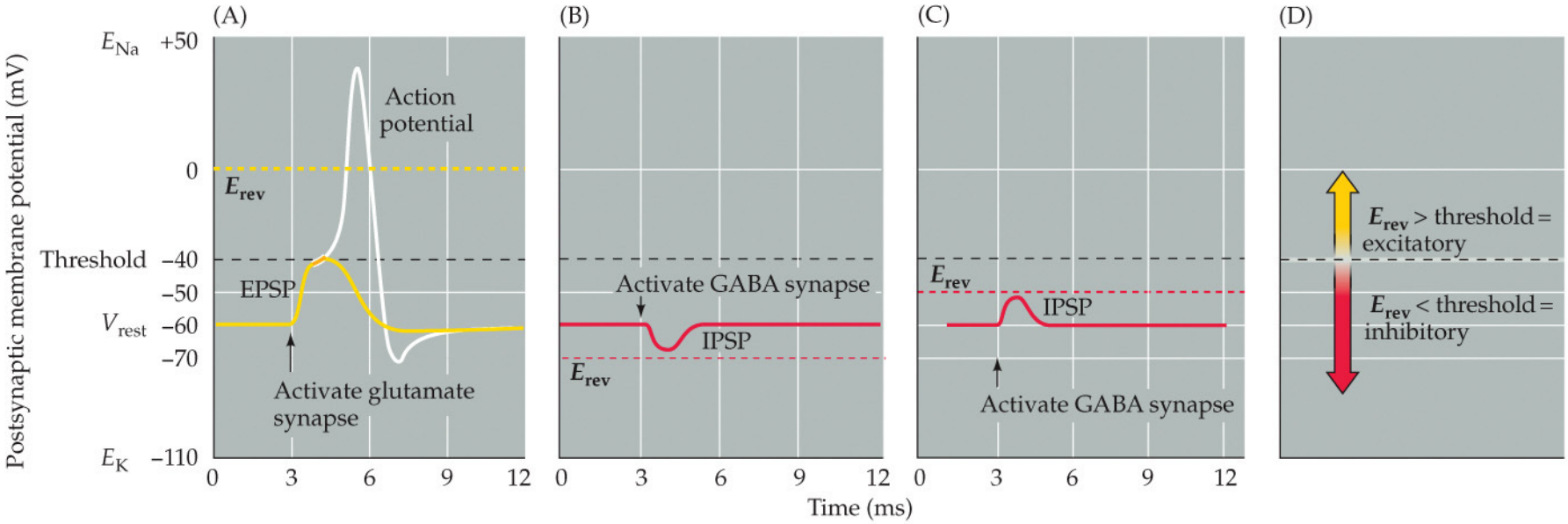
Reversal potentials and threshold potentials determine postsynaptic excitation and inhibition

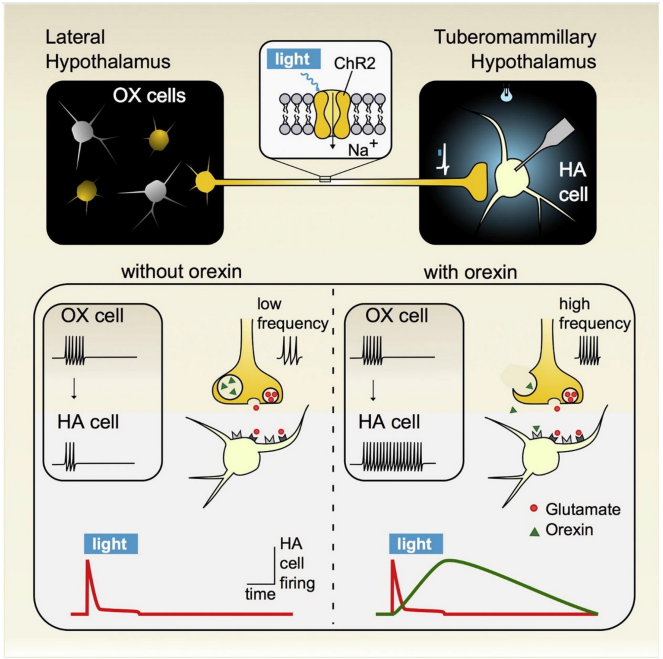


NEUROSCIENCE 6e, Figure 5.19

How many neurotransmitters does one neuron receive, and how many can it release?

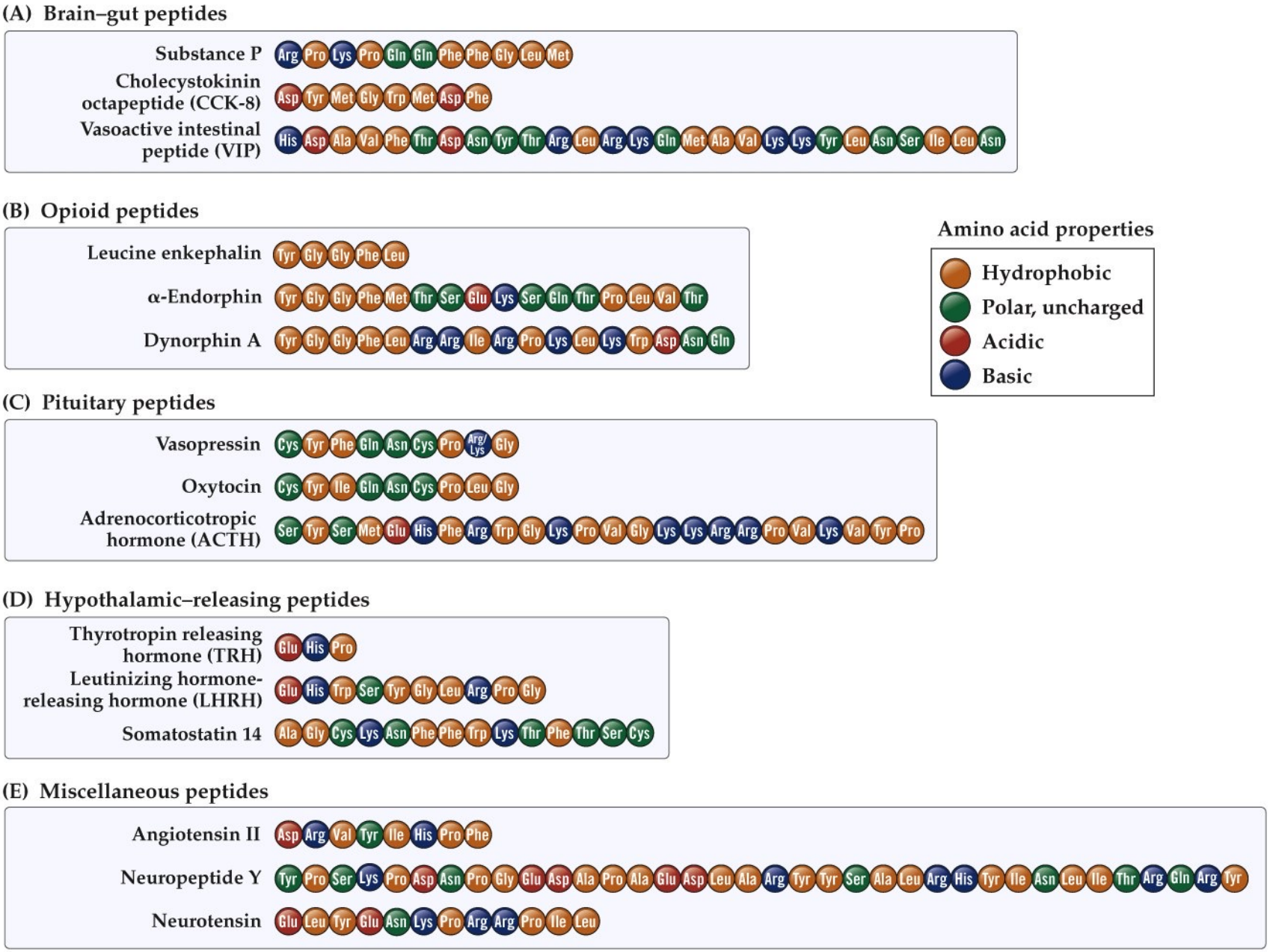
Chap 5, p.89:

Formal criteria have been established to definitively identify a substance as a neurotransmitter. These criteria have led to the identification of more than 100 different neurotransmitters, which can be classified into two broad categories: small-molecule neurotransmitters, such as ACh, and neuropeptides (see Chapter 6). Having more than one transmitter diversifies the physiological repertoire of synapses. Multiple neurotransmitters can produce different types of responses on individual postsynaptic cells. For example, a neuron can be excited by one type of neurotransmitter and inhibited by another type of neurotransmitter. The speed of postsynaptic responses produced by different transmitters also differs, allowing control of electrical signaling over different timescales. In general, small-molecule neurotransmitters mediate rapid synaptic actions, whereas neuropeptides tend to modulate slower, ongoing neuronal functions. In some cases, neurons synthesize and release two or more different neurotransmitters; in this case, the molecules are called **co-transmitters**. Co-transmitters can be differentially released according to the pattern of synaptic activity, so that the signaling properties of such synapses change dynamically according to the rate of activity.



