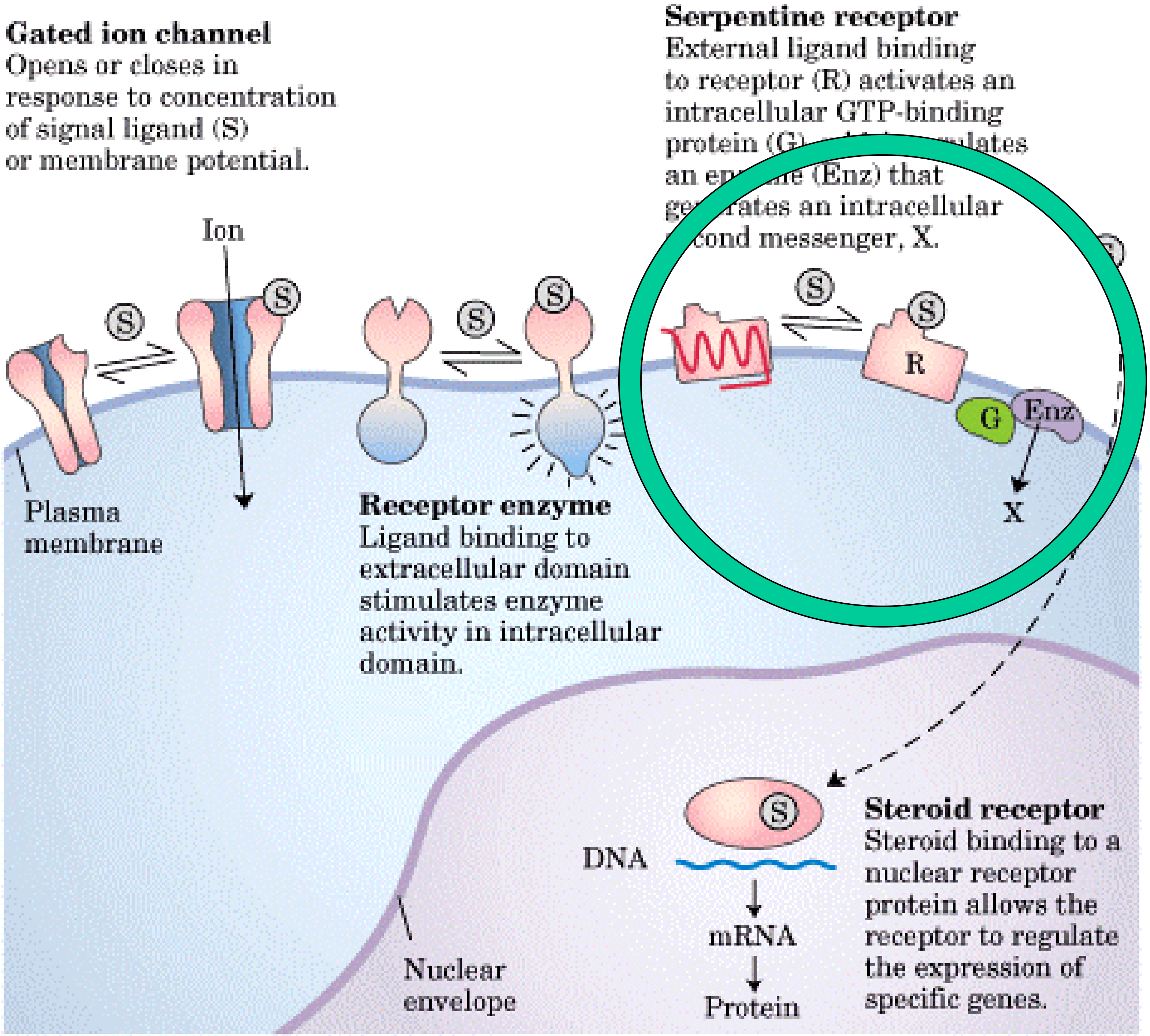
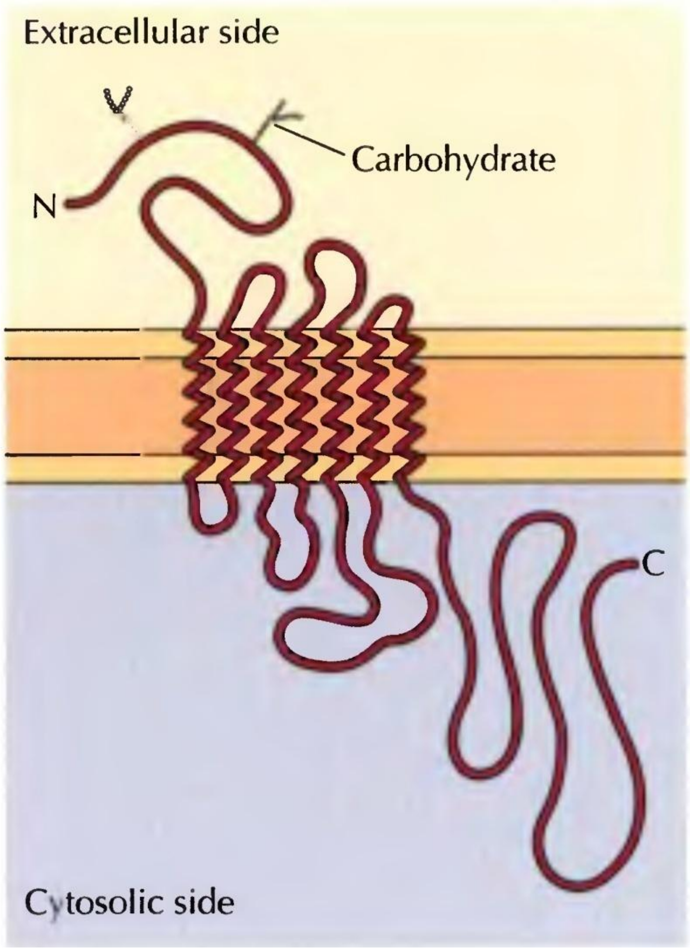
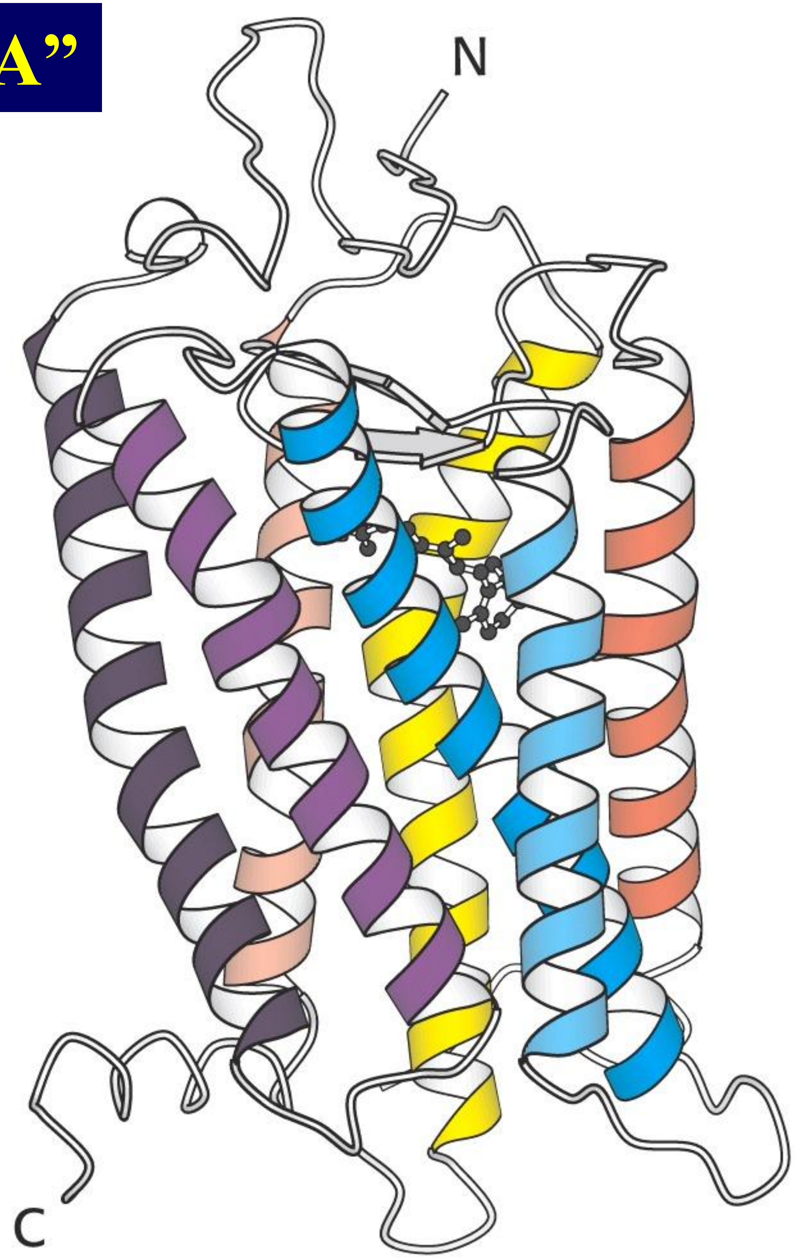


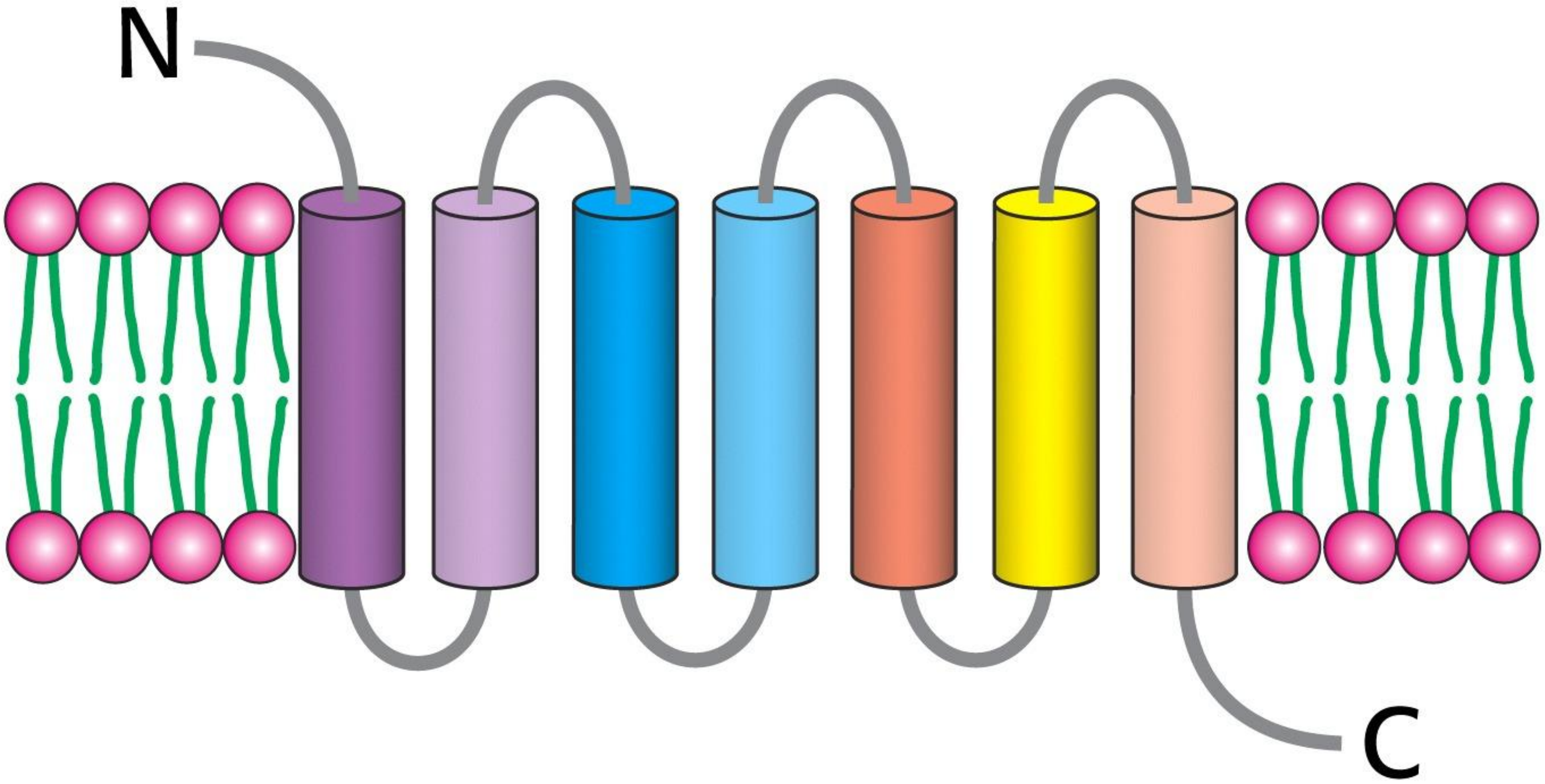

Gated ion channel
Opens or closes in response to concentration of signal ligand (S) or membrane potential.
Ion
S
Plasma membrane
S
S
Receptor enzyme
Ligand binding to extracellular domain stimulates enzyme activity in intracellular domain.
Serpentine receptor
External ligand binding to receptor (R) activates an intracellular GTP-binding protein (G)
an en
ates an intracellular
cond messenger, X.
S
S
R
G
Enz
X
DNA
S
mRNA
Protein
Steroid receptor
Steroid binding to a nuclear receptor protein allows the receptor to regulate the expression of specific genes.
Nuclear envelope

RECEPTORES "SERPENTINA"





(A)



RECEPTORES "SERPENTINA"

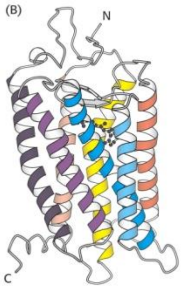


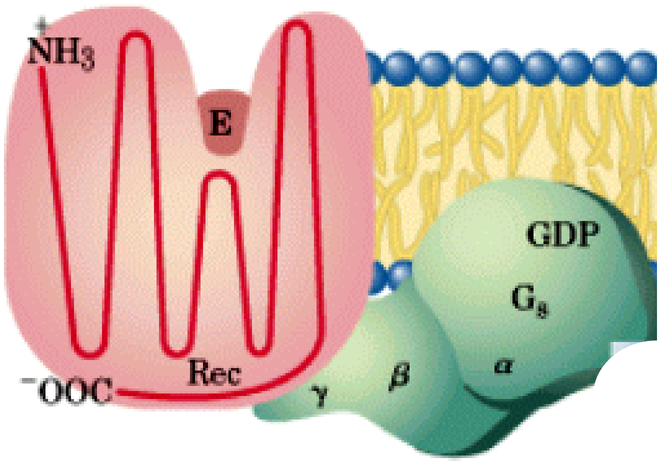
TABLE 15.1 Biological functions mediated by 7TM receptors

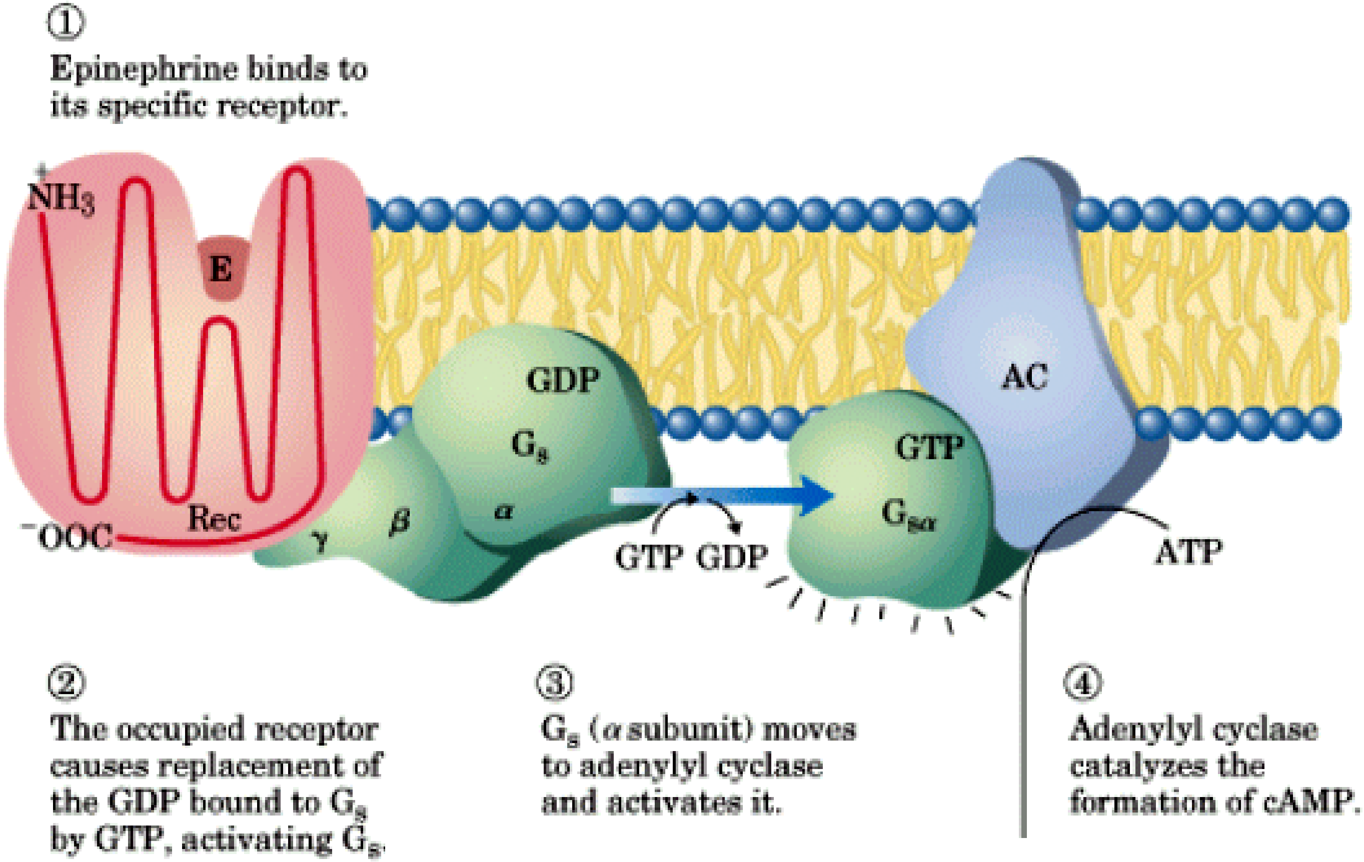
- Smell
- Taste
- Vision
- Neurotransmission
- Hormone secretion
- Chemotaxis
- Exocytosis
- Control of blood pressure
- Embryogenesis
- Cell growth and differentiation
- Development
- Viral infection
- Carcinogenesis