From: General Principles of Neuronal Co-transmission: Insights From Multiple Model Systems
By Erik Svensson et al. 2019

Amino acid sequences of neuropeptides



***NEUROSCIENCE 5e*, Figure 6.17**

TABLE 6.2 ■ Endogenous Opioid Peptides

Name	Amino acid sequence[a]
Endorphins	
α-Endorphin	*Tyr-Gly-Gly-Phe*-Met-Thr-Ser-Glu-Lys-Ser-Gln-Thr-Pro-Leu-Val-Thr
α-Neoendorphin	*Tyr-Gly-Gly-Phe*-Leu-Arg-Lys-Tyr-Pro-Lys
β-Endorphin	*Tyr-Gly-Gly-Phe*-Met-Thr-Ser-Glu-Lys-Ser-Gln-Thr-Pro-Leu-Val-Thr-Leu-Phe-Lys-Asn-Ala-Ile-Val-Lys-Asn-Ala-His-Lys-Gly-Gln
γ-Endorphin	*Tyr-Gly-Gly-Phe*-Met-Thr-Ser-Glu-Lys-Ser-Gln-Thr-Pro-Leu-Val-Thr-Leu
Enkephalins	
Leu-enkephalin	*Tyr-Gly-Gly-Phe*-Leu
Met-enkephalin	*Tyr-Gly-Gly-Phe*-Met
Dynorphins	
Dynorphin A	*Tyr-Gly-Gly-Phe*-Leu-Arg-Arg-Ile-Arg-Pro-Lys-Leu-Lys-Trp-Asp-Asn-Gln
Dynorphin B	*Tyr-Gly-Gly-Phe*-Leu-Arg-Arg-Gln-Phe-Lys-Val-Val-Thr

[a]Note the initial homology, indicated by italics.

NEUROSCIENCE 6e, Table 6.2

BMD ENG 301Quantitative Systems Physiology (Nervous System)

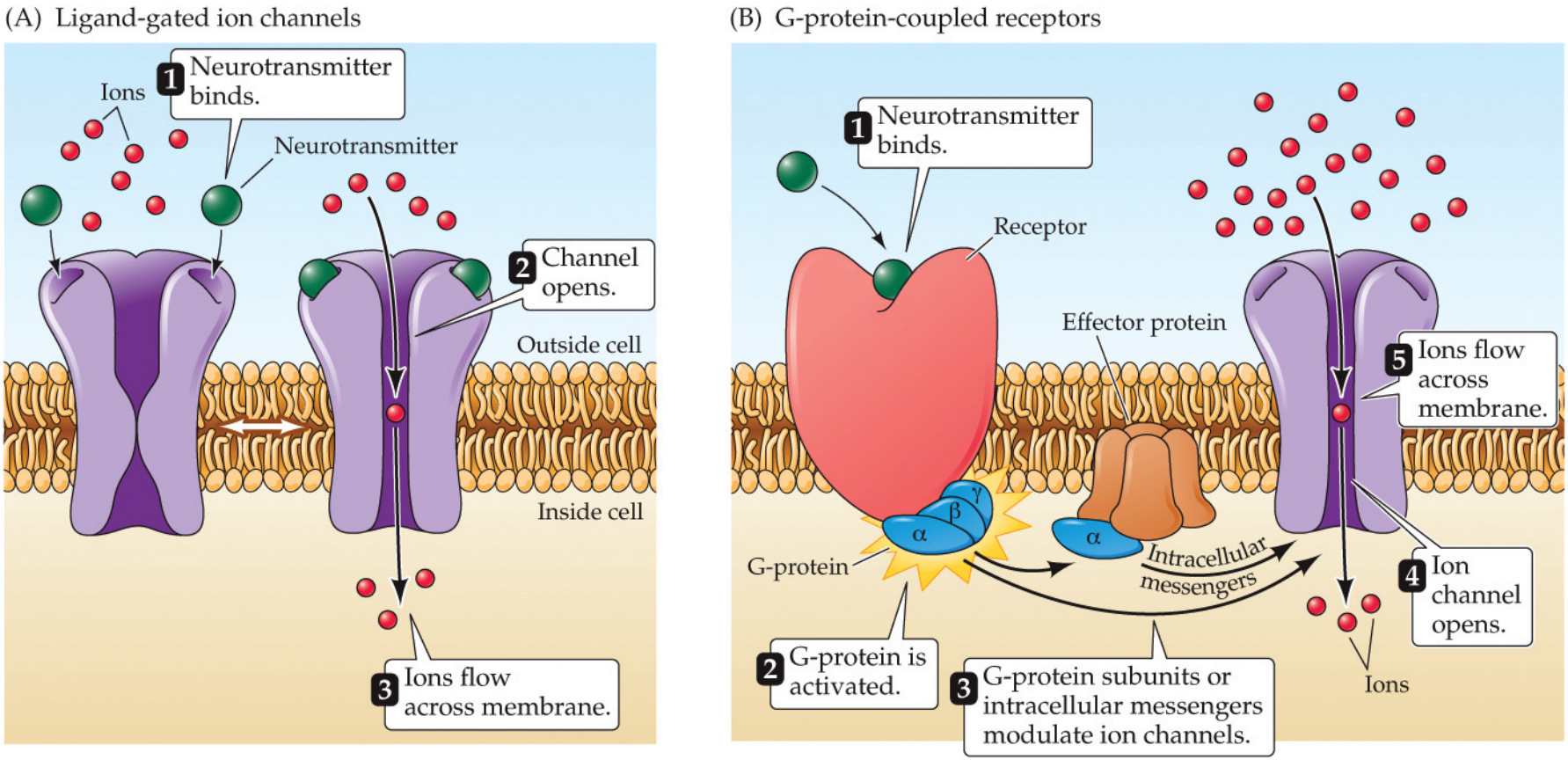
Lecture 12: Metabotropic Receptors 2022_v1

Professor Malcolm MacIver

Two different types of neurotransmitter receptors

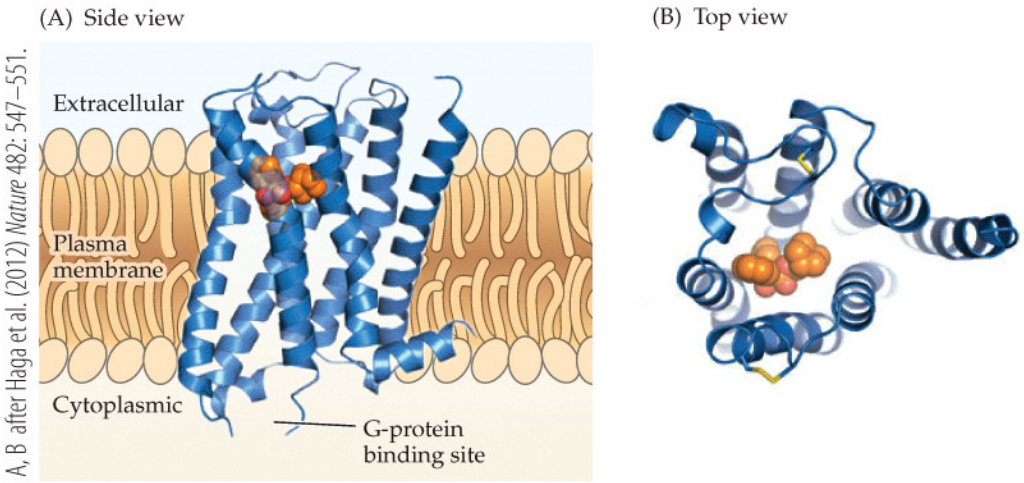
Fast

Slow



NEUROSCIENCE 6e, Figure 5.14

Metabotropic Receptors

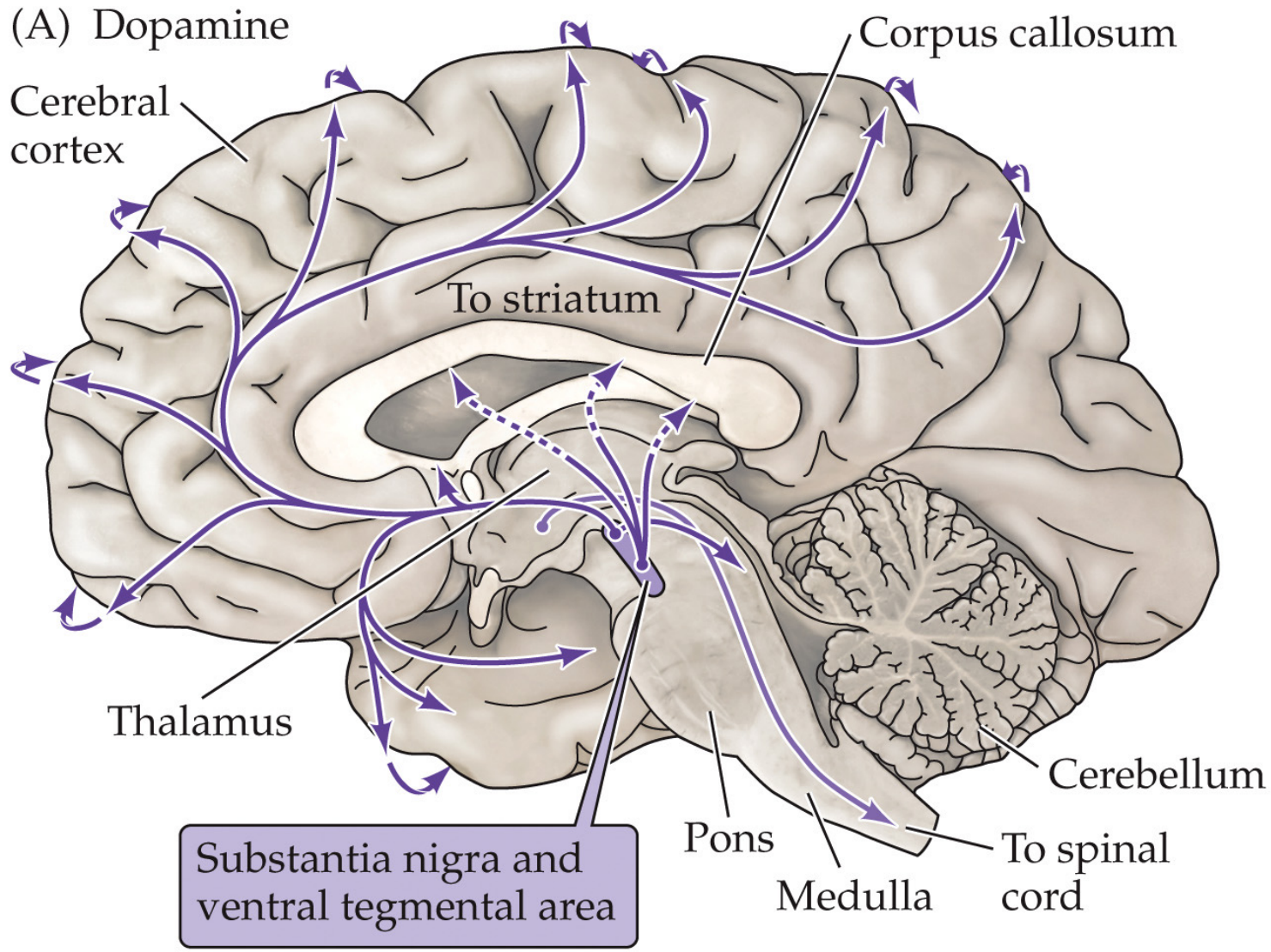


(C)

Receptor class	Muscarinic	Glutamate	$GABA_B$	Dopamine	Adrenergic	Histamine	Serotonin	Purines
Receptor subtype	M_1	Class I	$GABA_{B1}$	D1	Alpha	H_1	$5\text{-}HT_{1A}$	Adenosine
	M_2	$mGlu_1$	$GABA_{B2}$	D2	α_{1A}	H_2	$5\text{-}HT_{1B}$	A_1
	M_3	$mGlu_5$		D3	α_{1B}	H_3	$5\text{-}HT_{1D}$	A_{2A}
	M_4	Class II		D4	α_{1D}	H_4	$5\text{-}HT_{1E}$	A_{2B}
	M_5	$mGlu_2$		D5	α_{2A}		$5\text{-}HT_{1F}$	A_3
		$mGlu_3$			α_{2B}		$5\text{-}HT_{2A}$	P2Y
		Class III			α_{2C}		$5\text{-}HT_{2B}$	$P2Y_1$
		$mGlu_4$			Beta		$5\text{-}HT_{2C}$	$P2Y_2$
		$mGlu_6$			β_1		$5\text{-}HT_4$	$P2Y_4$
		$mGlu_7$			β_2		$5\text{-}HT_{5A}$	$P2Y_6$
		$mGlu_8$			β_3		$5\text{-}HT_6$	$P2Y_{11}$
							$5\text{-}HT_7$	$P2Y_{12}$
								$P2Y_{13}$
								$P2Y_{14}$