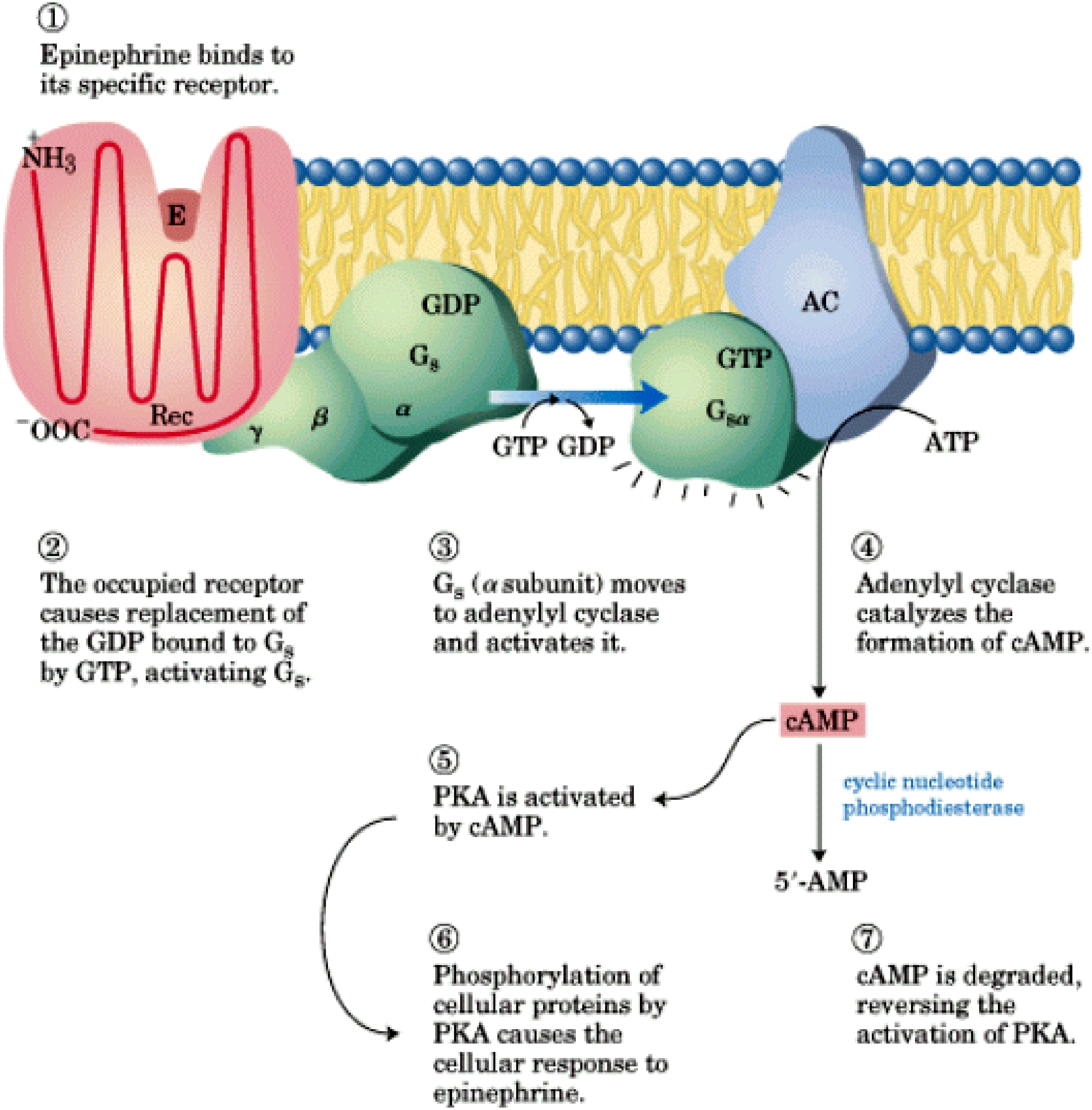
Source: After J. S. Gutkind, *J. Biol. Chem.* 273(1998):1839.

①

Epinephrine binds to its specific receptor.



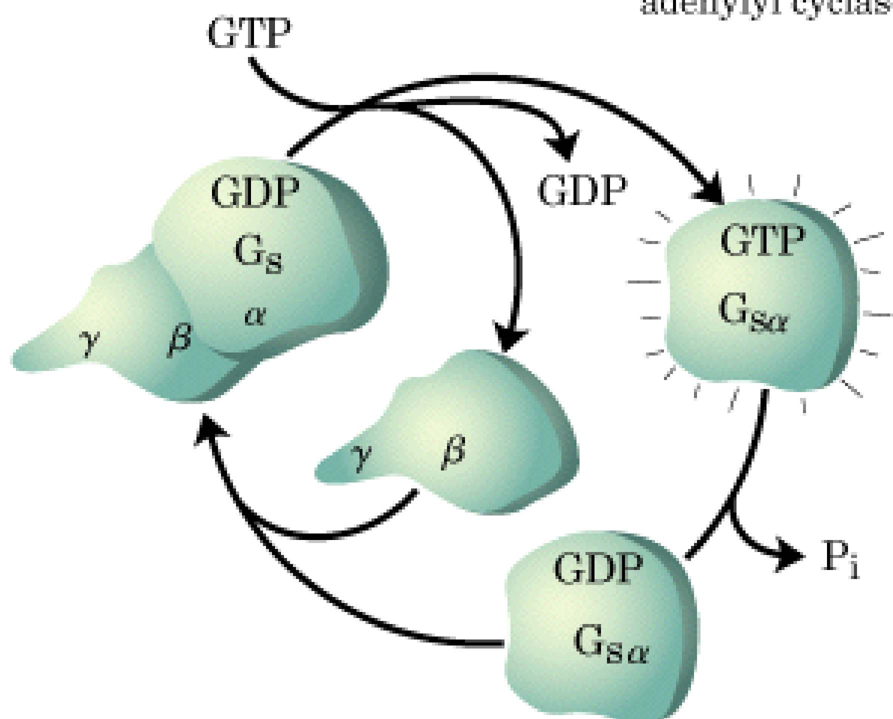

① Epinephrine binds to its specific receptor.
NH_3^+
E
Rec
^{-}OOC
GDP
G_s
γ
β
α
GTP
GDP
GTP
$G_{s\alpha}$
AC
ATP
② The occupied receptor causes replacement of the GDP bound to G_s by GTP, activating G_s.
③ G_s (α subunit) moves to adenylyl cyclase and activates it.
④ Adenylyl cyclase catalyzes the formation of cAMP.


①
Epinephrine binds to its specific receptor.
$^{+}NH_3$
E
Rec
^{-}OOC
γ
β
α
GDP
G_s
GTP GDP
GTP
$G_{s\alpha}$
AC
ATP
②
The occupied receptor causes replacement of the GDP bound to G_s by GTP, activating G_s.
③
G_s (α subunit) moves to adenylyl cyclase and activates it.
④
Adenylyl cyclase catalyzes the formation of cAMP.
cAMP
⑤
PKA is activated by cAMP.
cyclic nucleotide phosphodiesterase
5′-AMP
⑥
Phosphorylation of cellular proteins by PKA causes the cellular response to epinephrine.
⑦
cAMP is degraded, reversing the activation of PKA.

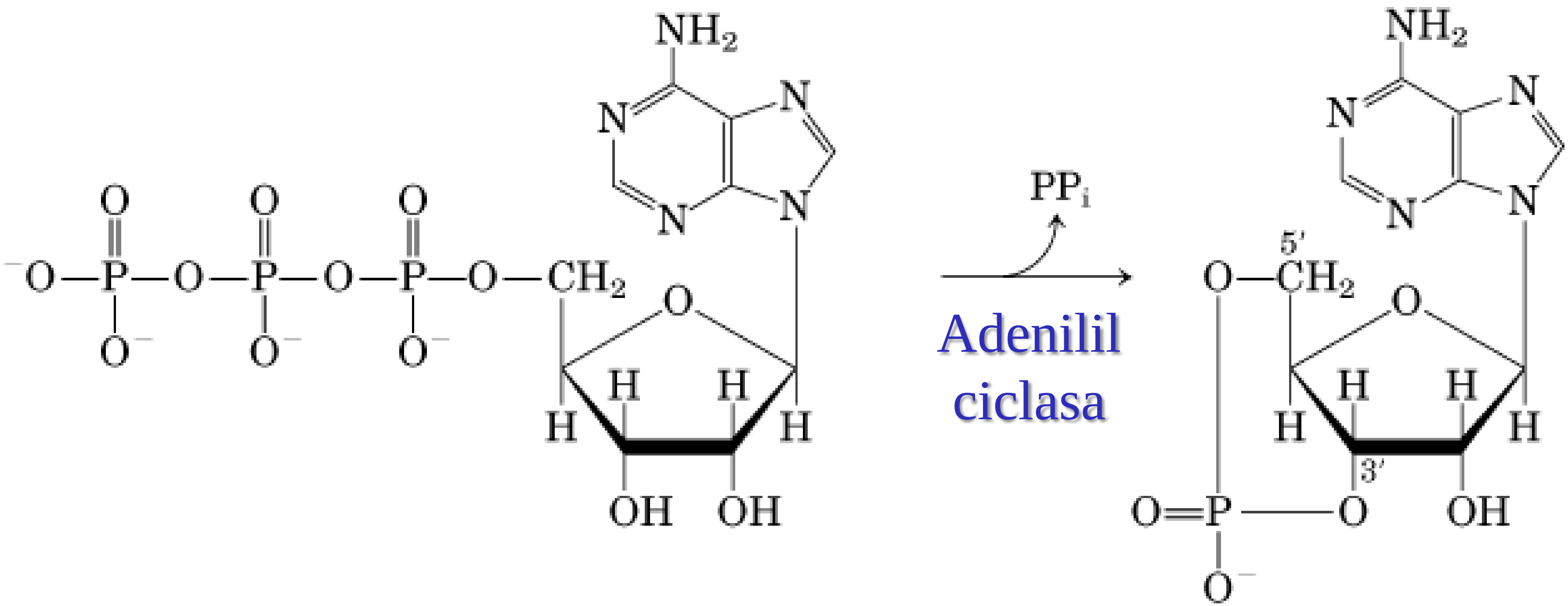
① G_s with GDP bound is turned off; it cannot activate adenylyl cyclase.

② Contact of G_s with hormone-receptor complex causes displacement of bound GDP by GTP.

③ G_s with GTP bound dissociates into α and βγ subunits. $G_{s\alpha}$-GTP is turned on; it can activate adenylyl cyclase.



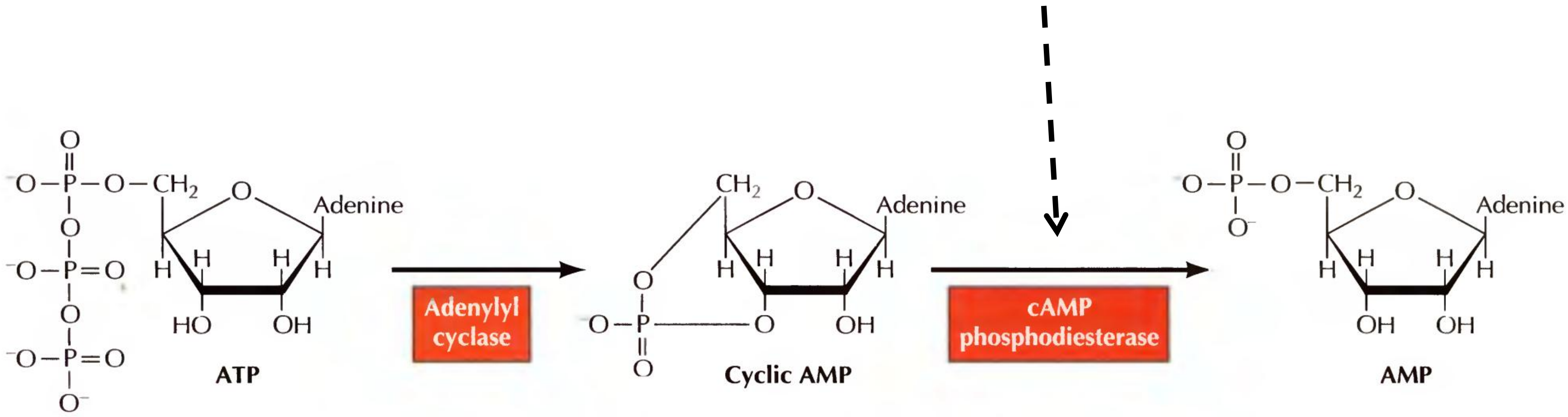
④ GTP bound to $G_{s\alpha}$ is hydrolyzed by the protein's intrinsic GTPase; $G_{s\alpha}$ thereby turns itself off. The inactive α subunit reassociates with the β, γ subunits.



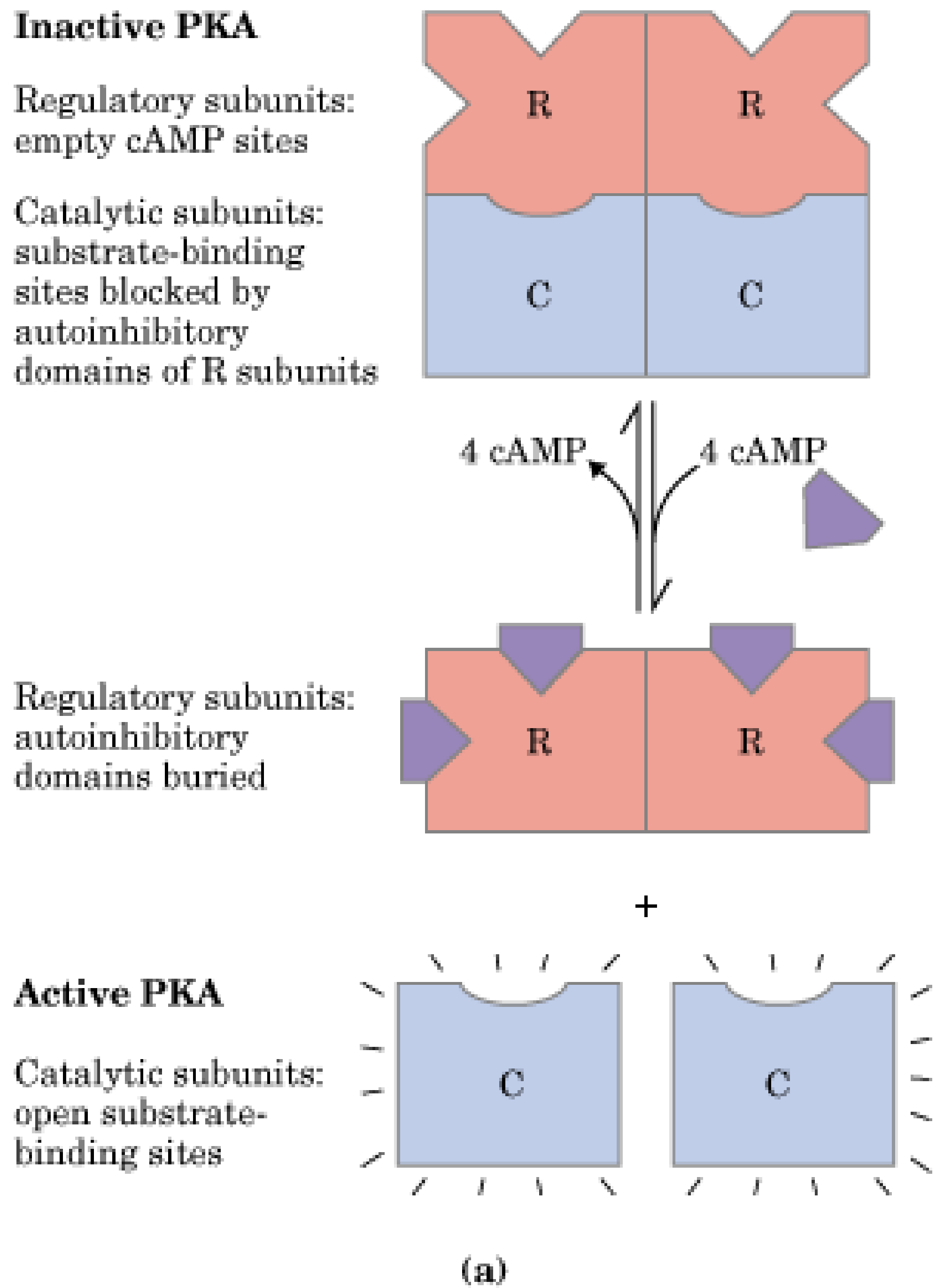
ATP

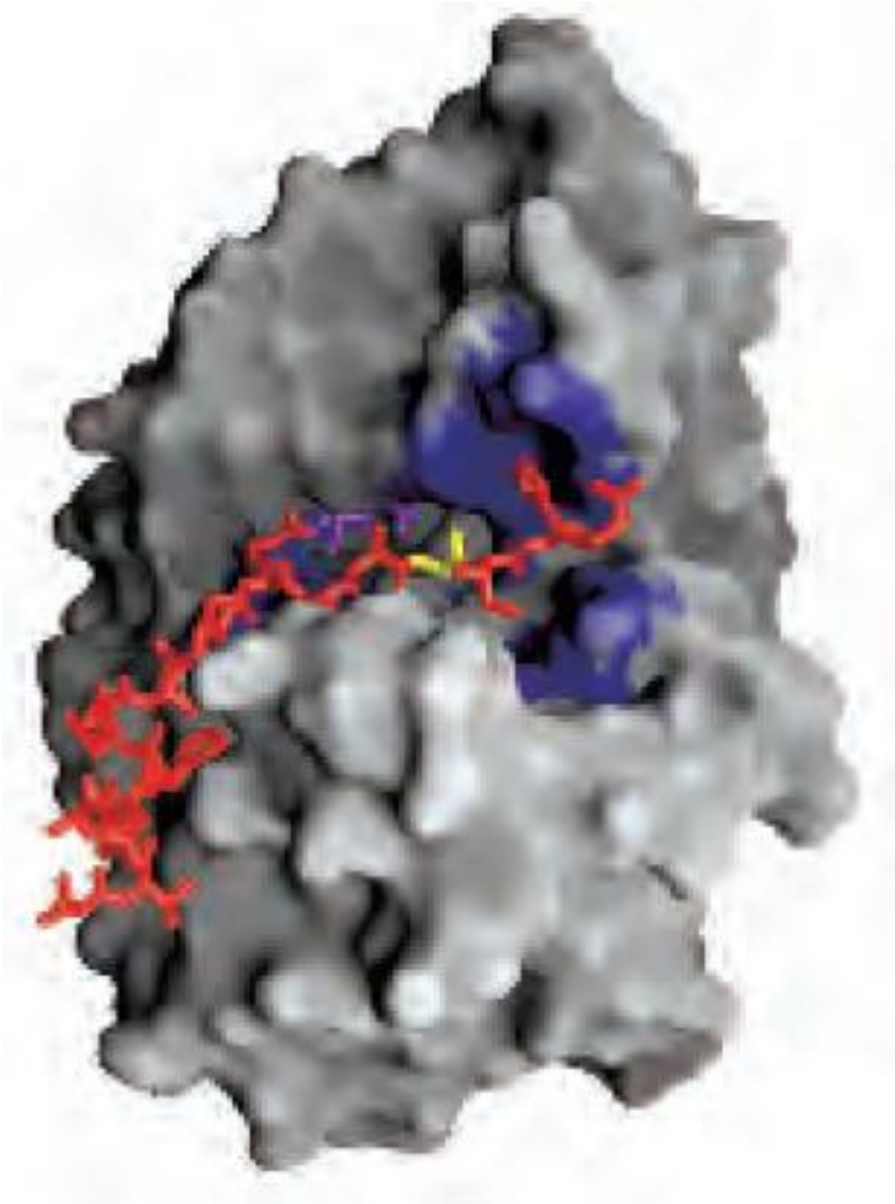
Adenosine 3′,5′-cyclic monophosphate (cAMP)