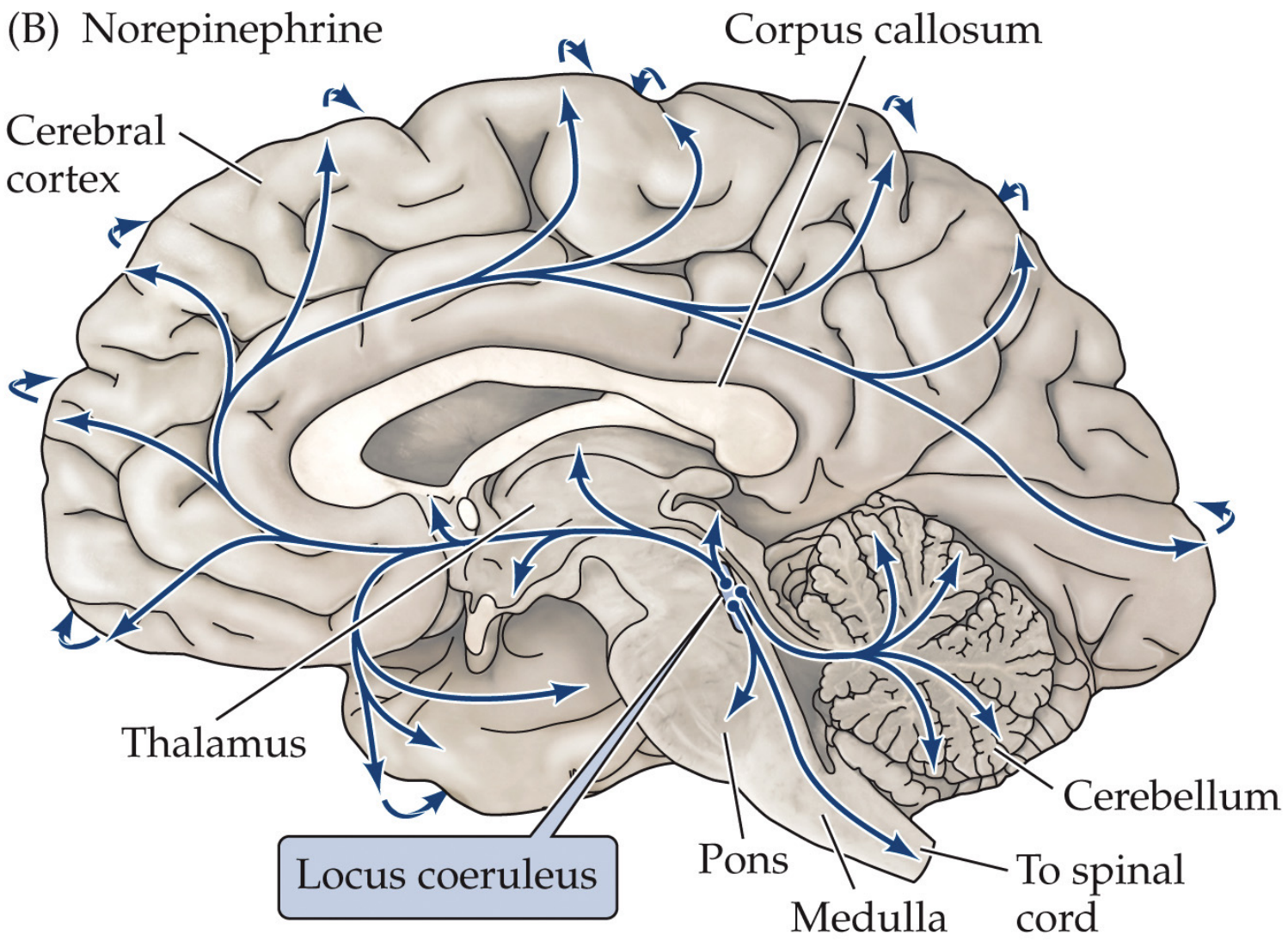
NEUROSCIENCE 6e, Figure 6.4

The distribution of dopamine in the human brain



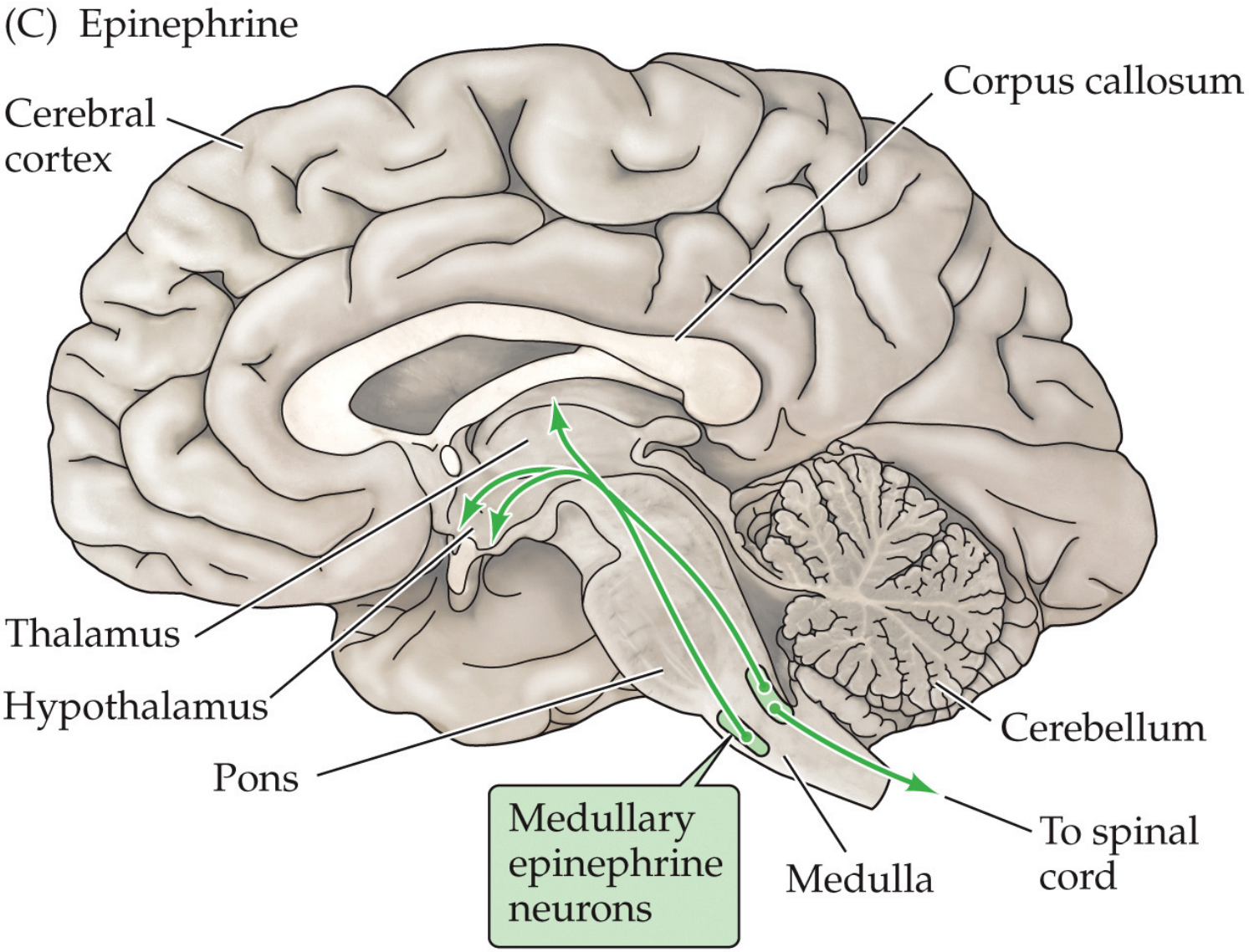
NEUROSCIENCE 6e, Figure 6.15 (Part 1)

The distribution of noradrenaline in the human brain



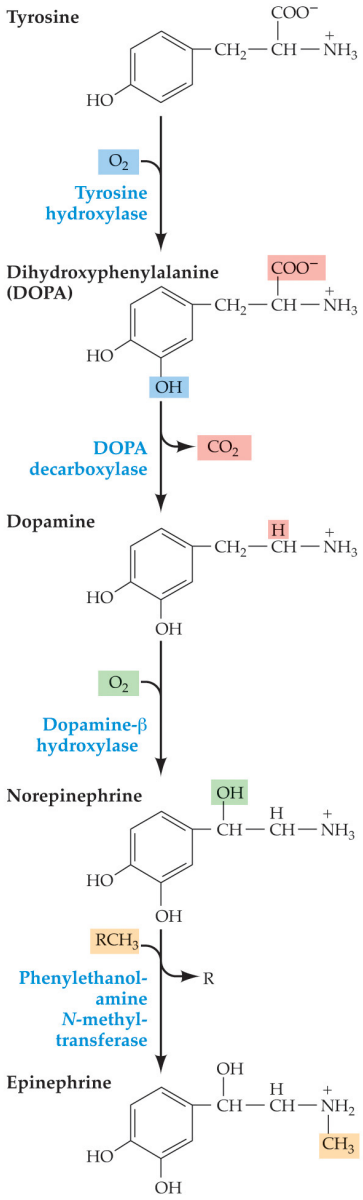
NEUROSCIENCE 6e, Figure 6.15 (Part 2)

The distribution of adrenaline in the human brain



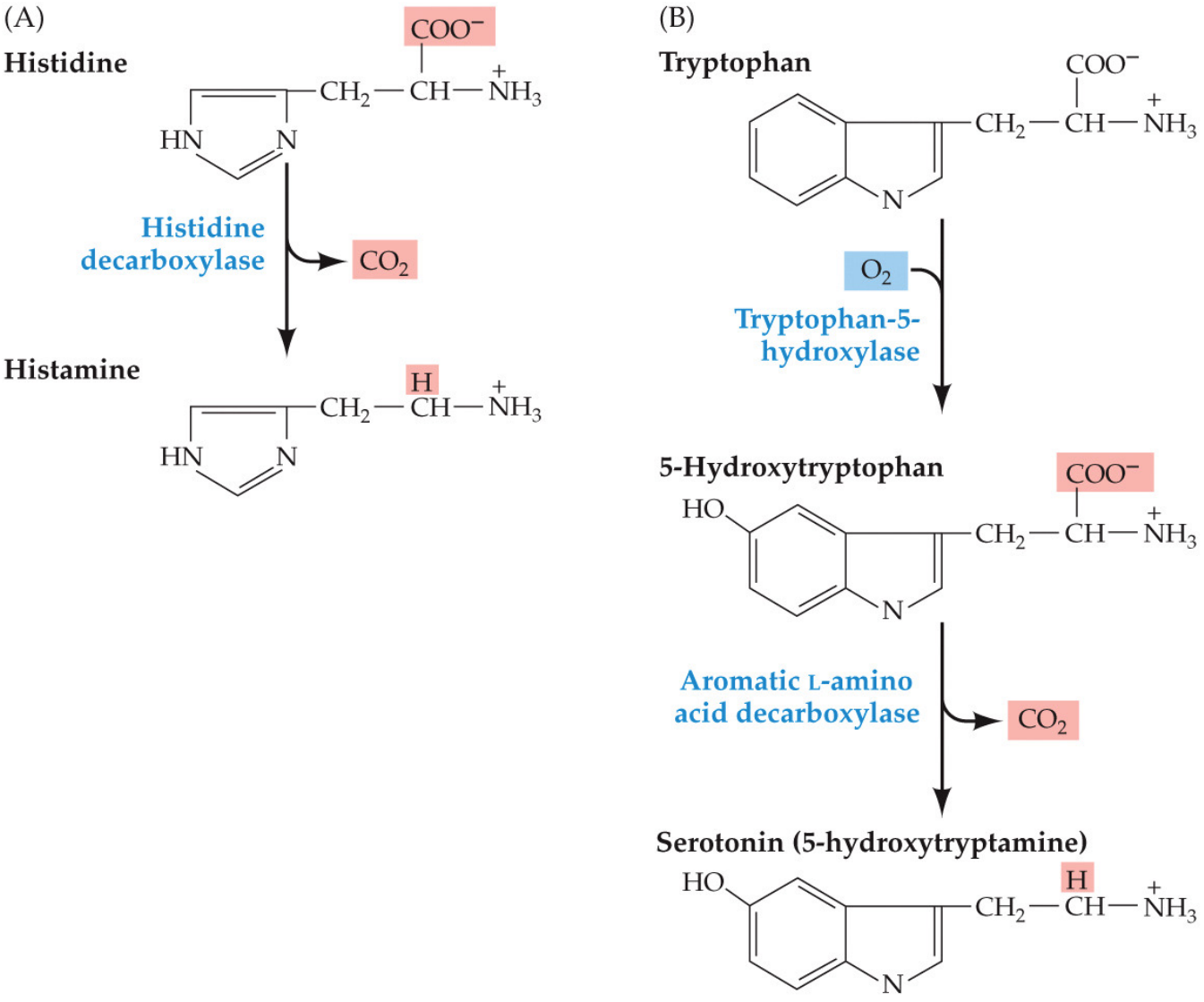
NEUROSCIENCE 6e, Figure 6.15 (Part 3)