FOSFODIESTERASA



Proteína quinasa
o
Proteína cinasa
(PKA)





Región de unión al sustrato de la subunidad catalítica. Péptido sustrato (rojo), cadenas laterales de los residuos de aminoácidos críticos para la unión del sustrato (azul), residuo de serina (amarillo)

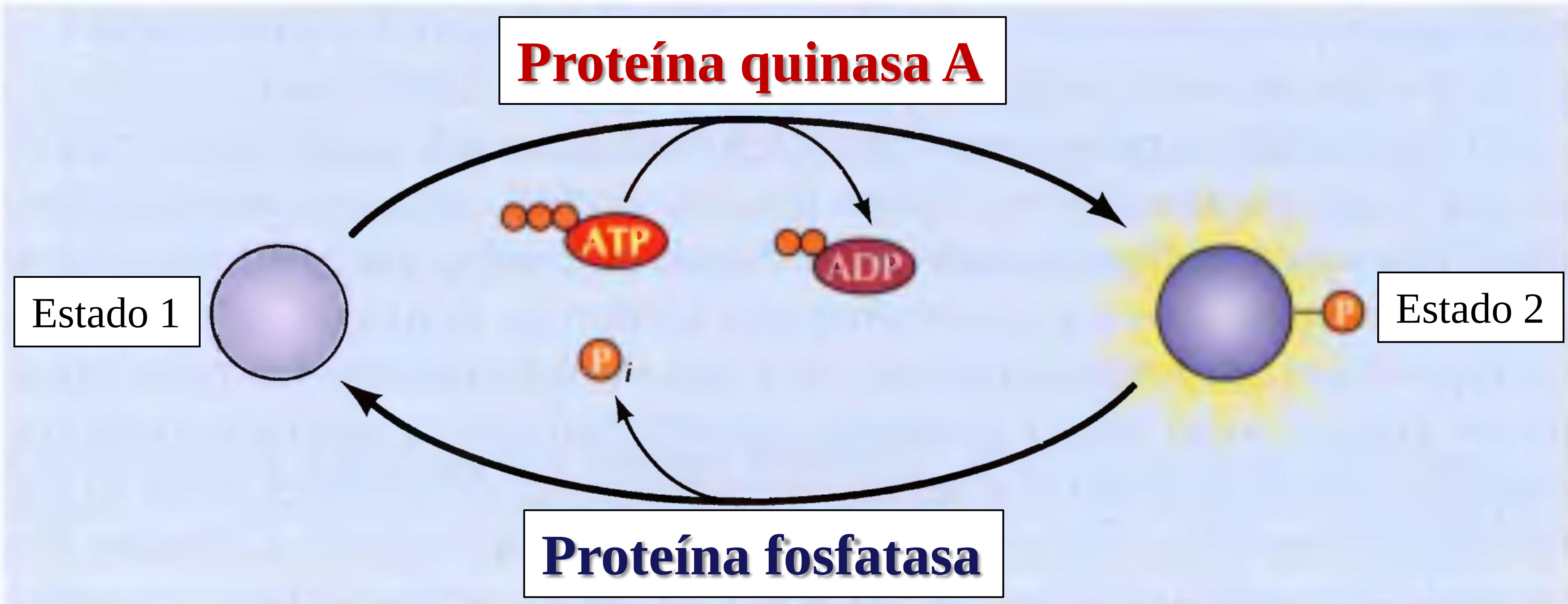
Proteínas fosforiladas por PKA

TABLE 12–3 Some Enzymes and Other Proteins Regulated by cAMP-Dependent Phosphorylation (by PKA)

Enzyme/protein	*Sequence phosphorylated*[*]	*Pathway/process regulated*
Glycogen synthase	RASCTSSS	Glycogen synthesis
Phosphorylase *b* kinase		
α subunit	VEFRRLSI	Glycogen breakdown
β subunit	RTKRSGSV	Glycogen breakdown
Pyruvate kinase (rat liver)	GVLRRASVAZL	Glycolysis
Pyruvate dehydrogenase complex (type L)	GYLRRASV	Pyruvate to acetyl-CoA
Hormone-sensitive lipase	PMRRSV	Triacylglycerol mobilization and fatty acid oxidation
Phosphofructokinase-2/fructose 2,6-bisphosphatase	LQRRRGSSIPQ	Glycolysis/gluconeogenesis
Tyrosine hydroxylase	FIGRRQSL	Synthesis of L-DOPA, dopamine, norepinephrine, and epinephrine
Histone H1	AKRKASGPPVS	DNA condensation
Histone H2B	KKAKASRKESYSVYVYK	DNA condensation
Cardiac phospholamban (cardiac pump regulator)	AIRRAST	Intracellular [Ca^{2+}]
Protein phosphatase-1 inhibitor-1	IRRRRPTP	Protein dephosphorylation
PKA consensus sequence[†]	XR(R/K)X(S/T)B	Many

*The phosphorylated S or T residue is shown in red. All residues are given as their one-letter abbreviations (see Table 3-1).

†X is any amino acid; B is any hydrophobic amino acid.



Al menos el 10% de las proteínas en una célula eucarionte sufren modificación covalente por fosforilación. Se han descrito 2000 kinasas y unas 1000 fosfatasas.

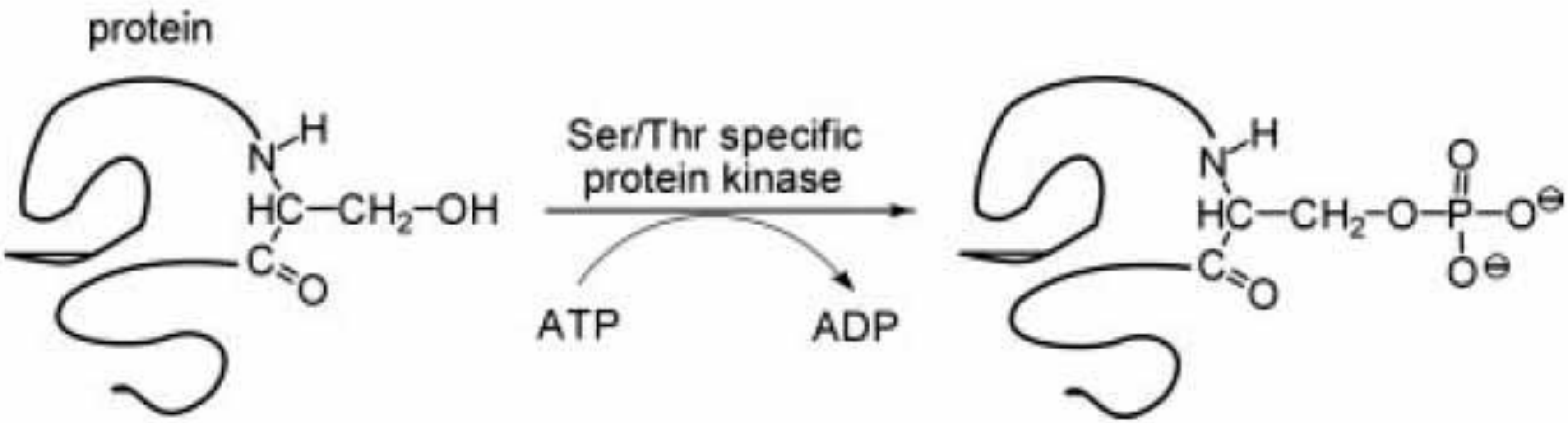
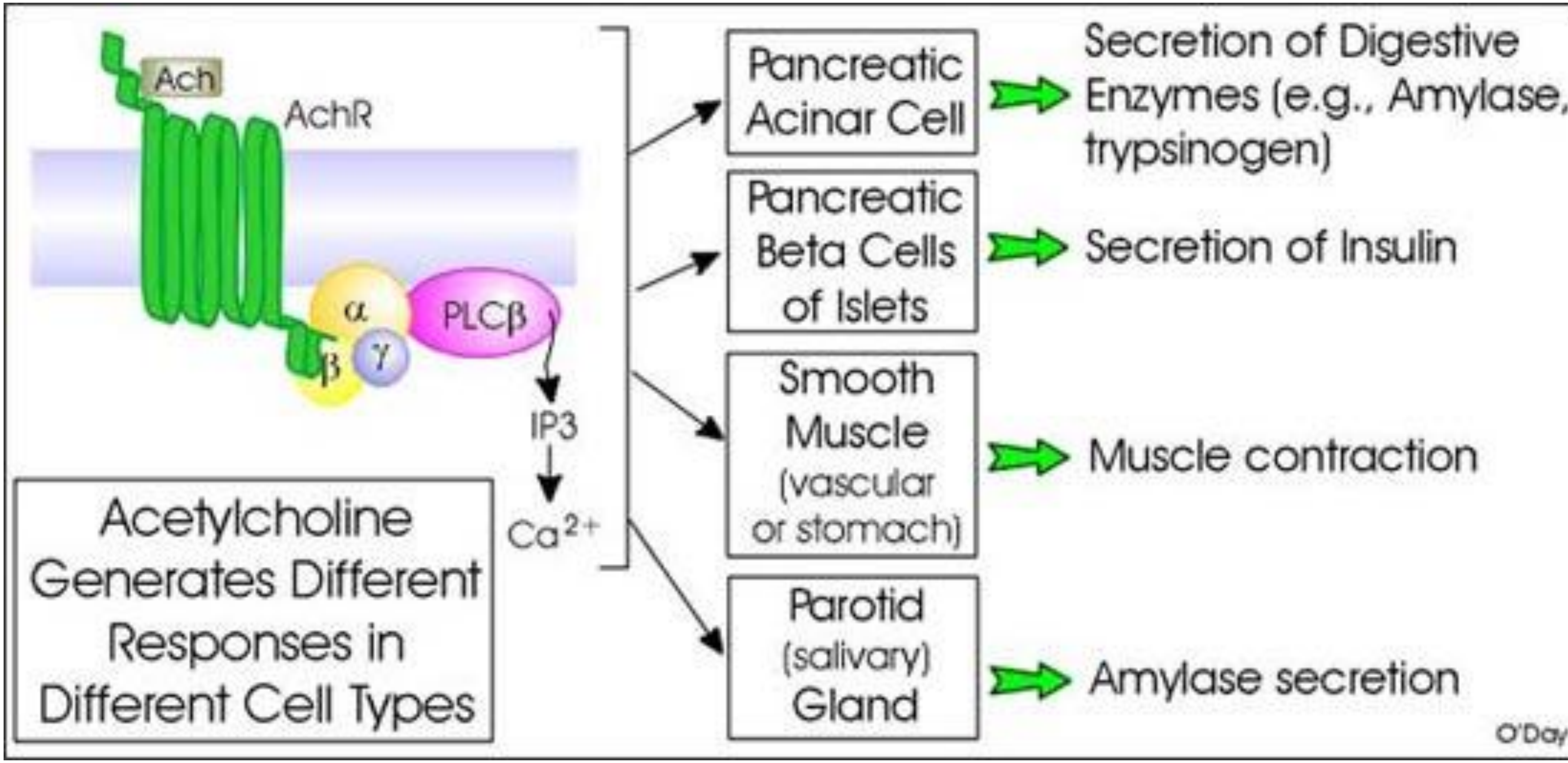
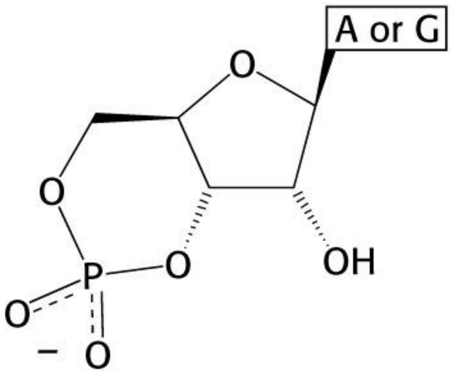


Fig. 2.5 Change in charge state of proteins via phosphorylation. The phosphorylation of Ser residues is catalyzed by a Ser/Thr-specific protein kinase that utilizes ATP as the phosphate group donor. The product of the reaction is a Ser-phosphate ester which carries a net charge of -2 at physiological pH.

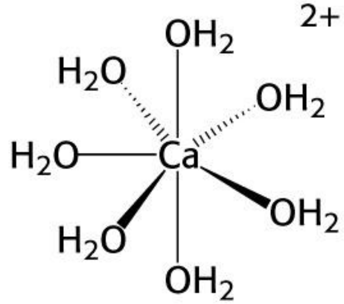
La Acetilcolina actúa vía proteína G



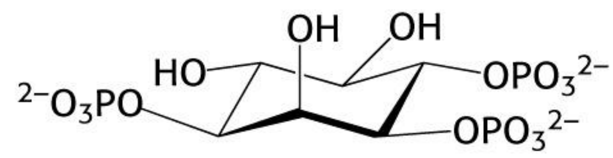
SEGUNDOS MENSAJEROS



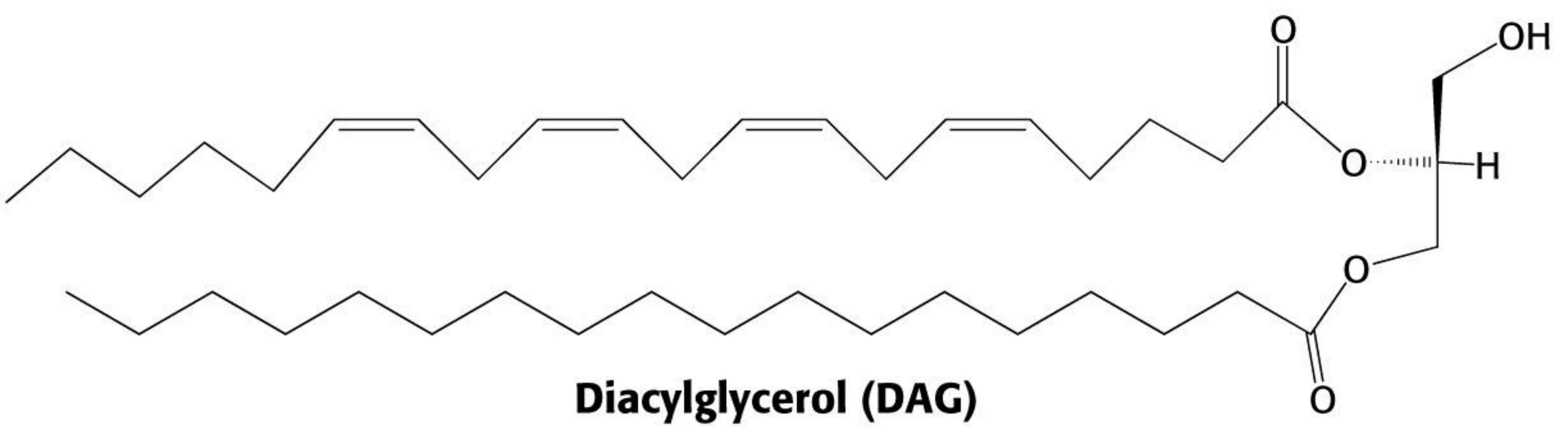
cAMP, cGMP



Calcium ion



Inositol 1,4,5-trisphosphate (IP_3)



Diacylglycerol (DAG)

Class or Type	Stimulus	Effector	Effect
G_s (G_s)			
α_s	Glucagon, β-adrenergics	↑ Adenylyl cyclase ↑ Cardiac Ca^{2+}, Cl^-, and Na^+ channels	Gluconeogenesis, lipolysis, glycogenolysis
α_{olf}	Odorant	↑ Adenylyl cyclase	Olfaction
G_i (G_i)			
$\alpha_{i\text{-}1,2,3}$	Acetylcholine, α_2-adrenergics M_2 cholinergics	↓ Adenylyl cyclase ↑ Potassium channels ↓ Calcium channels	Slowed heart rate
α_o	Opioids, endorphins	↑ Potassium channels	Neuronal electrical activity
α_t	Light	↑ cGMP phosphodiesterase	Vision
G_q (G_q)			
α_q	M_1 cholinergics α_1-Adrenergics	↑ Phospholipase C-β1	↑ Muscle contraction and
α_{11}	α_1-Adrenergics	↑ Phospholipase c-β2	↑ Blood pressure