The biosynthetic pathway for the catecholamine neurotransmitters



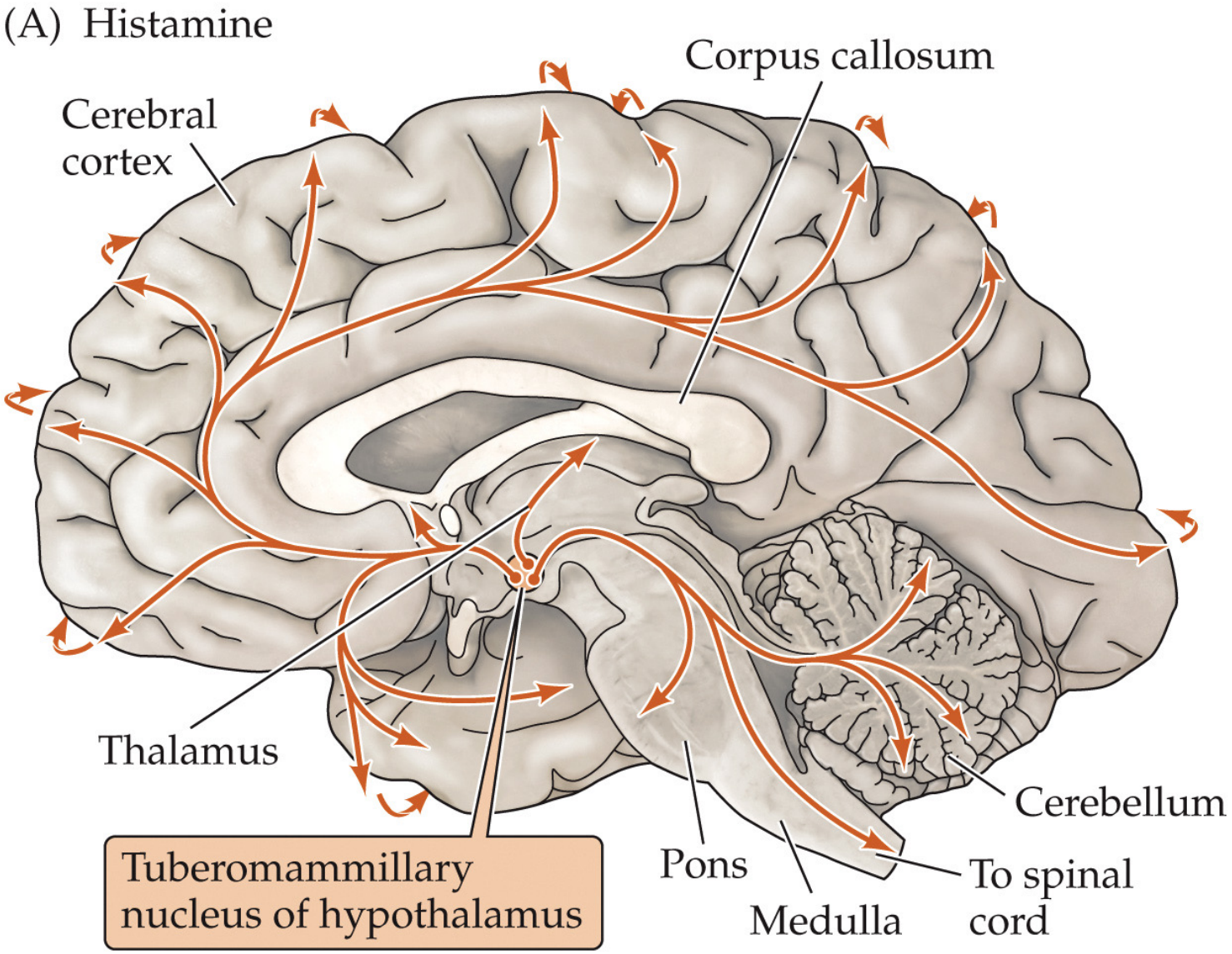
NEUROSCIENCE 6e, Figure 6.14

Synthesis of histamine and serotonin



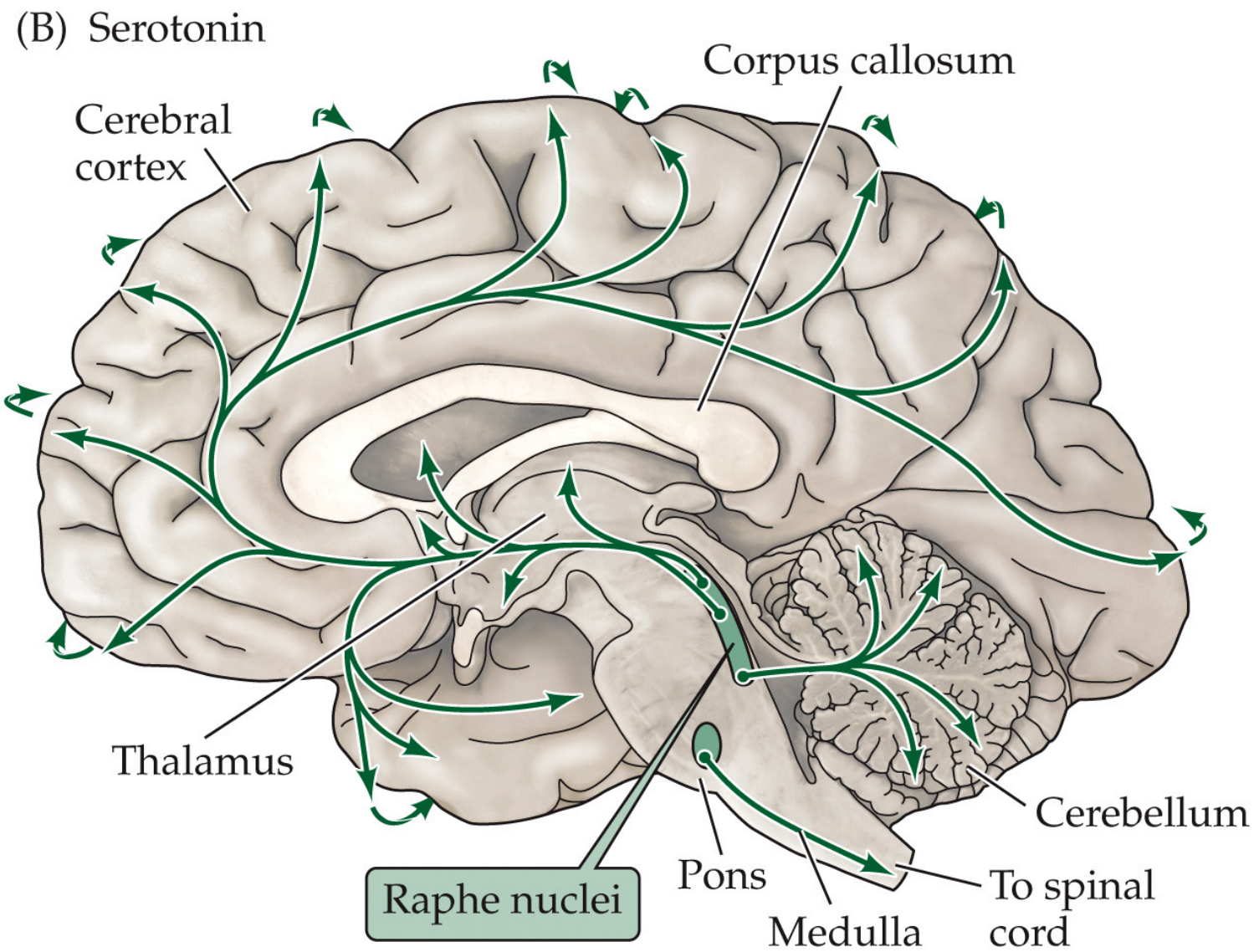
NEUROSCIENCE 6e, Figure 6.18

The distribution of histamine neurotransmitter in the human brain



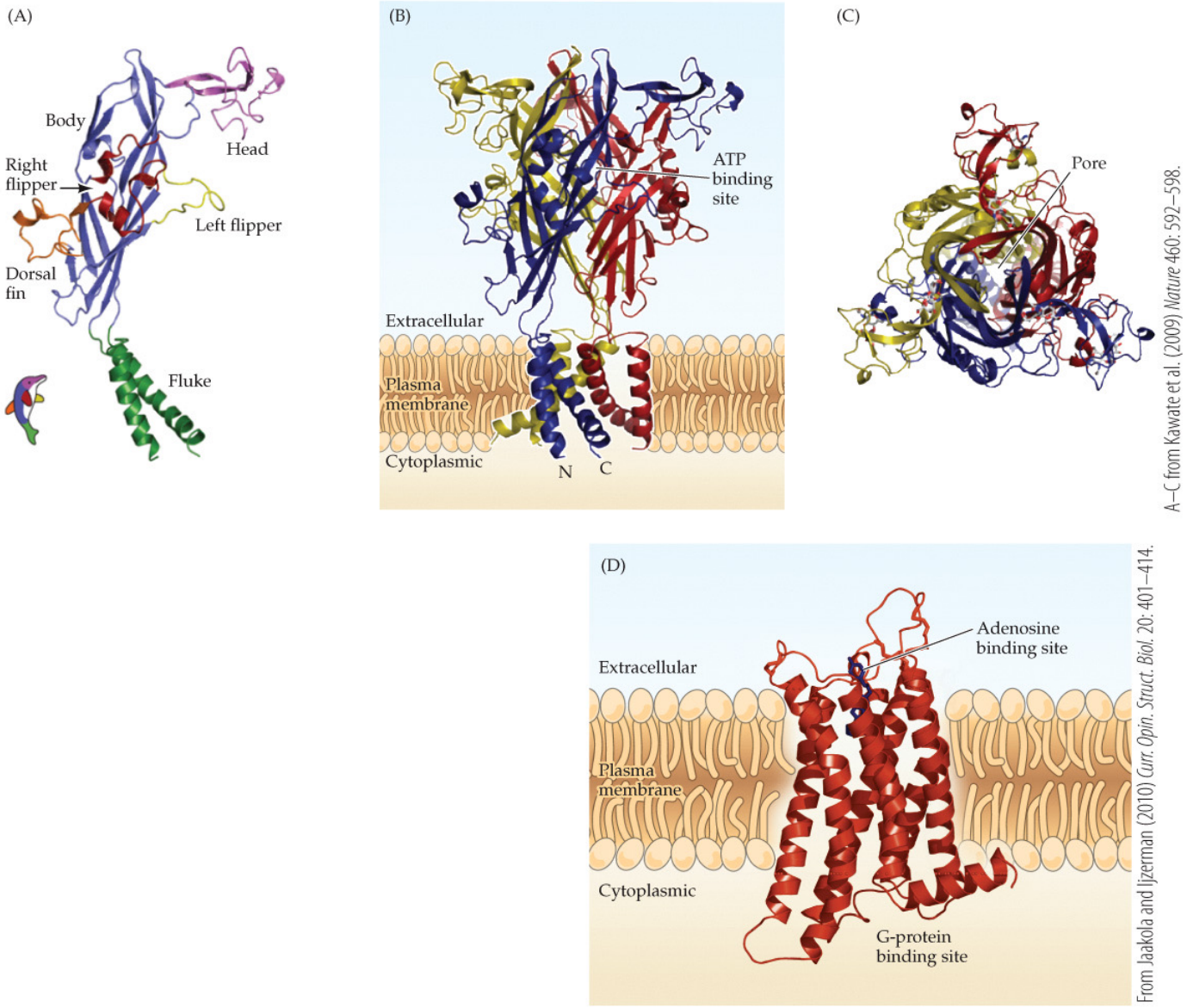
NEUROSCIENCE 6e, Figure 6.17 (Part 1)

The distribution of serotonin neurotransmitter in the human brain



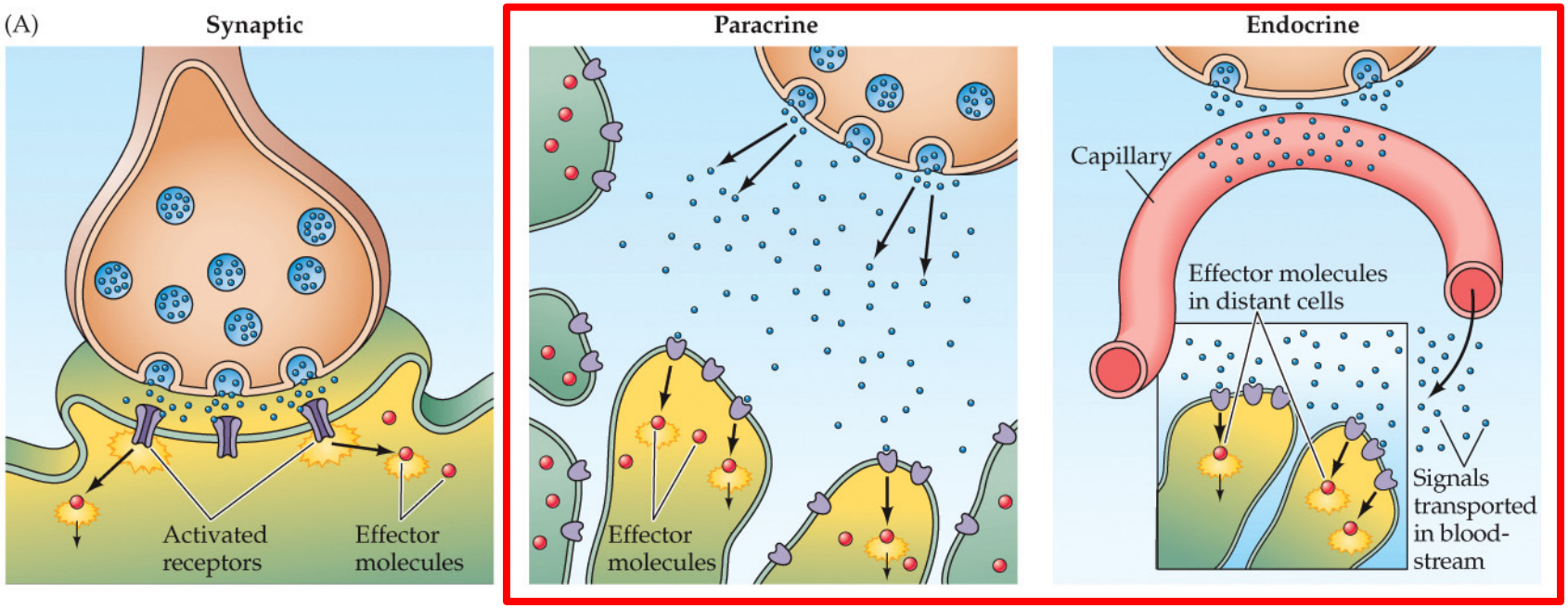
NEUROSCIENCE 6e, Figure 6.17 (Part 2)