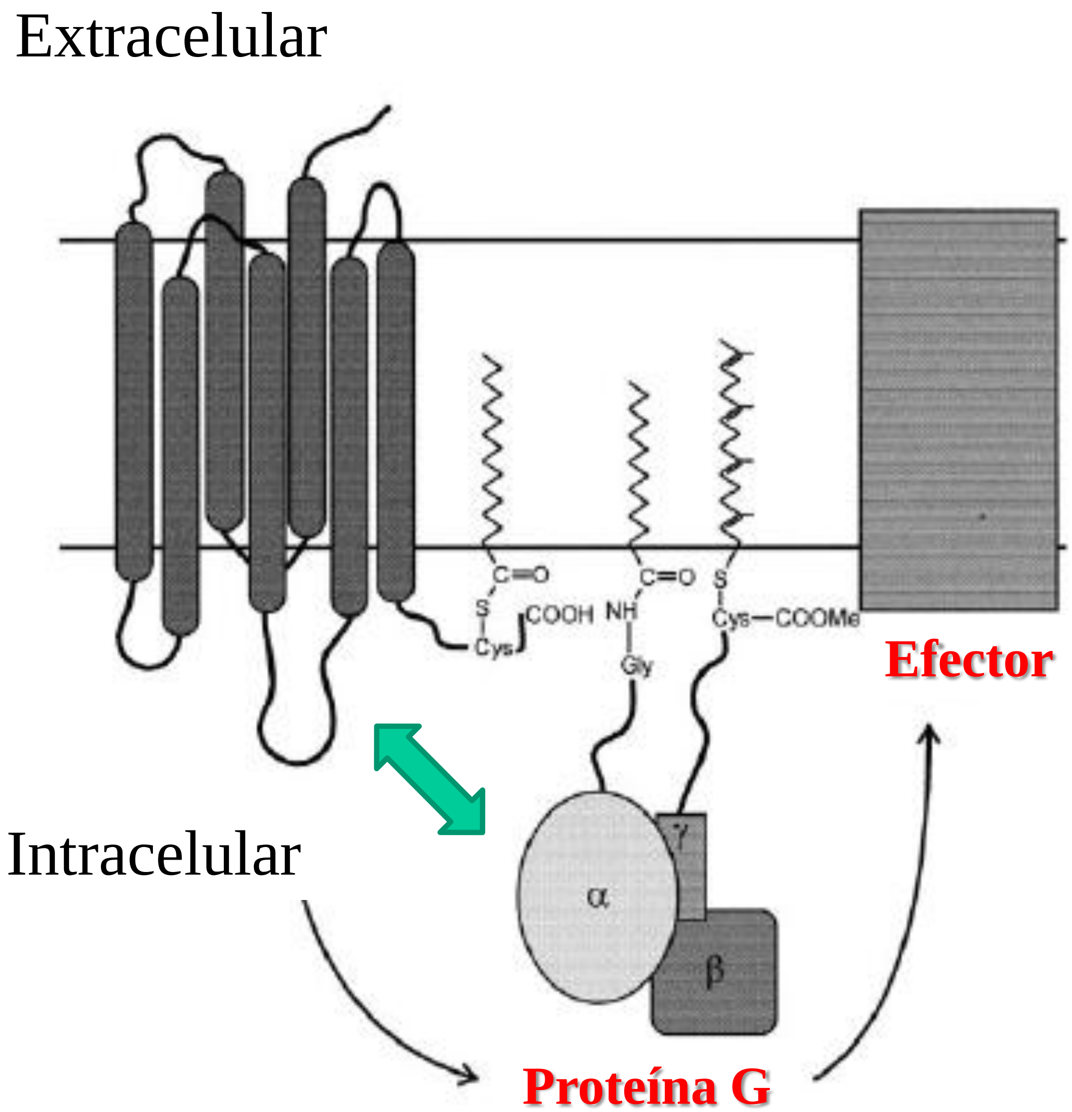
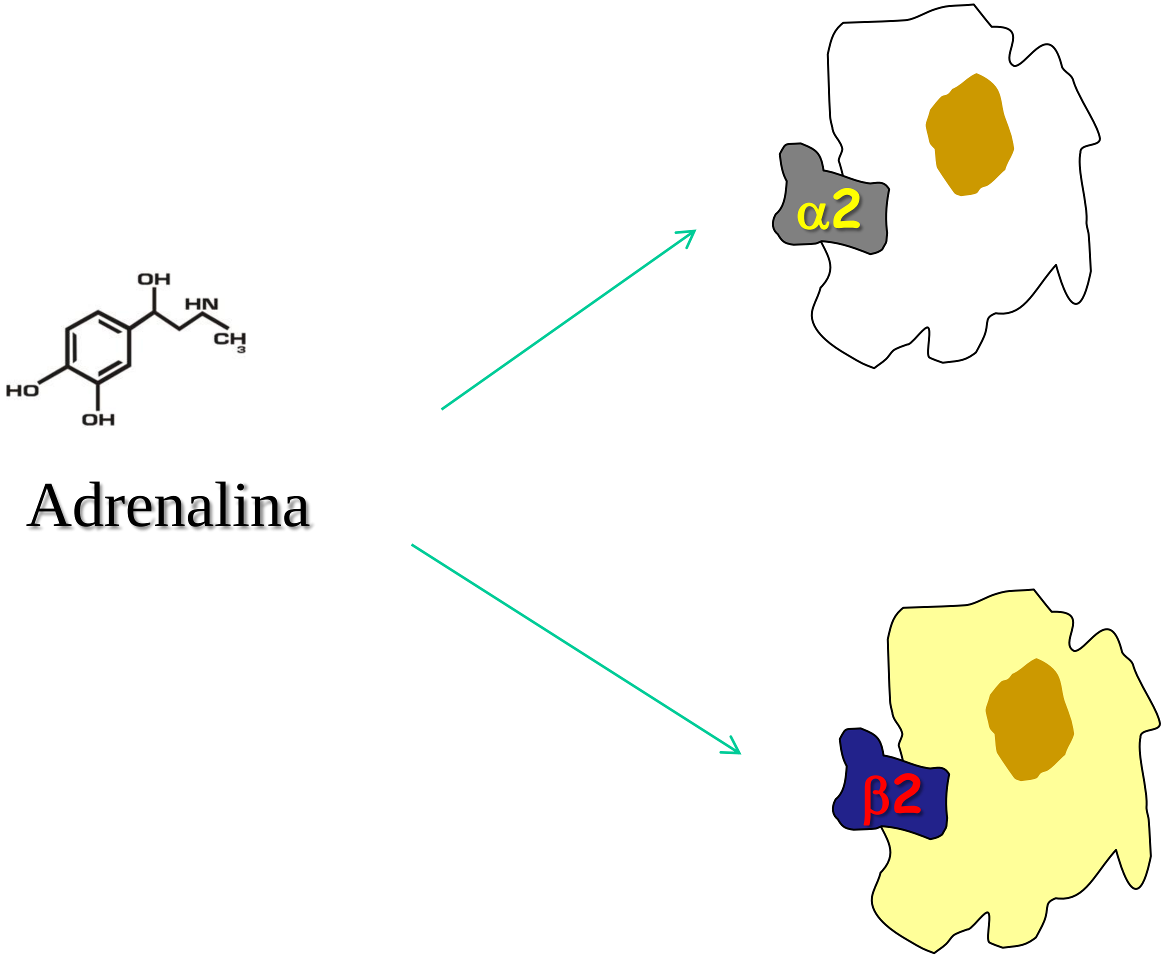
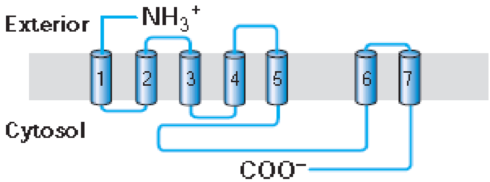

Extracelular
C=O
S
COOH
Cys
C=O
NH
Gly
S
Cys—COOMe
Efector
Intracelular
γ
α
β
Proteína G

Table 43–2. Subclassification of group II.A hormones.

Hormones That Stimulate Adenylyl Cyclase (H_s)	Hormones That Inhibit Adenylyl Cyclase (H_I)
ACTH	Acetylcholine
ADH	α_2-Adrenergics
β-Adrenergics	Angiotensin II
Calcitonin	Somatostatin
CRH	
FSH	
Glucagon	
hCG	
LH	
LPH	
MSH	
PTH	
TSH	

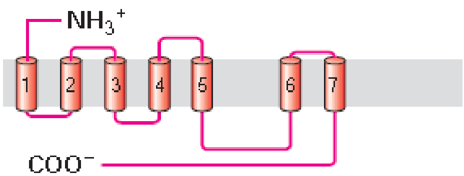

OH
HN
CH3
HO
OH
Adrenalina
α2
β2

Effect on adenylyl cyclase



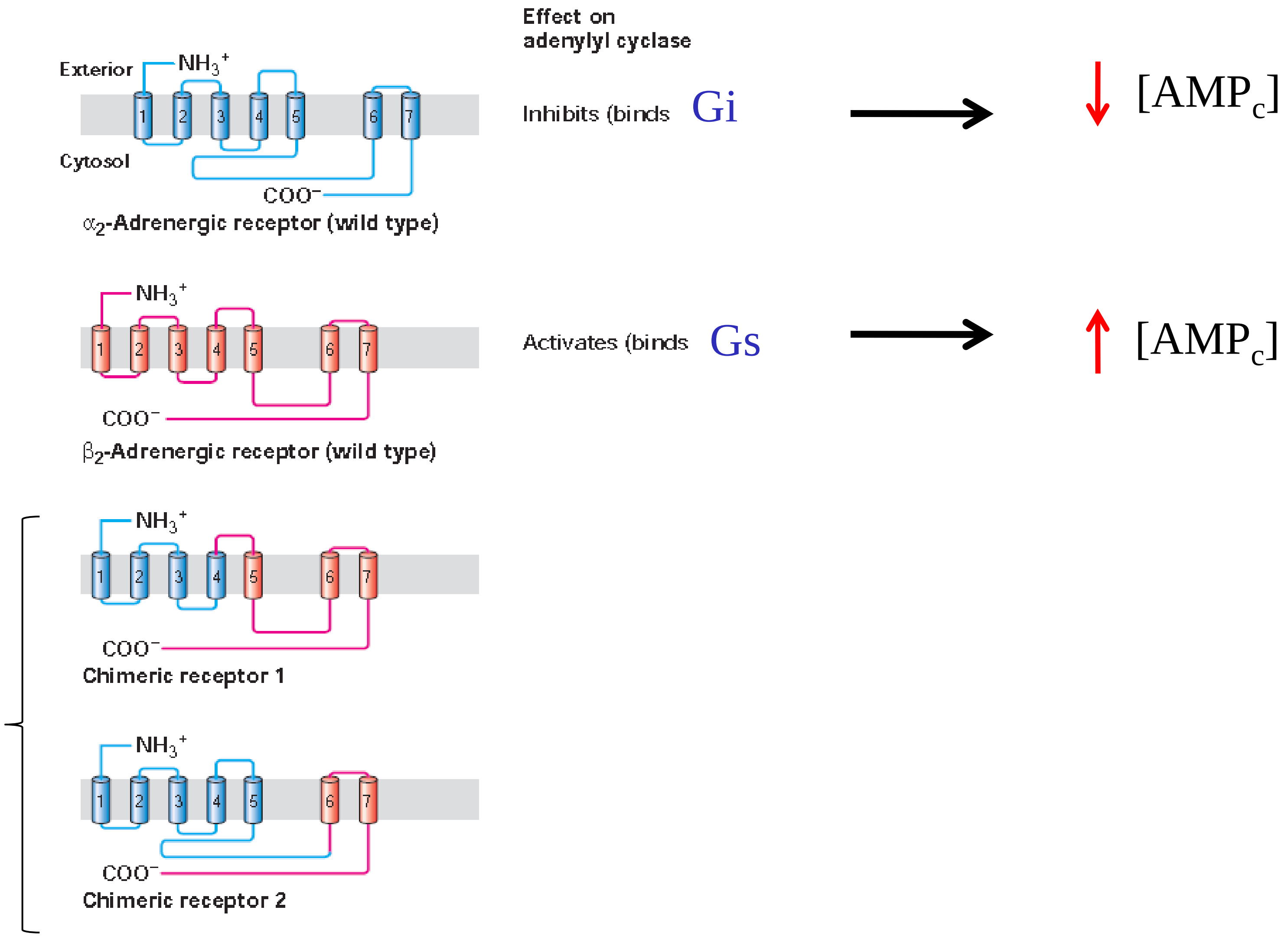
α_2-Adrenergic receptor (wild type)

Inhibits (binds Gi → ↓ [AMP_c]

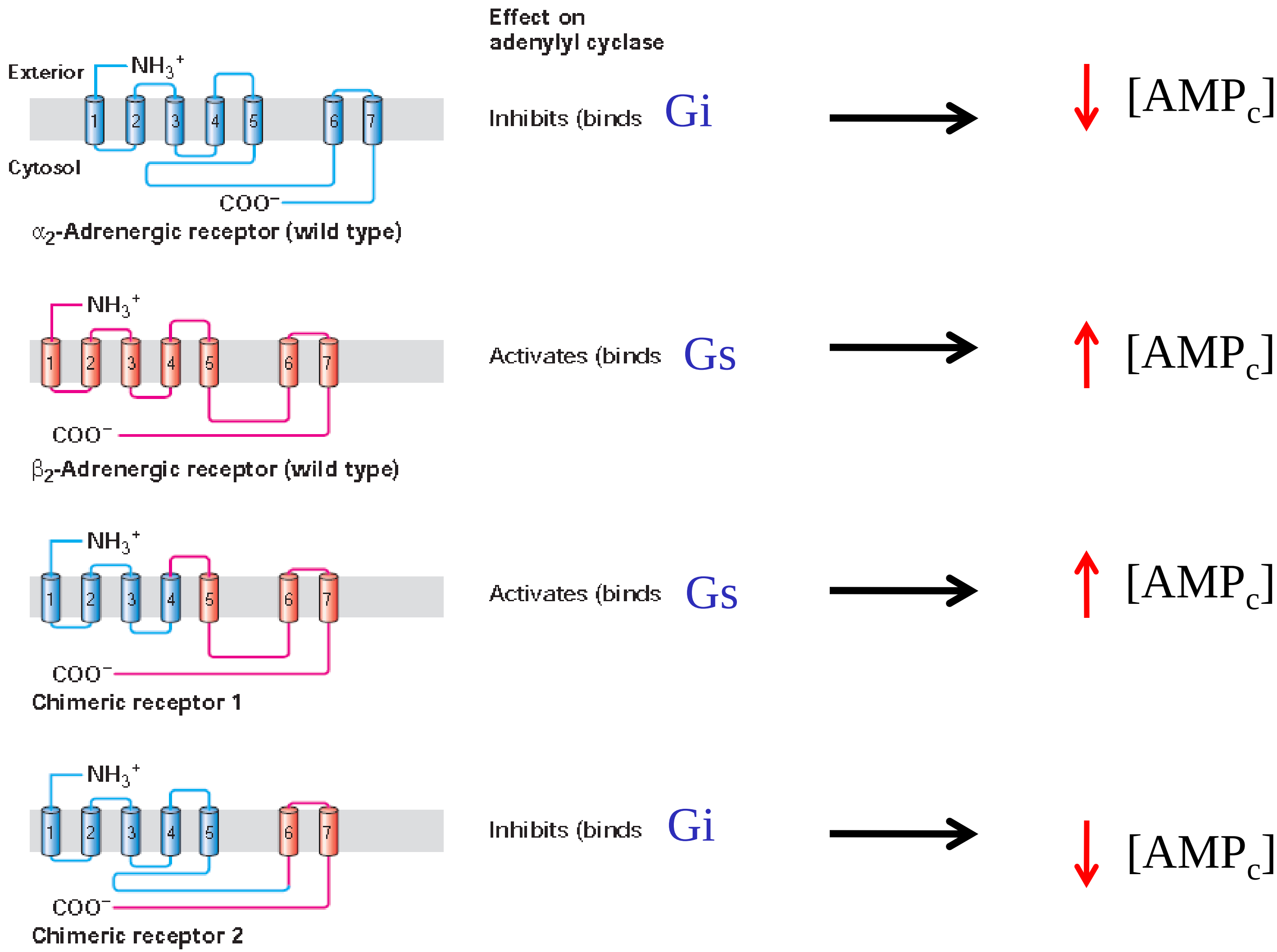


β_2-Adrenergic receptor (wild type)

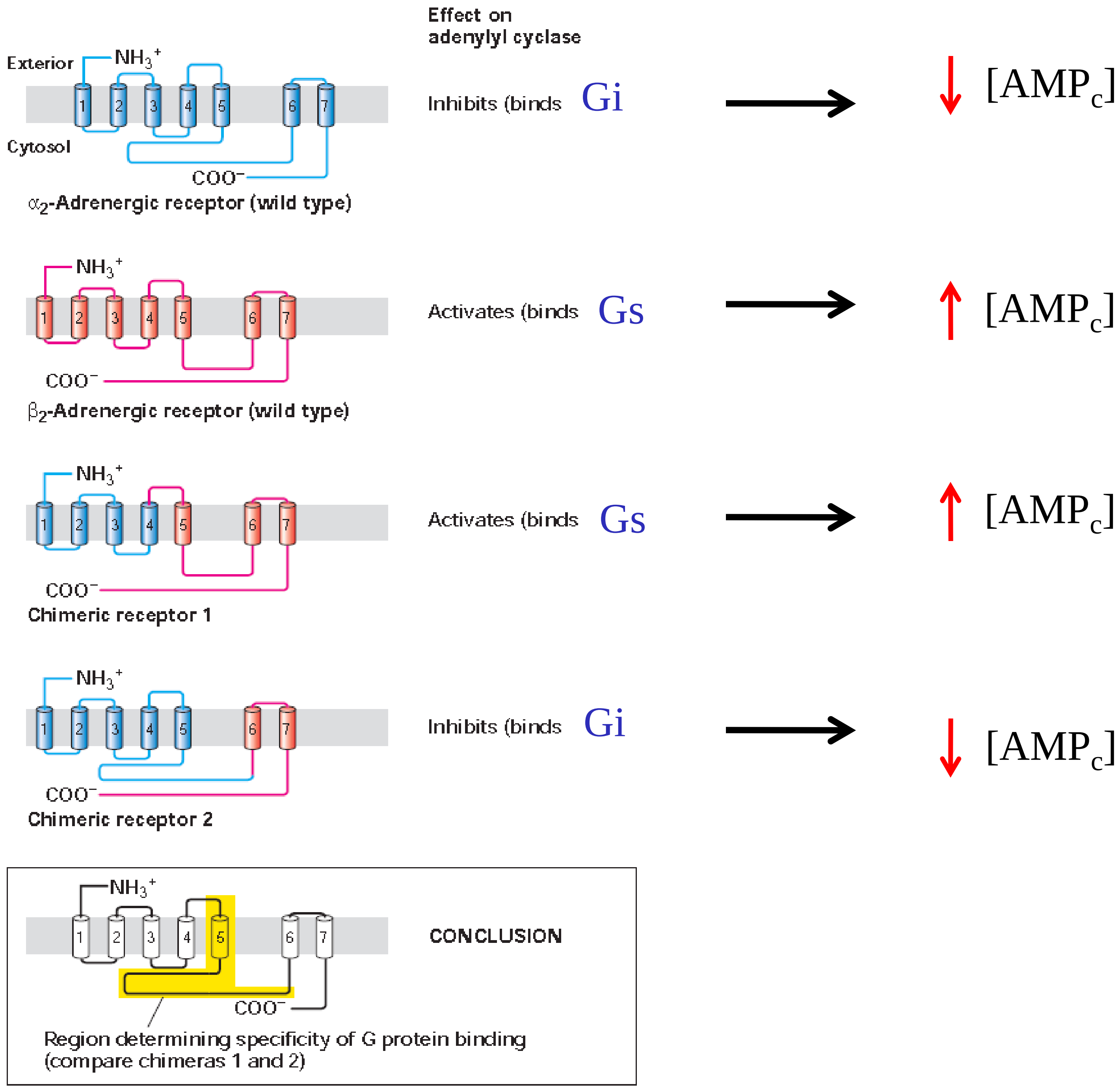
Activates (binds Gs → ↑ [AMP_c]