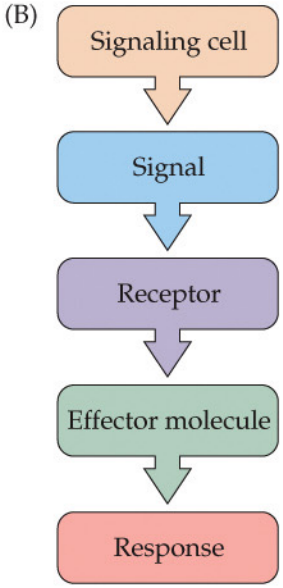
Purinergic receptors



NEUROSCIENCE 6e, Figure 6.20

Chemical signaling





Pre-synaptic

Neurotransmitter

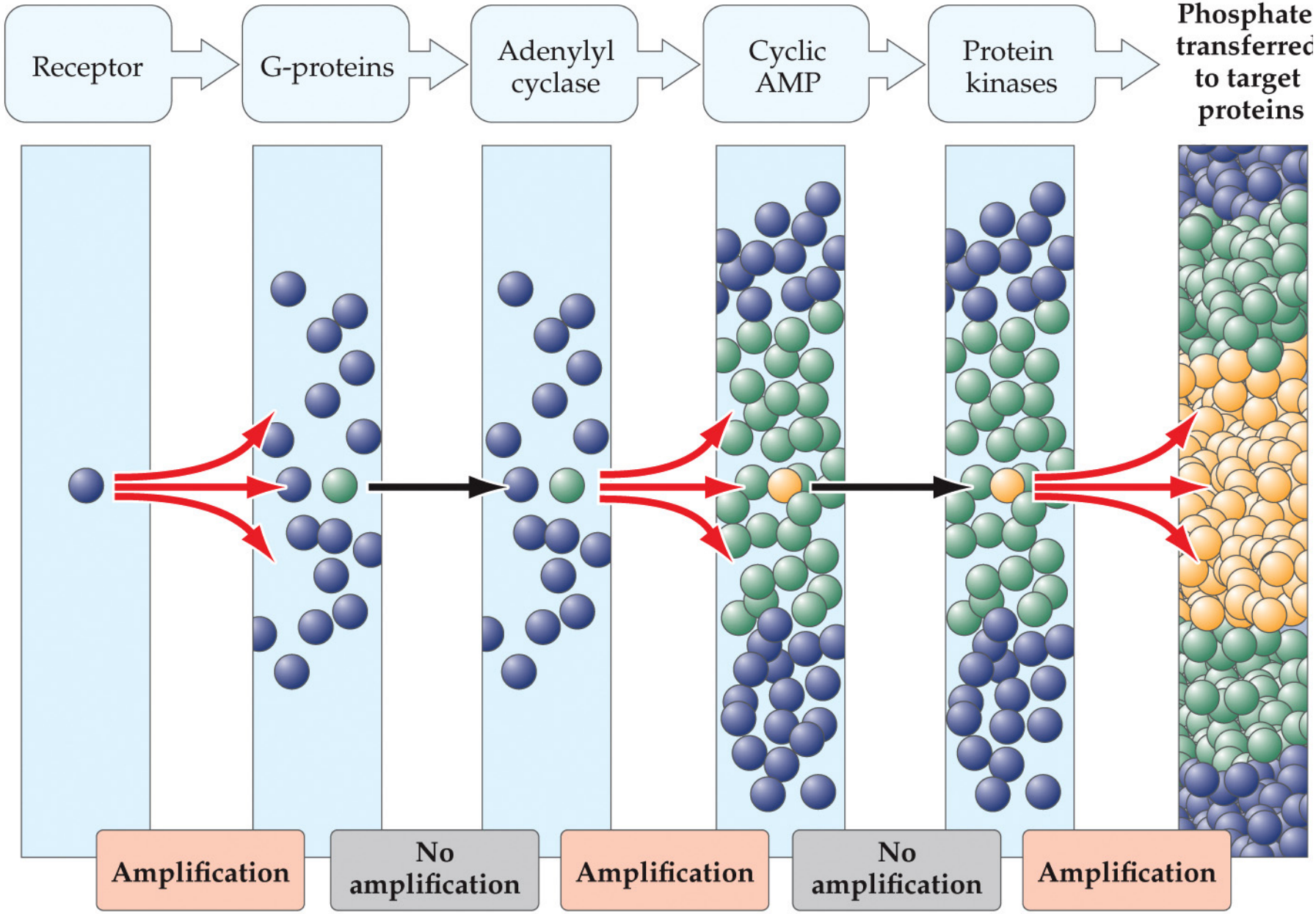
Ionotropic or Metabotropic

Ions or 2nd Messenger Pathway

Simple or Complex

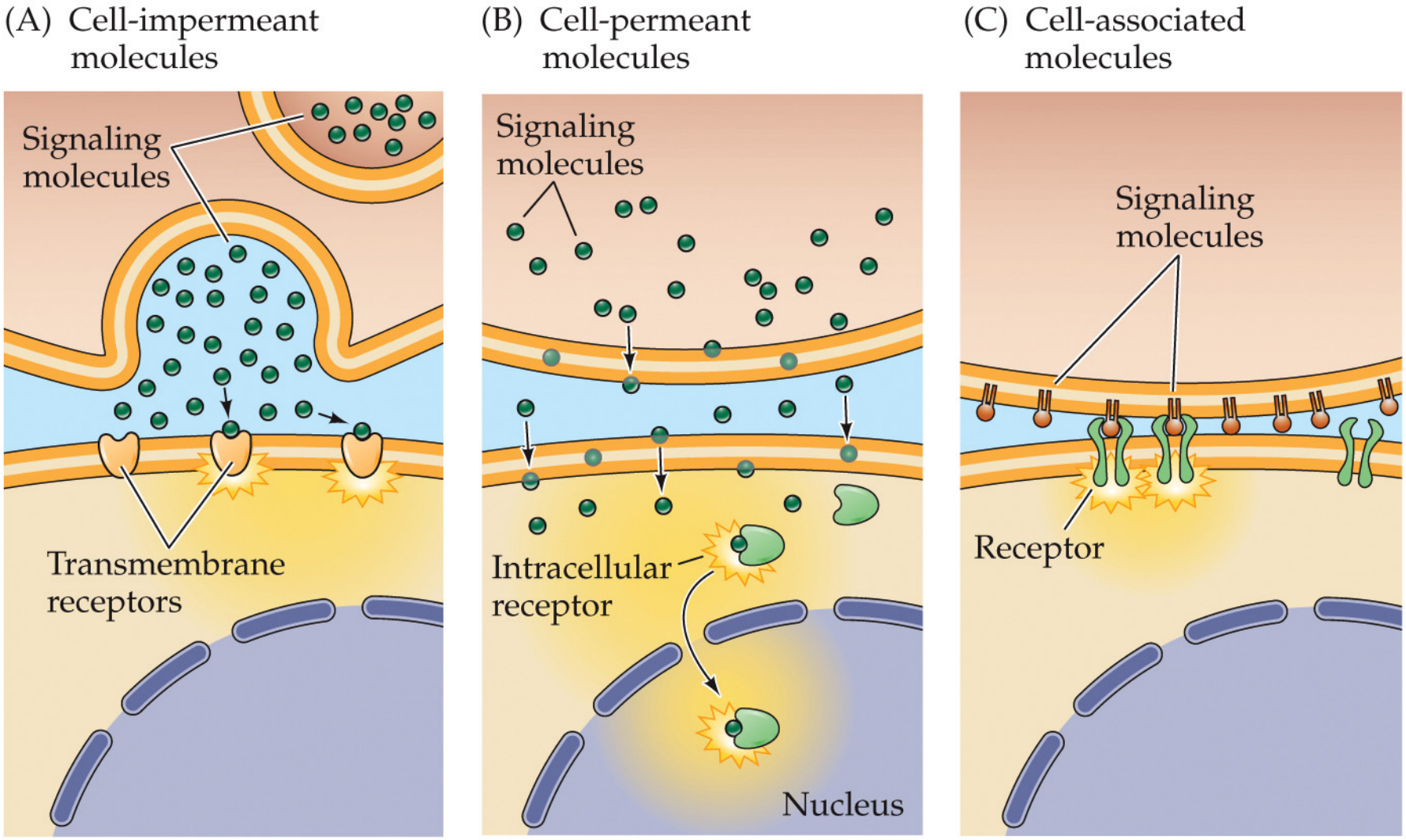
NEUROSCIENCE 6e, Figure 7.1

Amplification in signal transduction pathways