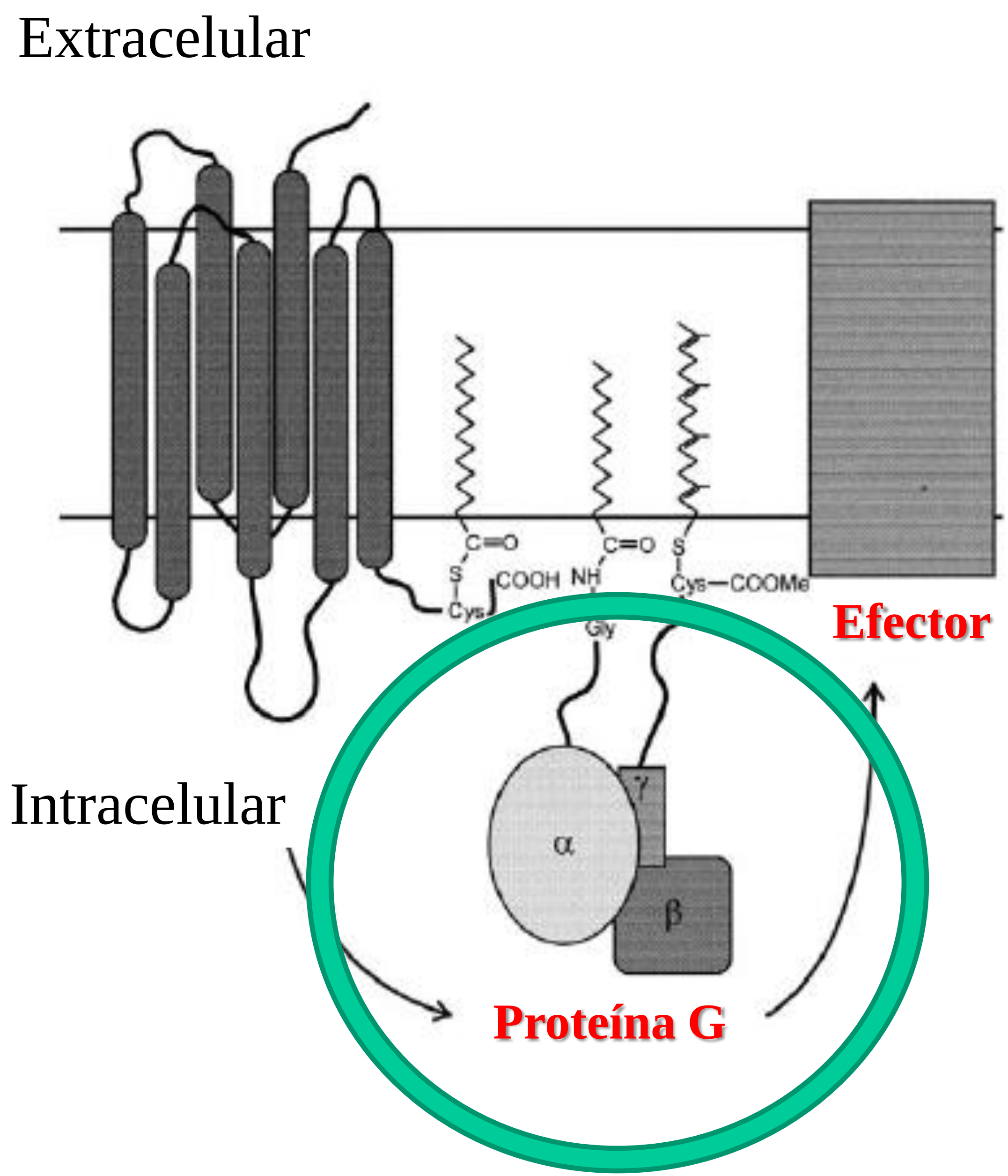
Receptores quiméricos

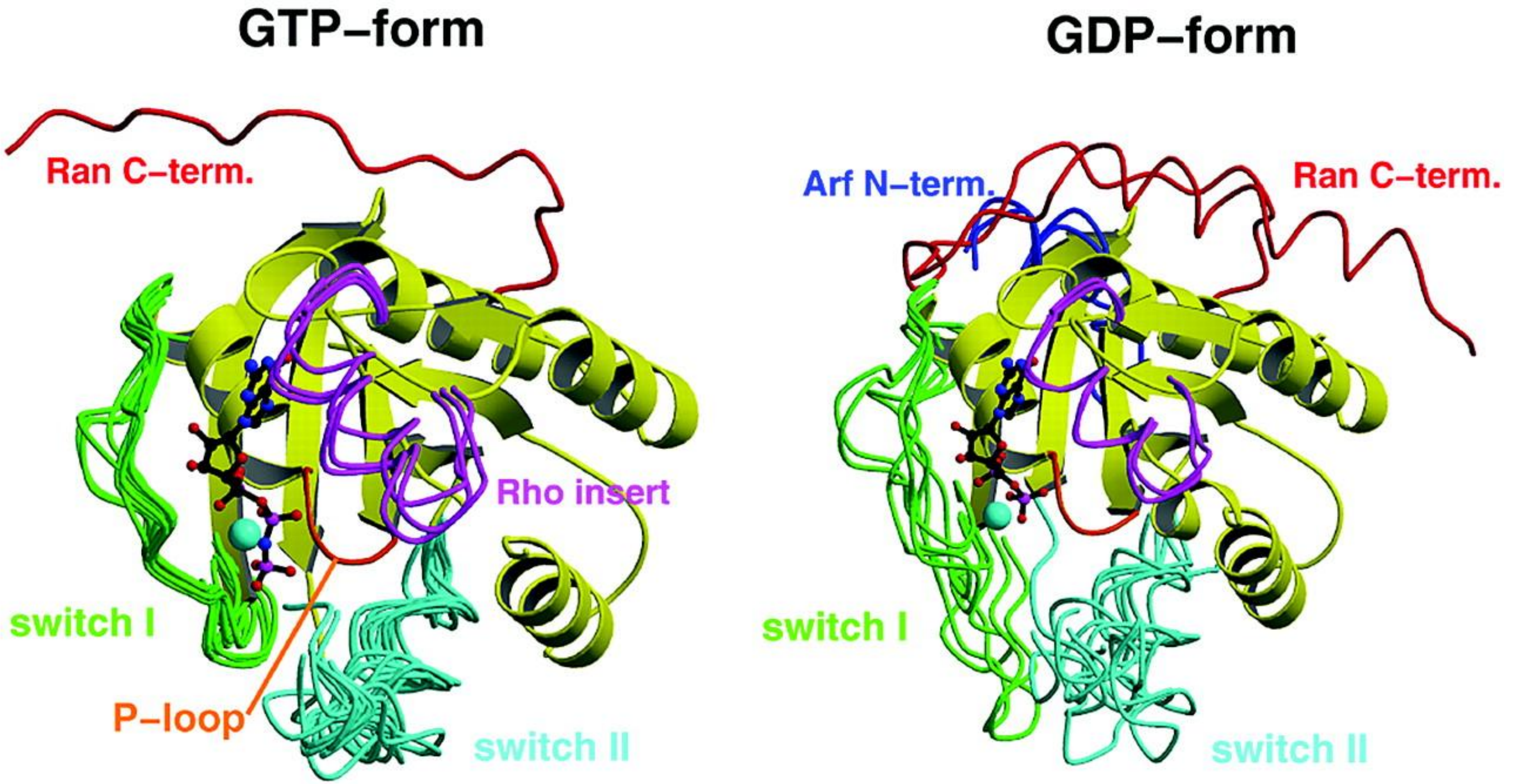


Effect on adenylyl cyclase
Exterior
NH_3^+
Cytosol
COO^-
α_2-Adrenergic receptor (wild type)
Inhibits (binds Gi → ↓ [AMP_c]
NH_3^+
COO^-
β_2-Adrenergic receptor (wild type)
Activates (binds Gs → ↑ [AMP_c]
NH_3^+
COO^-
Chimeric receptor 1
Activates (binds Gs → ↑ [AMP_c]
NH_3^+
COO^-
Chimeric receptor 2
Inhibits (binds Gi → ↓ [AMP_c]

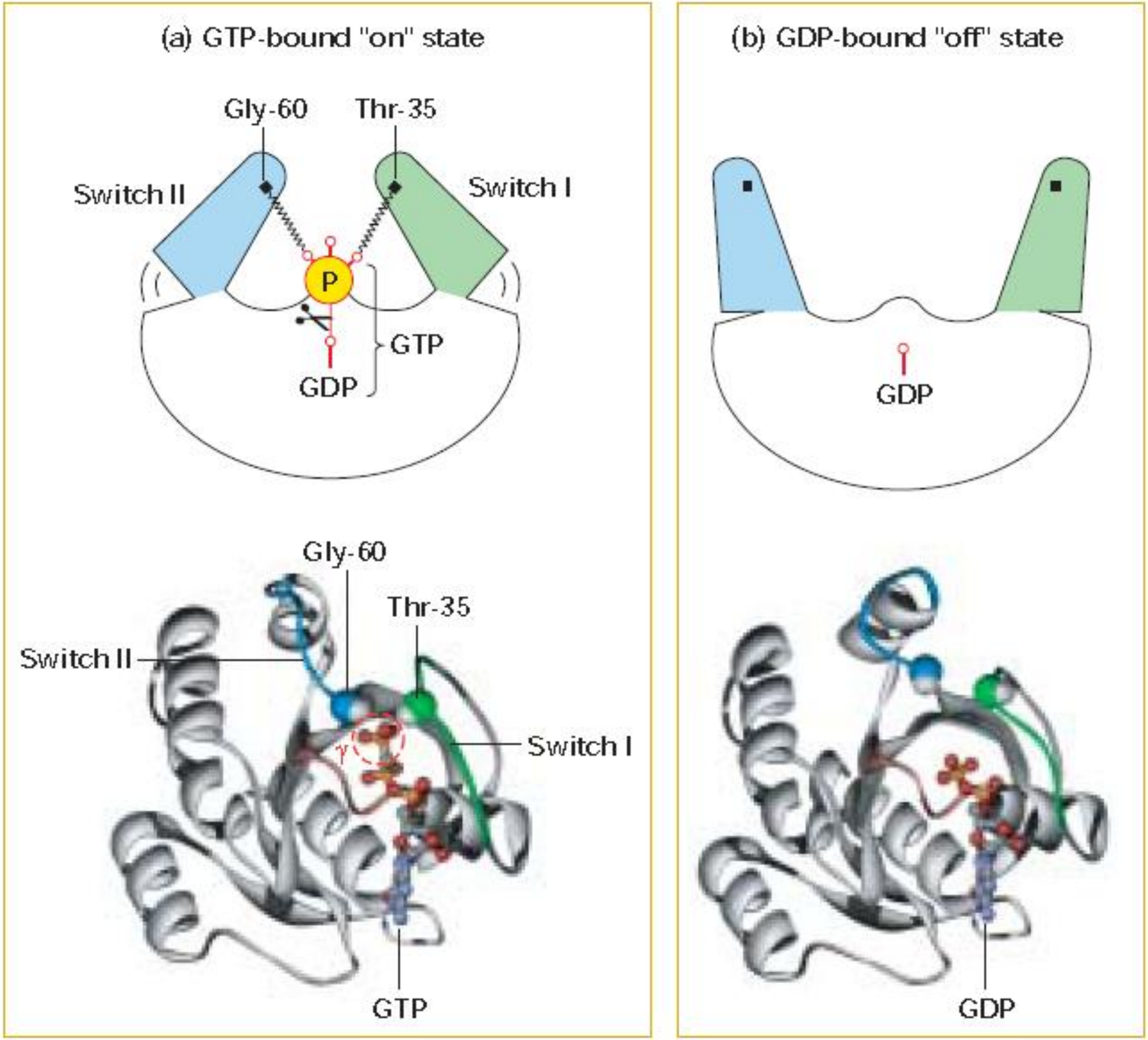


Effect on adenylyl cyclase
Exterior
NH_3^+
Cytosol
COO^-
α_2-Adrenergic receptor (wild type)
Inhibits (binds Gi
↓ [AMP_c]
NH_3^+
COO^-
β_2-Adrenergic receptor (wild type)
Activates (binds Gs
↑ [AMP_c]
NH_3^+
COO^-
Chimeric receptor 1
Activates (binds Gs
↑ [AMP_c]
NH_3^+
COO^-
Chimeric receptor 2
Inhibits (binds Gi
↓ [AMP_c]
NH_3^+
COO^-
CONCLUSION
Region determining specificity of G protein binding (compare chimeras 1 and 2)


Extracelular
C=O
S
Cys
COOH
NH
Gly
S
Cys—COOMe
Efector
Intracelular
α
γ
β
Proteína G



GTP–form
GDP–form
Ran C–term.
Arf N–term.
Ran C–term.
Rho insert
switch I
P–loop
switch II
switch I
switch II



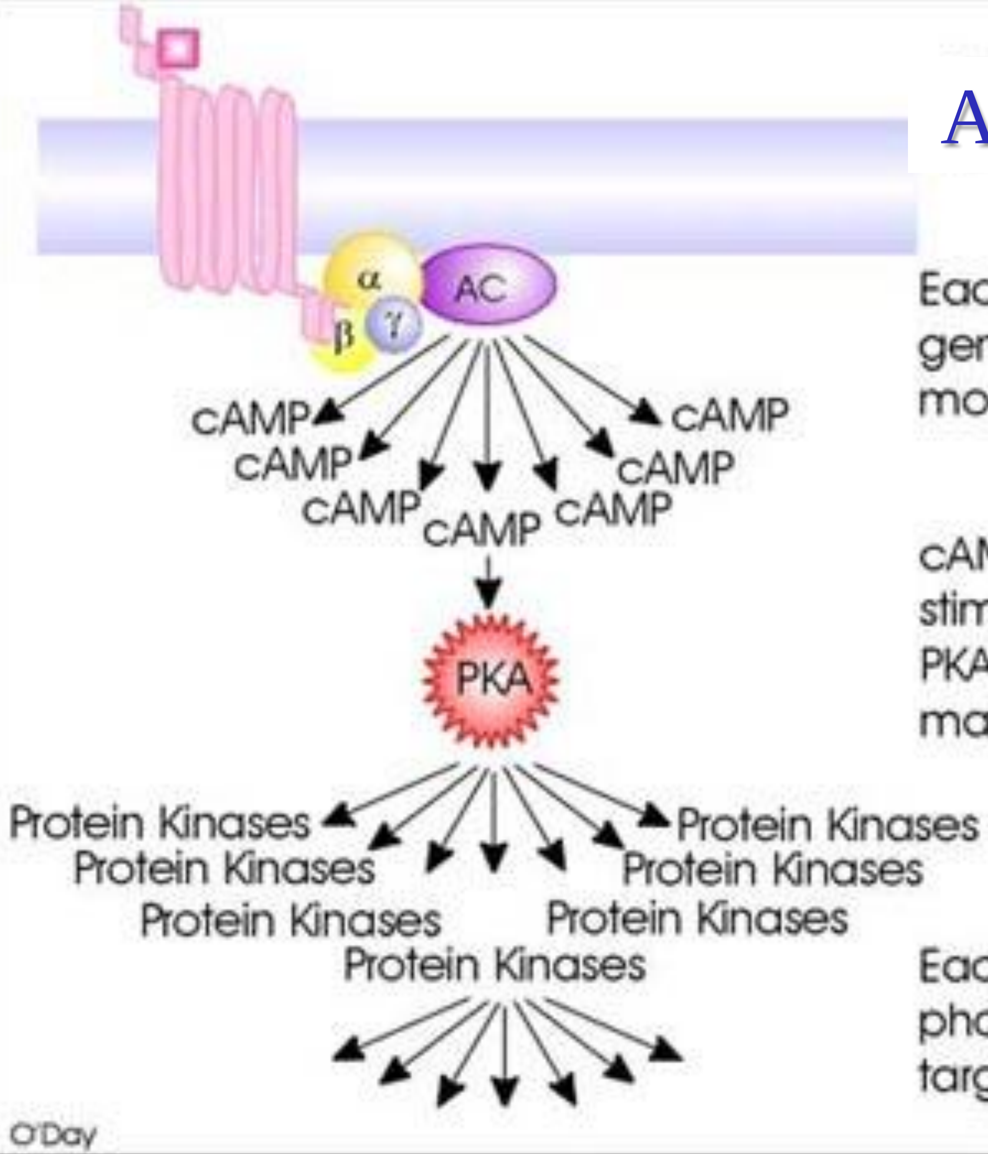
Vetter and A. Wittinghofer, 2001, *Science* ***294*:1299**

TABLE 12–4 Some Signals That Use cAMP as Second Messenger

Corticotropin (ACTH)
Corticotropin-releasing hormone (CRH)
Dopamine [D_1, D_2]*
Epinephrine (β-adrenergic)
Follicle-stimulating hormone (FSH)
Glucagon
Histamine [H_2]*
Luteinizing hormone (LH)
Melanocyte-stimulating hormone (MSH)
Odorants (many)
Parathyroid hormone
Prostaglandins E_1, E_2 (PGE_1, PGE_2)
Serotonin [5-HT-1a, 5-HT-2]*
Somatostatin
Tastants (sweet, bitter)
Thyroid-stimulating hormone (TSH)

*Receptor subtypes in square brackets. Subtypes may have different transduction mechanisms. For example, serotonin is detected in some tissues by receptor subtypes 5-HT-1a and 5-HT-1b, which act through adenylyl cyclase and cAMP, and in other tissues by receptor subtype 5-HT-1c, acting through the phospholipase C–IP_3 mechanism (see Table 12–5).

Amplificación de la señal



Each activated AC generates many cAMP molecules

Amplification

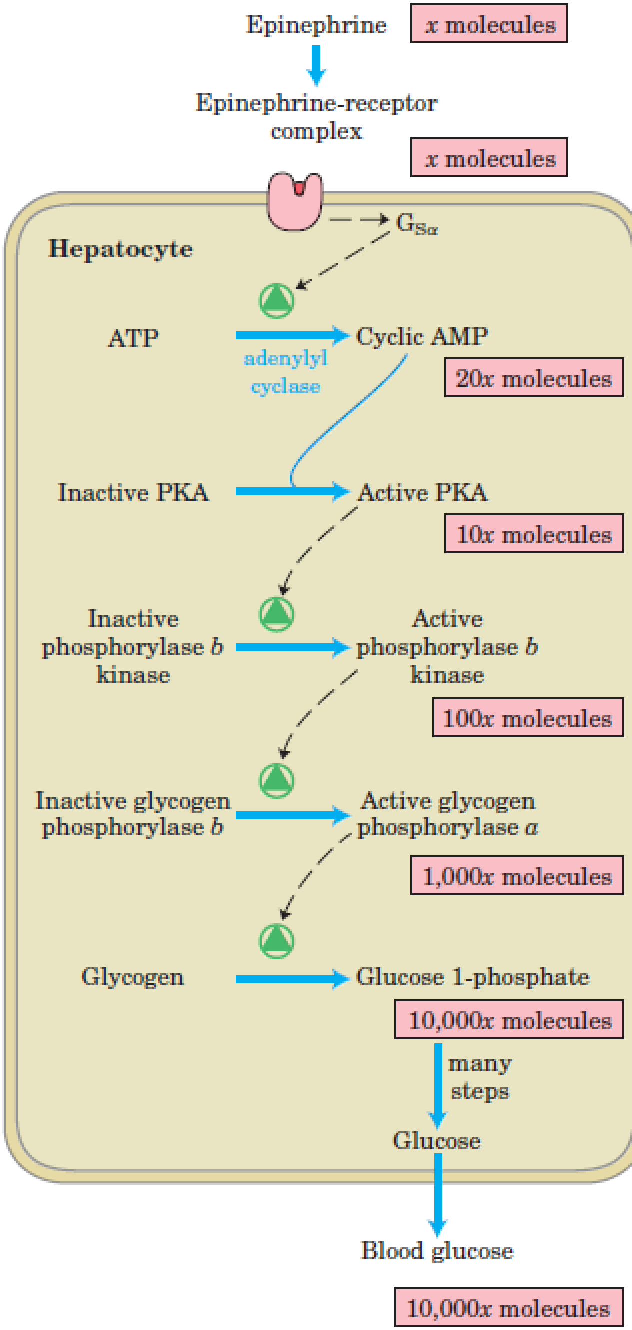
cAMP molecules stimulate PKA; Each PKA phosphorylates many kinases

Amplification

Amplification

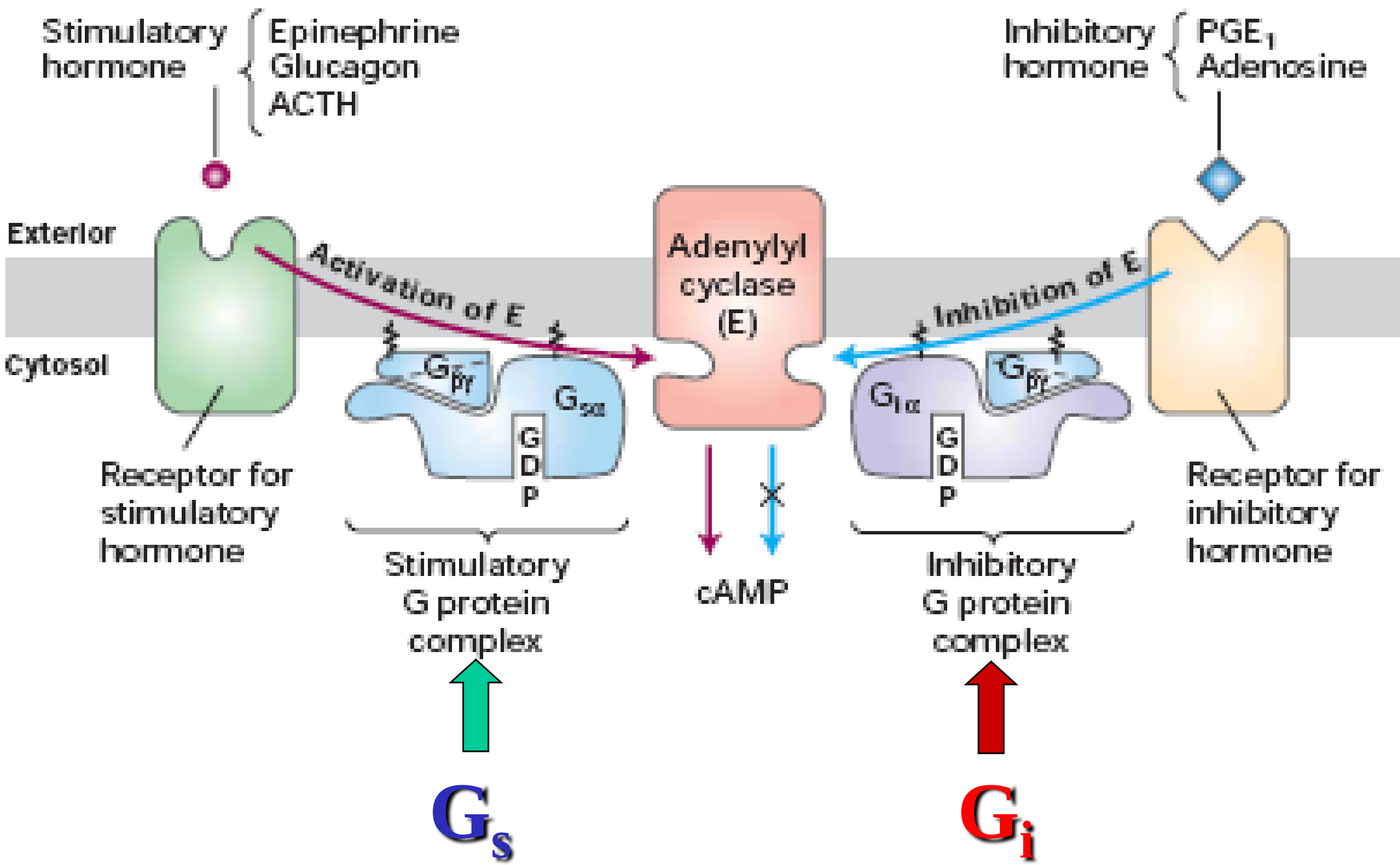
Each kinases phosphorylates more targets (including kinases)

Amplification?

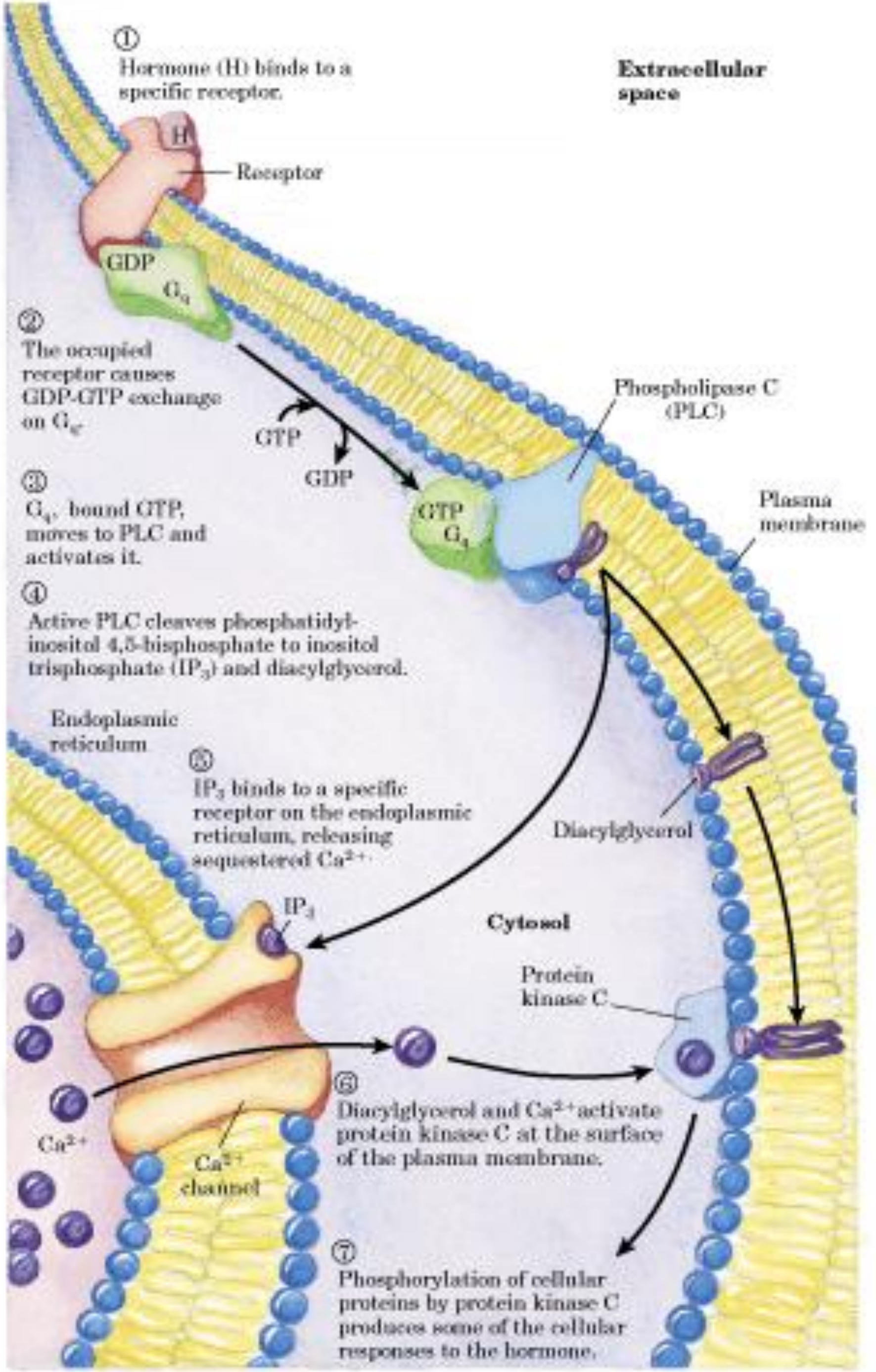


Epinephrine
x molecules
Epinephrine-receptor complex
x molecules
Hepatocyte
$G_{S\alpha}$
ATP
adenylyl cyclase
Cyclic AMP
20x molecules
Inactive PKA
Active PKA
10x molecules
Inactive phosphorylase b kinase
Active phosphorylase b kinase
100x molecules
Inactive glycogen phosphorylase b
Active glycogen phosphorylase a
1,000x molecules
Glycogen
Glucose 1-phosphate
10,000x molecules
many steps
Glucose
Blood glucose
10,000x molecules

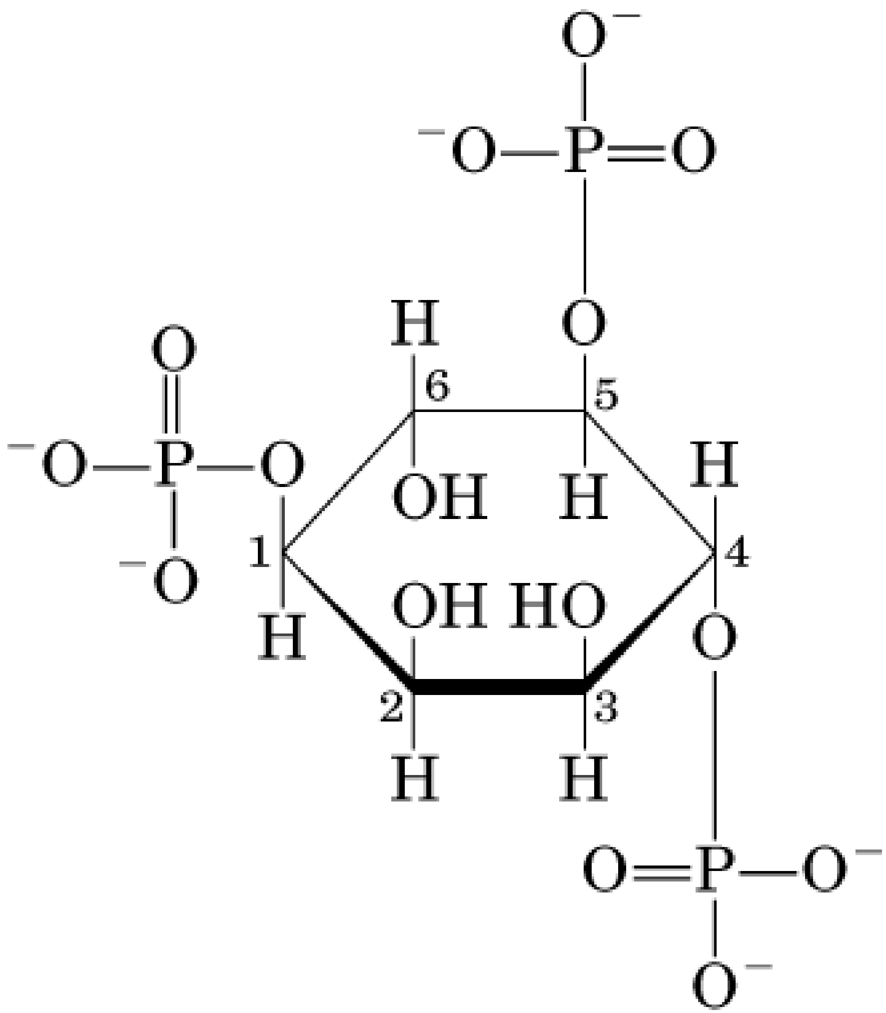
Class or Type	Stimulus	Effector	Effect
G_s **G_s**			
α_s	Glucagon, β-adrenergics	↑ Adenylyl cyclase ↑ Cardiac Ca^{2+}, Cl^-, and Na^+ channels	Gluconeogenesis, lipolysis, glycogenolysis
α_{olf}	Odorant	↑ Adenylyl cyclase	Olfaction
G_i **G_i**			
$\alpha_{i-1,2,3}$	Acetylcholine, α_2-adrenergics M_2 cholinergics	↓ Adenylyl cyclase ↑ Potassium channels ↓ Calcium channels	Slowed heart rate
α_o	Opioids, endorphins	↑ Potassium channels	Neuronal electrical activity
α_t	Light	↑ cGMP phosphodiesterase	Vision
G_q **G_q**			
α_q	M_1 cholinergics α_1-Adrenergics	↑ Phospholipase C-β1	↑ Muscle contraction and
α_{11}	α_1-Adrenergics	↑ Phospholipase c-β2	↑ Blood pressure


Stimulatory hormone
Epinephrine
Glucagon
ACTH
Inhibitory hormone
PGE1
Adenosine
Exterior
Cytosol
Activation of E
Inhibition of E
Adenylyl cyclase (E)
Gβγ
Gsα
GDP
Giα
Receptor for stimulatory hormone
Stimulatory G protein complex
cAMP
Inhibitory G protein complex
Receptor for inhibitory hormone
Gs
Gi

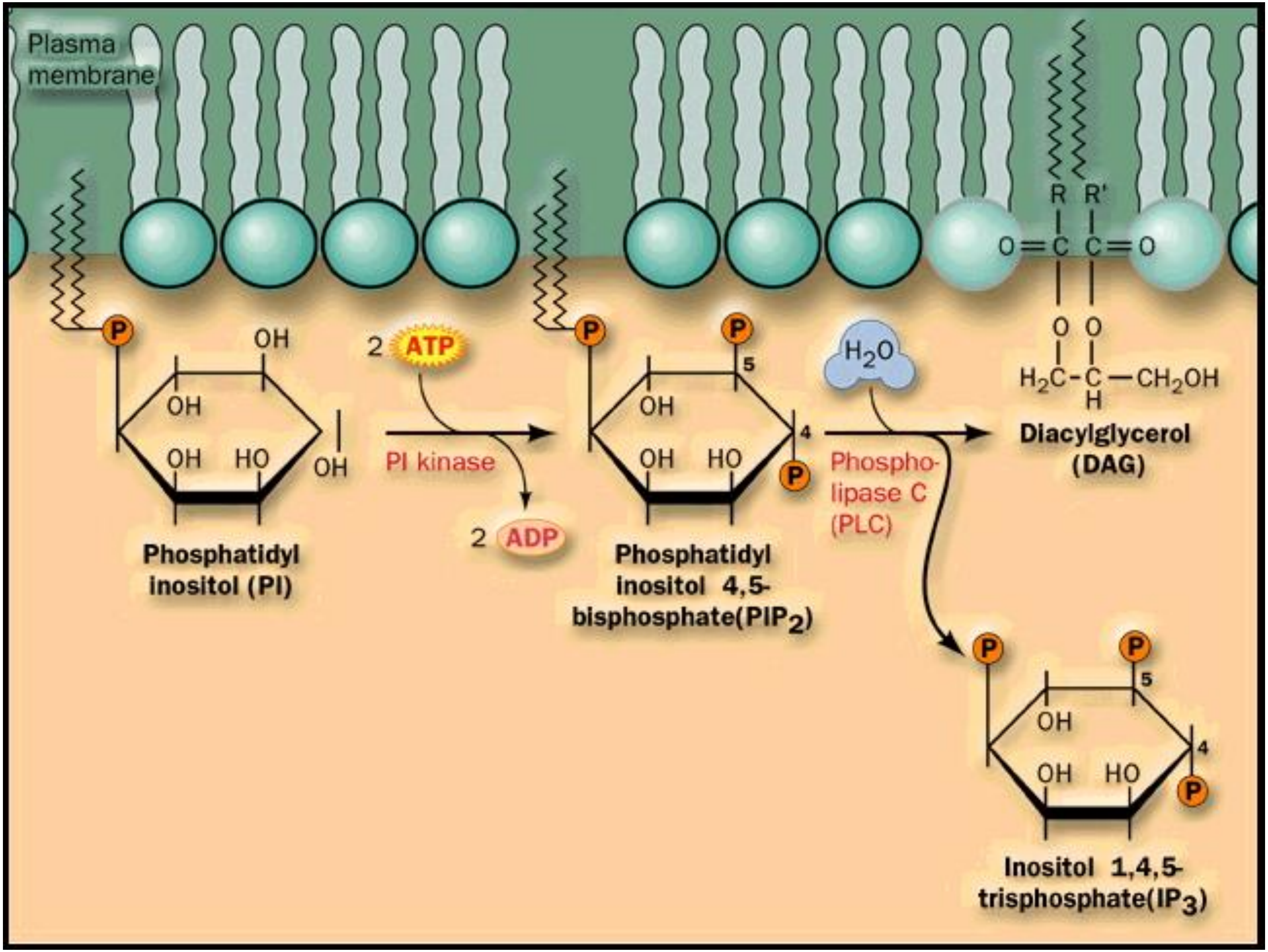
G_q



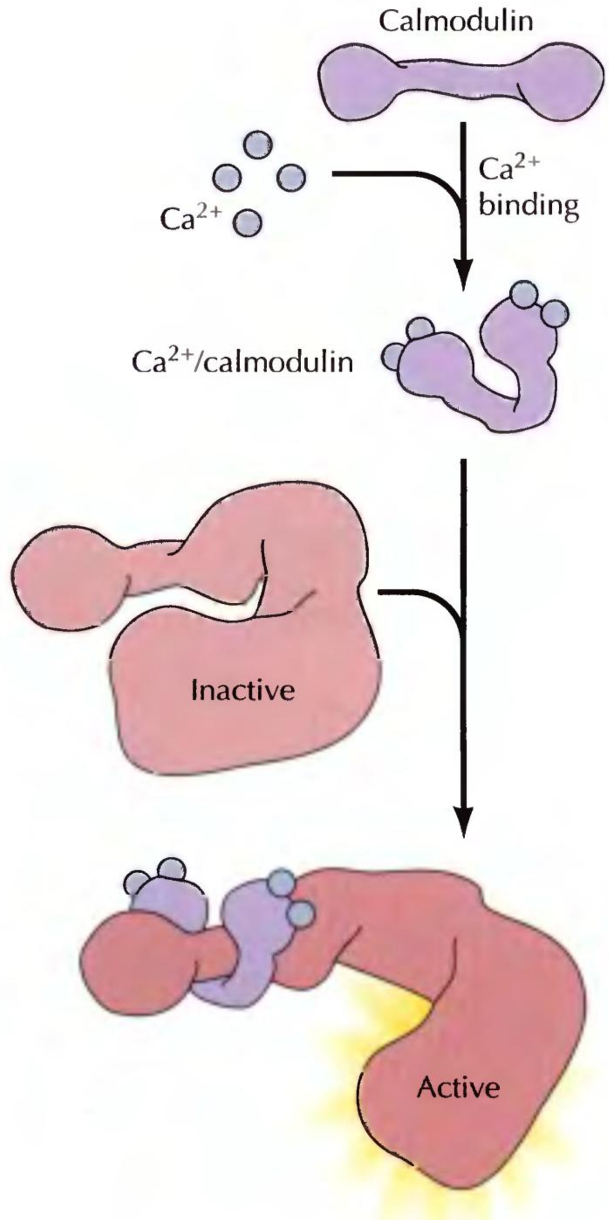
①
Hormone (H) binds to a specific receptor.
Extracellular space
H
Receptor
GDP
G_q
②
The occupied receptor causes GDP-GTP exchange on G_q.
GTP
GDP
Phospholipase C (PLC)
③
G_q, bound GTP, moves to PLC and activates it.
GTP
G_q
Plasma membrane
④
Active PLC cleaves phosphatidylinositol 4,5-bisphosphate to inositol trisphosphate (IP_3) and diacylglycerol.
Endoplasmic reticulum
⑤
IP_3 binds to a specific receptor on the endoplasmic reticulum, releasing sequestered Ca^{2+}.
Diacylglycerol
IP_3
Cytosol
Protein kinase C
⑥
Diacylglycerol and Ca^{2+} activate protein kinase C at the surface of the plasma membrane.
Ca^{2+}
Ca^{2+} channel
⑦
Phosphorylation of cellular proteins by protein kinase C produces some of the cellular responses to the hormone.



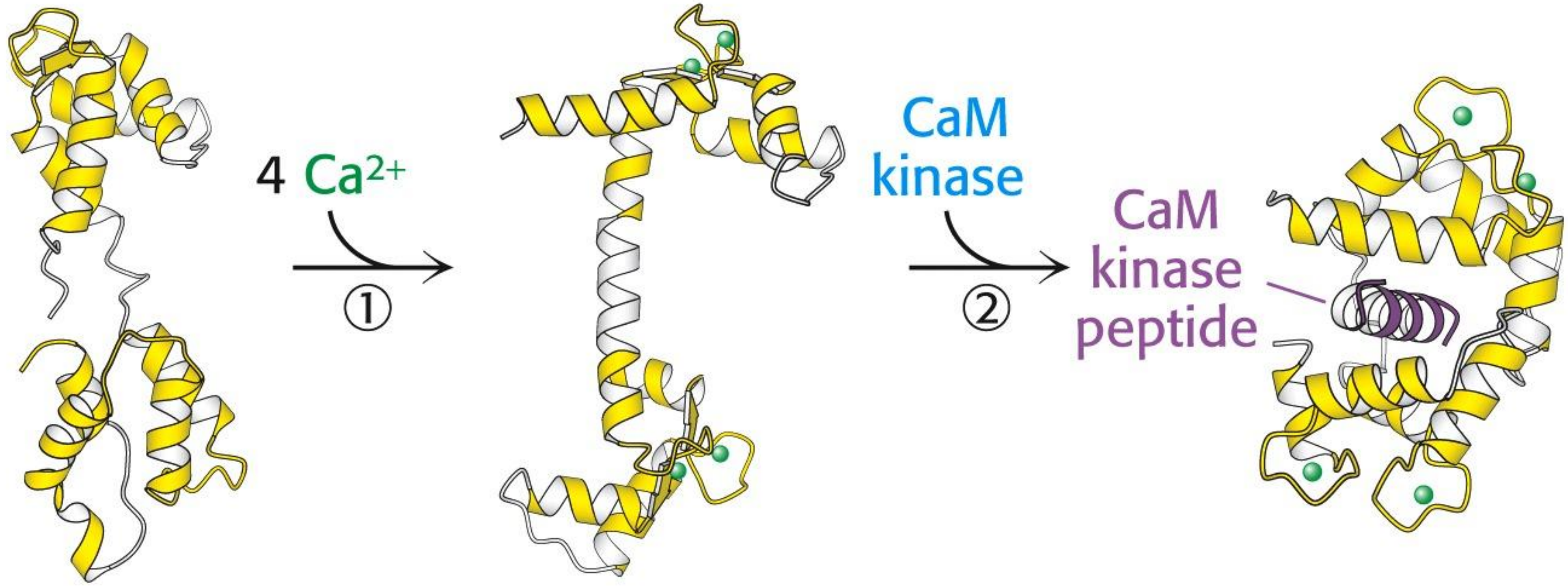
Inositol 1,4,5-trisphosphate



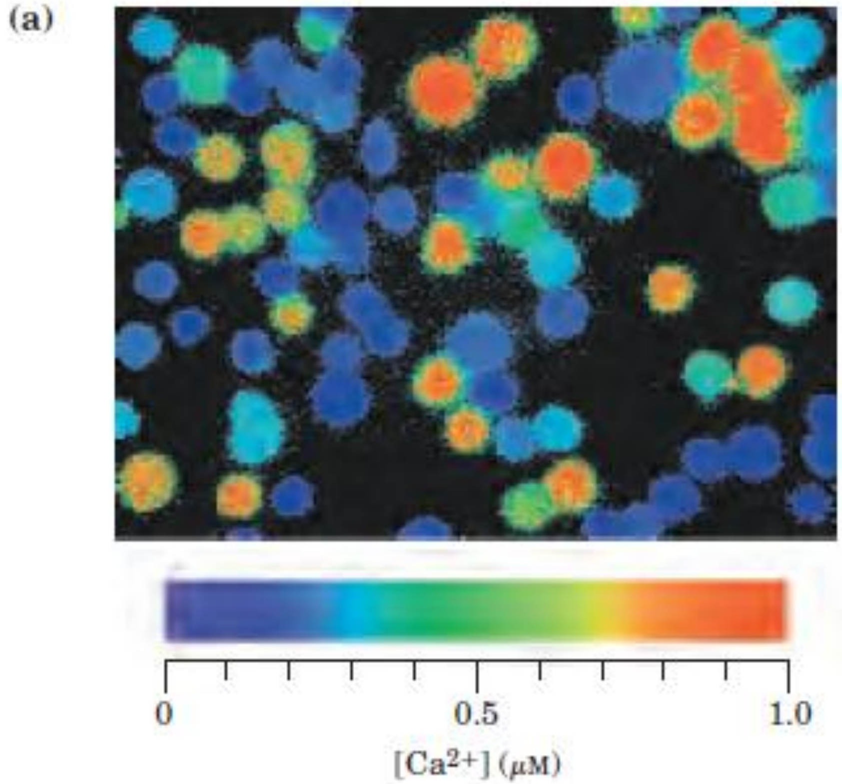
Plasma membrane
R R'
O=C C=O
O O
$H_2C-C-CH_2OH$
H
P
OH
OH
OH HO
OH
2 ATP
PI kinase
2 ADP
Phosphatidyl inositol (PI)
5
4
Phosphatidyl inositol 4,5-bisphosphate(PIP_2)
H_2O
Phospho-lipase C (PLC)
Diacylglycerol (DAG)
Inositol 1,4,5-trisphosphate(IP_3)

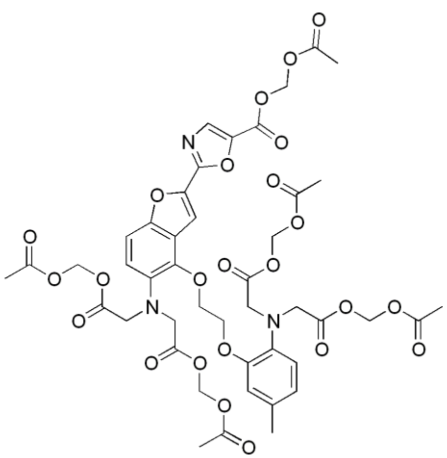

Calmodulin
Ca2+
Ca2+
binding
Ca2+/calmodulin
Inactive
Active

(B)



Calmodulin (apo)

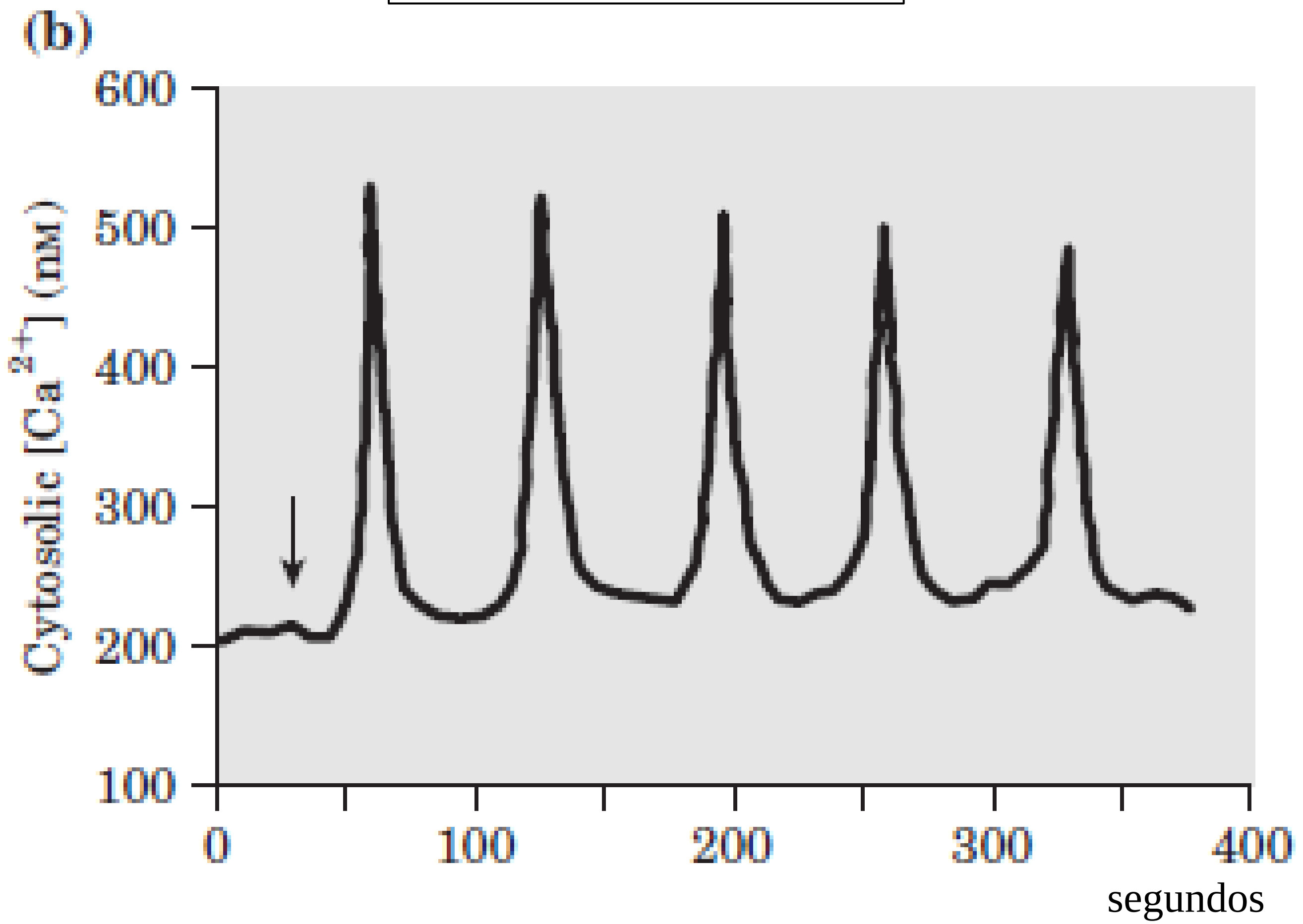




Glías

Fura: En presencia de Ca^{+2} cambia la fluorescencia emitida

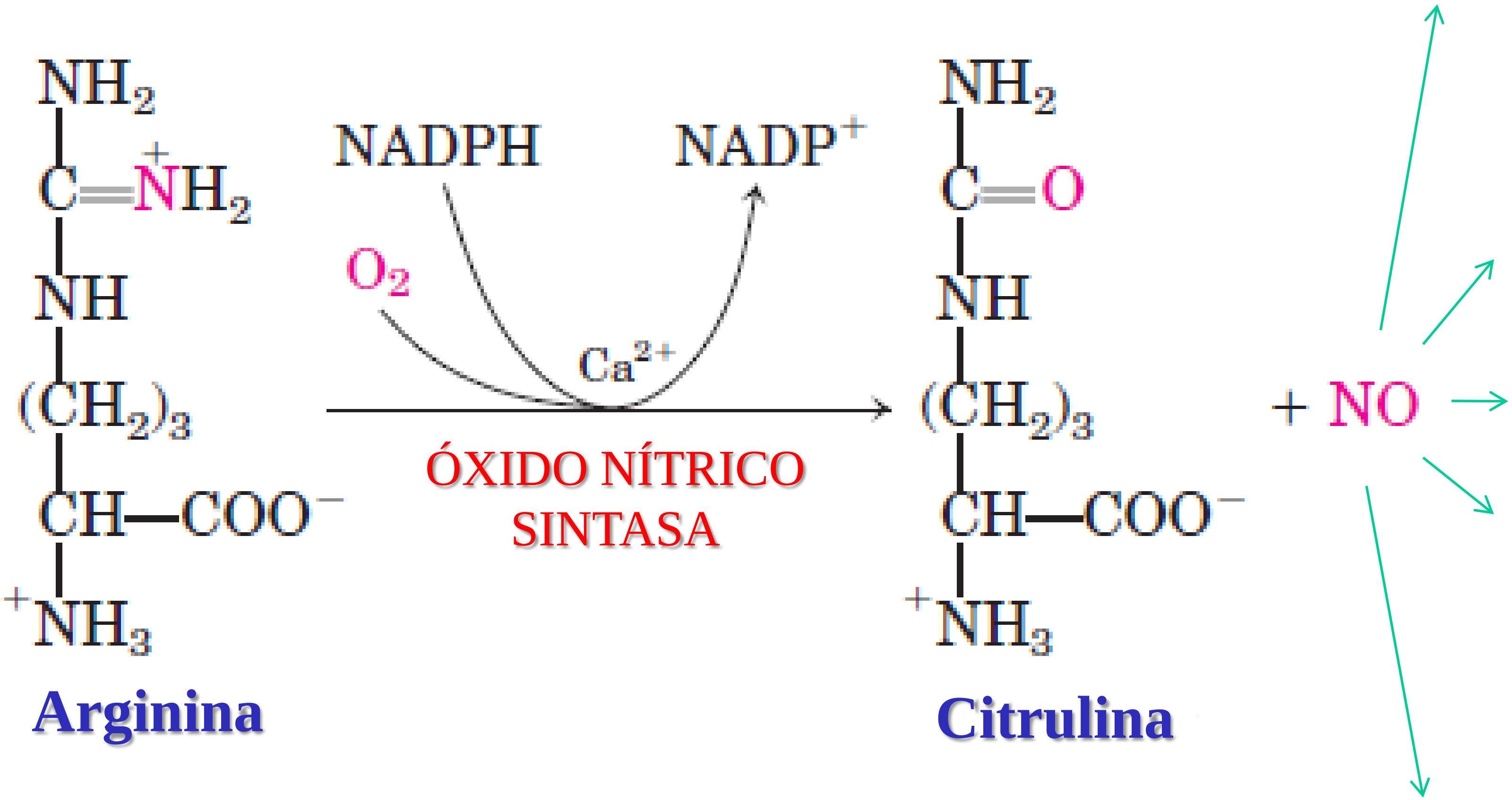
Ondas de calcio



Se estimuló una célula (hepatocito) con un agonista de norepinefrina (flecha)

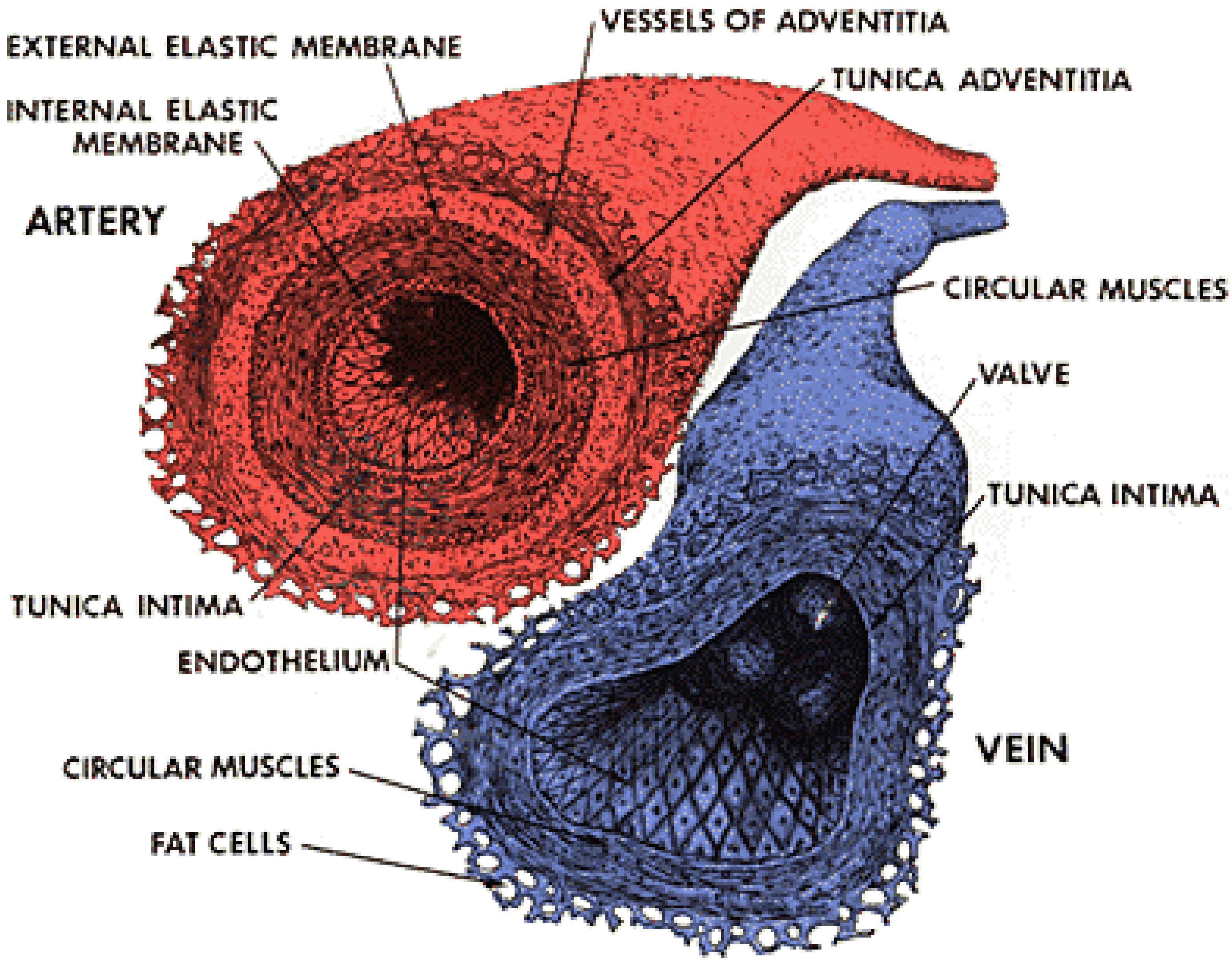
Table 43–4. Enzymes and proteins regulated by calcium or calmodulin.

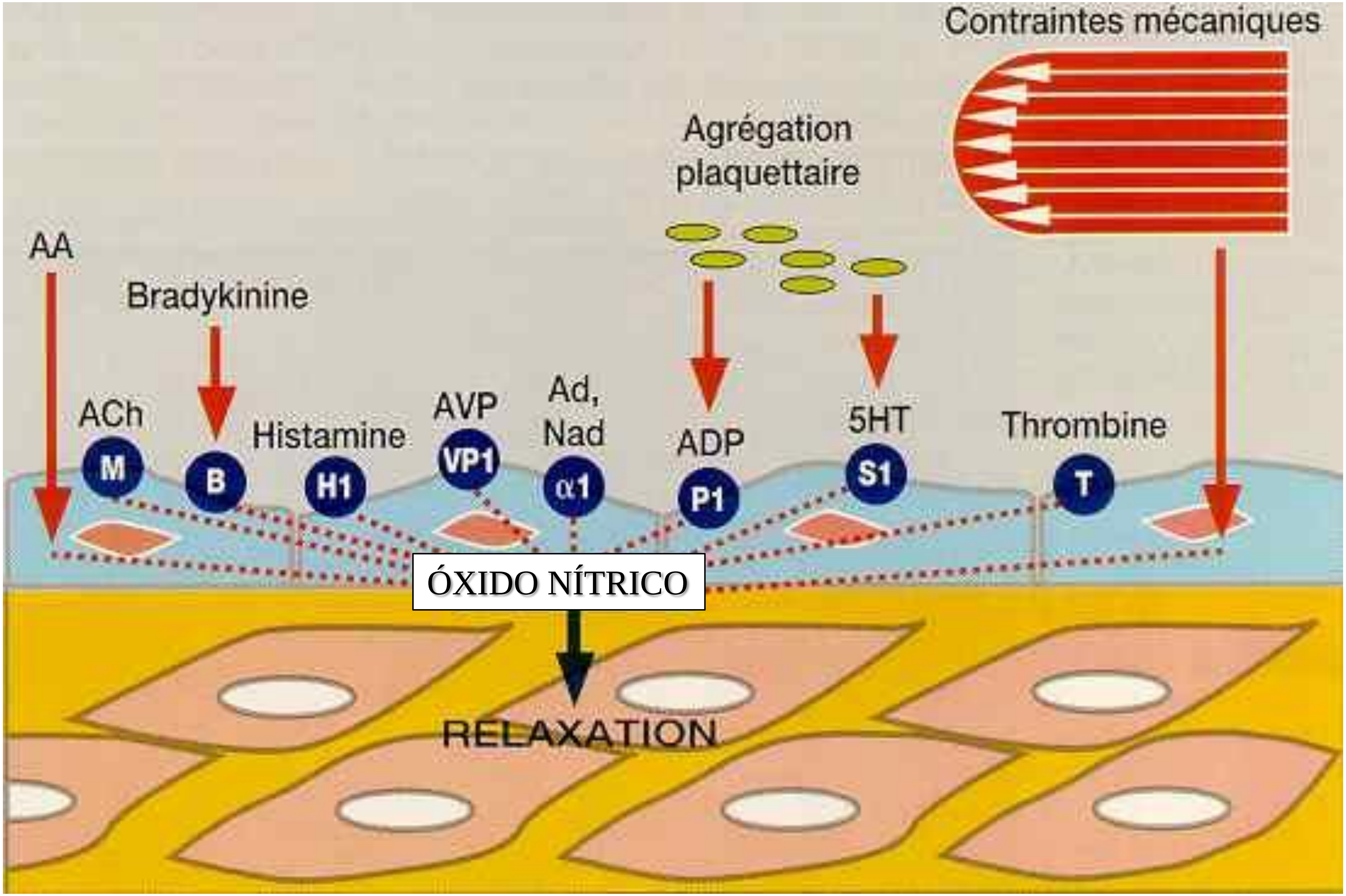
Adenylyl cyclase
Ca^{2+}-dependent protein kinases
Ca^{2+}-Mg^{2+} ATPase
Ca^{2+}-phospholipid-dependent protein kinase
Cyclic nucleotide phosphodiesterase
Some cytoskeletal proteins
Some ion channels (eg, L-type calcium channels)
Nitric oxide synthase
Phosphorylase kinase
Phosphoprotein phosphatase 2B
Some receptors (eg, NMDA-type glutamate receptor)



NH2
C=NH2
NH
(CH2)3
CH—COO−
NH3
Arginina
NADPH
NADP+
O2
Ca2+
ÓXIDO NÍTRICO
SINTASA
NH2
C=O
NH
(CH2)3
CH—COO−
NH3
Citrulina
+ NO

Endotelio vascular




Contraintes mécaniques
Agrégation plaquettaire
AA
Bradykinine
ACh
M
B
Histamine
H1
AVP
VP1
Ad, Nad
α1
ADP
P1
5HT
S1
Thrombine
T
ÓXIDO NÍTRICO
RELAXATION

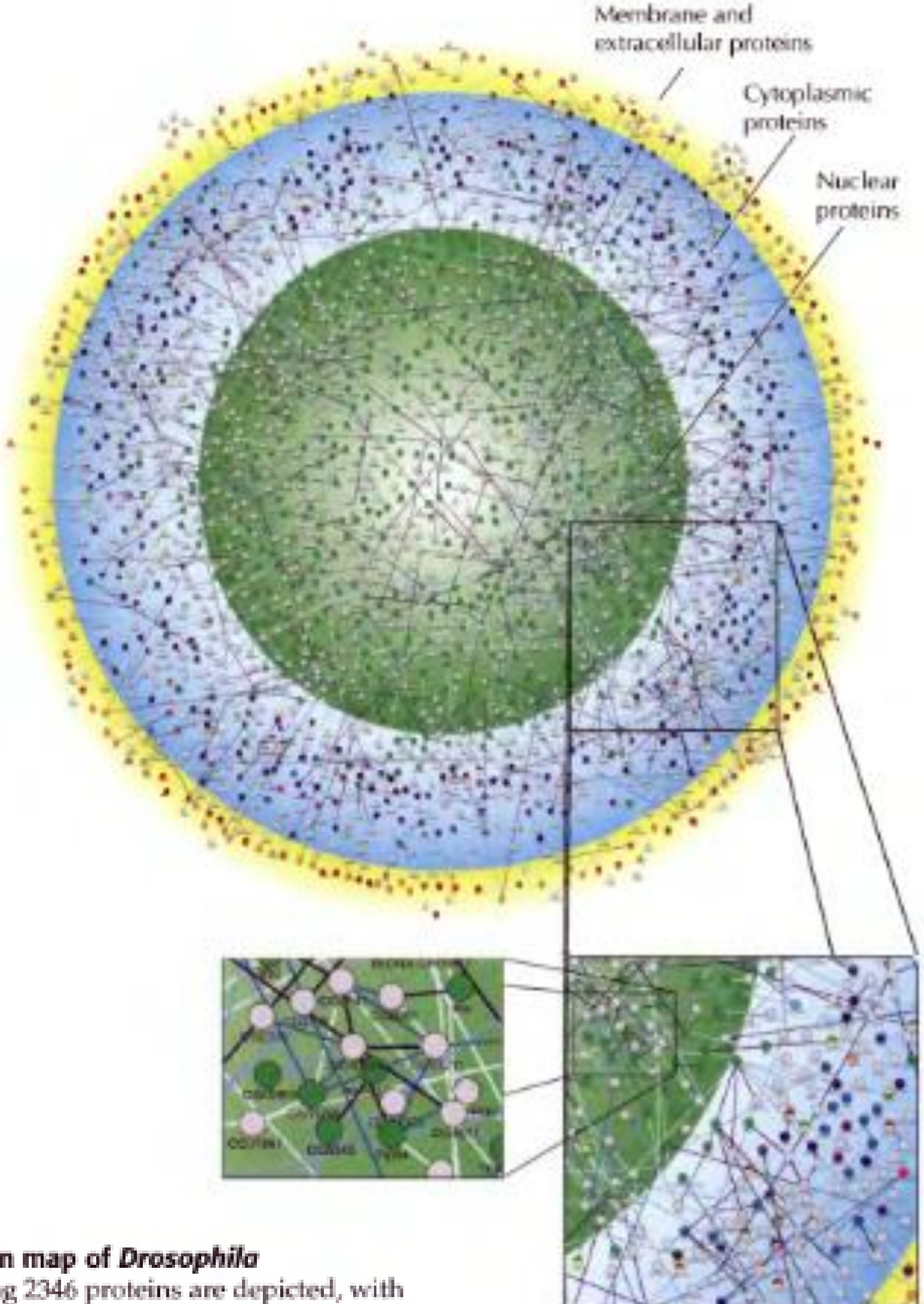


FIGURE 2.33 A protein interaction map of *Drosophila melanogaster* Interactions among 2346 proteins are depicted, with each protein represented as a circle placed according to its subcellular localization. (From L. Glot et al., 2003. *Science* 302: 1727).

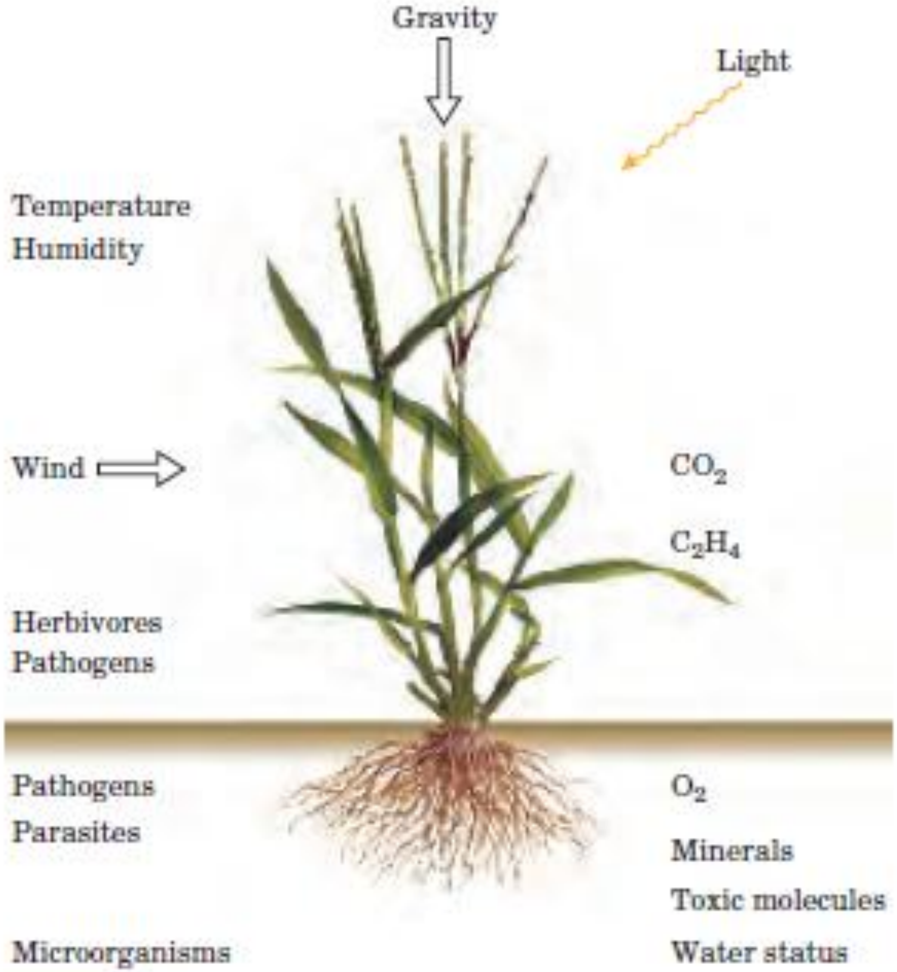


FIGURE 12-27 Some stimuli that produce responses in plants.

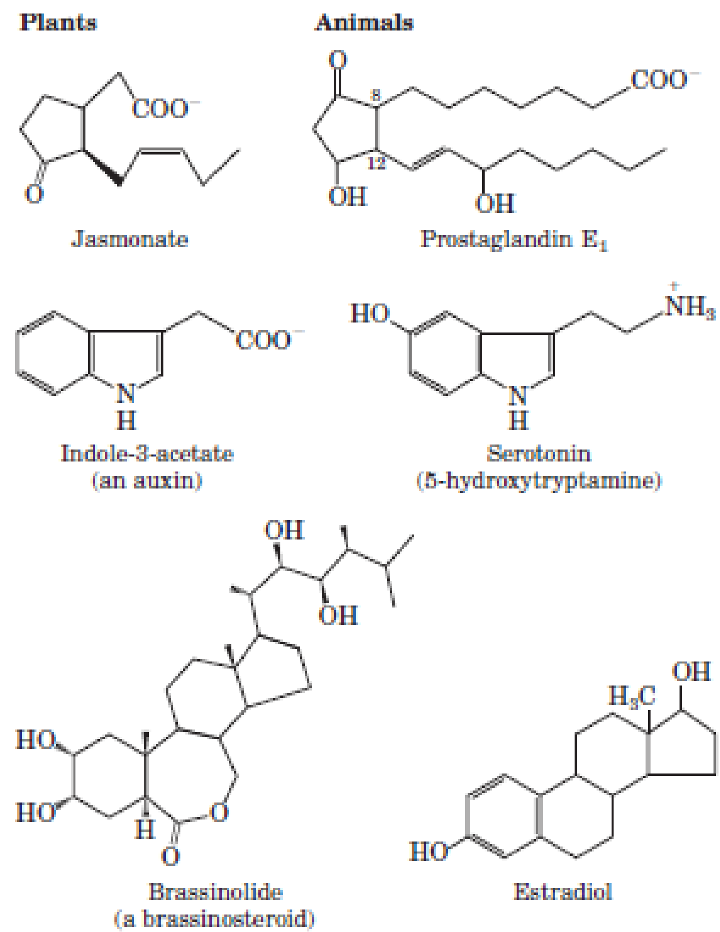


FIGURE 12–28 Structural similarities between plant and animal signals. The plant signals jasmonate, indole-3-acetate, and brassinolide resemble the mammalian signals prostaglandin E$_1$, serotonin, and estradiol.

TABLE 12–7 Signaling Components Present in Mammals, Plants, or Bacteria

Signaling protein	*Mammals*	*Plants*	*Bacteria*
Ion channels	+	+	+
Electrogenic ion pumps	+	+	+
Two-component His kinases	+	+	+
Adenylyl cyclase	+	+	+
Guanylyl cyclase	+	+	?
Receptor protein kinases (Ser/Thr)	+	+	?
Ca^{2+} as second messenger	+	+	?
Ca^{2+} channels	+	+	?
Calmodulin, CaM-binding protein	+	+	−
MAPK cascade	+	+	−
Cyclic nucleotide–gated channels	+	+	−
IP_3-gated Ca^{2+} channels	+	+	−
Phosphatidylinositol kinases	+	+	−
Serpentine receptors	+	+/−	+
Trimeric G proteins	+	+/−	−
PI-specific phospholipase C	+	?	−
Tyrosine kinase receptors	+	?	−
SH2 domains	+	?	?
Nuclear steroid receptors	+	−	−
Protein kinase A	+	−	−
Protein kinase G	+	−	−