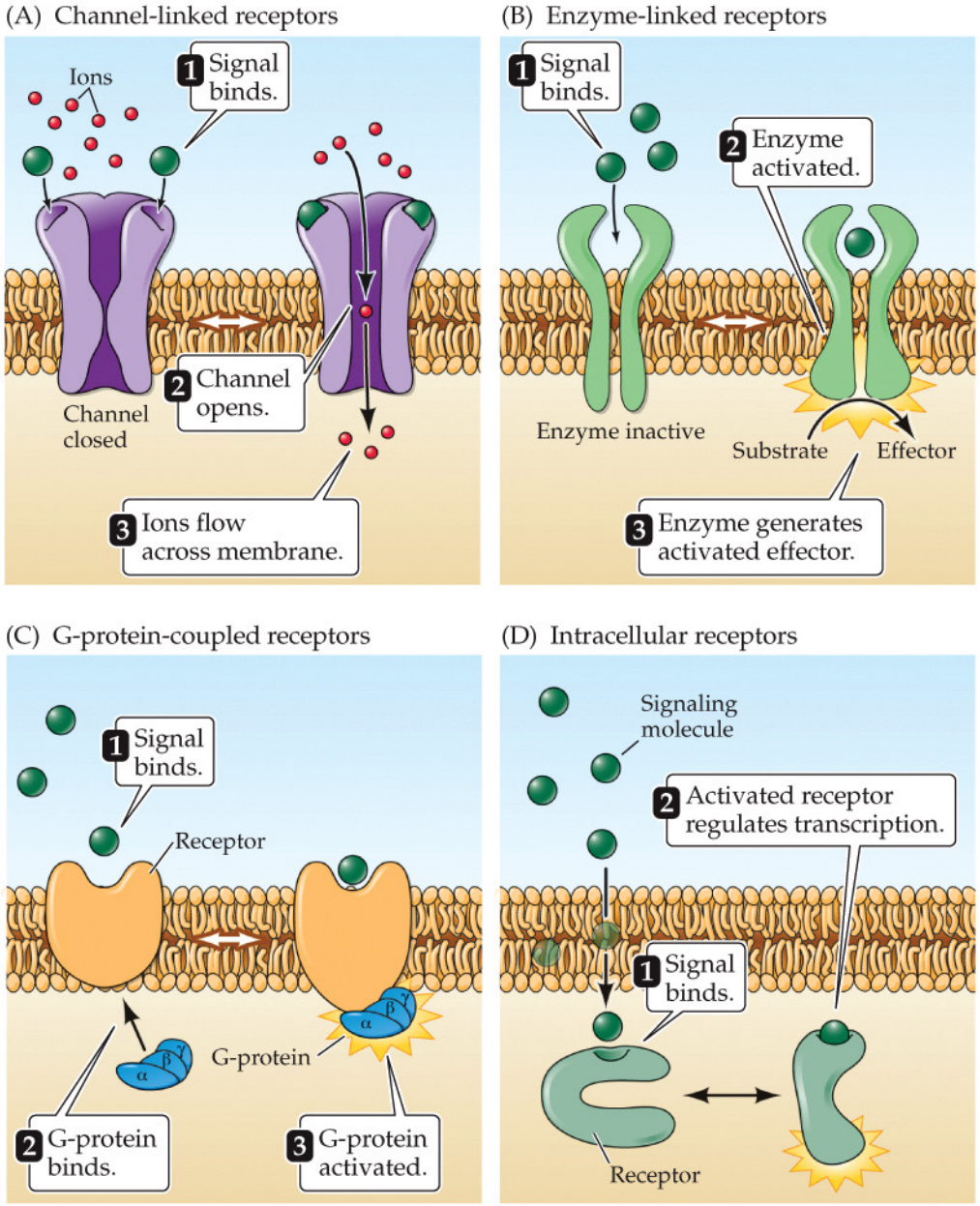
NEUROSCIENCE 6e, Figure 7.2

Three classes of cell signaling molecules



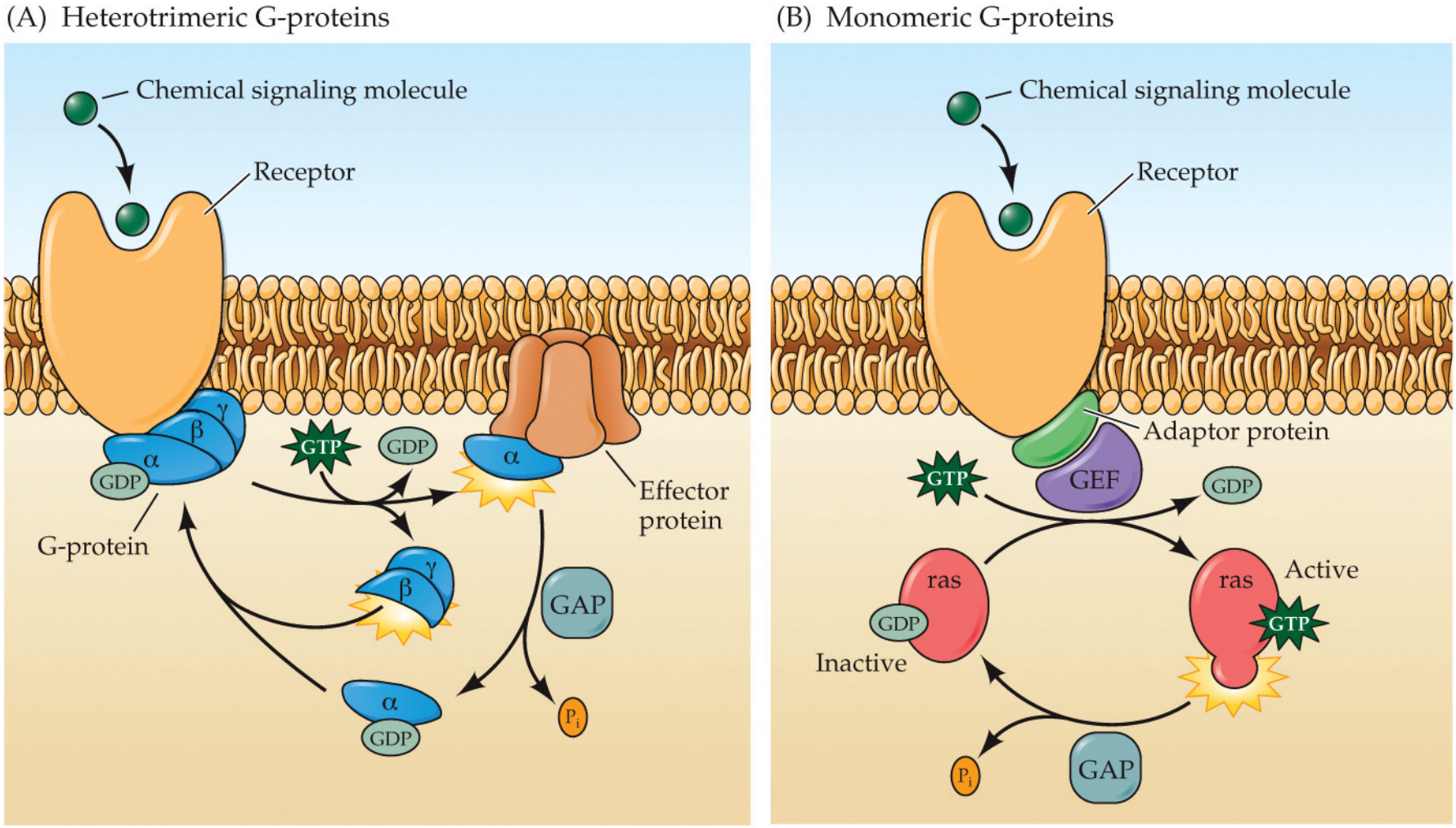
NEUROSCIENCE 6e, Figure 7.3

Categories of cellular receptors



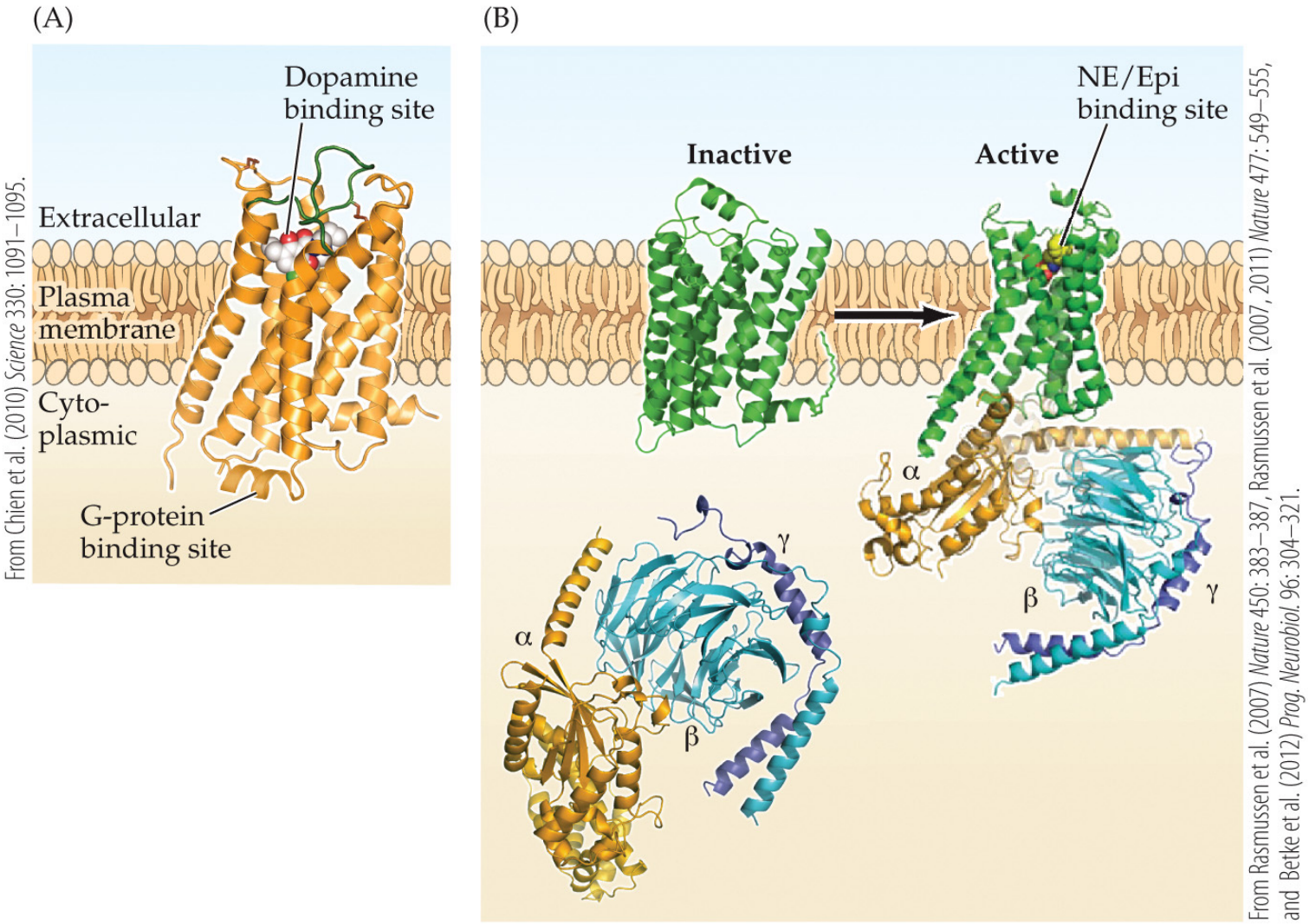
NEUROSCIENCE 6e, Figure 7.4

Types of GTP-binding proteins



NEUROSCIENCE 6e, Figure 7.5

Metabotropic receptors for catecholamine neurotransmitters

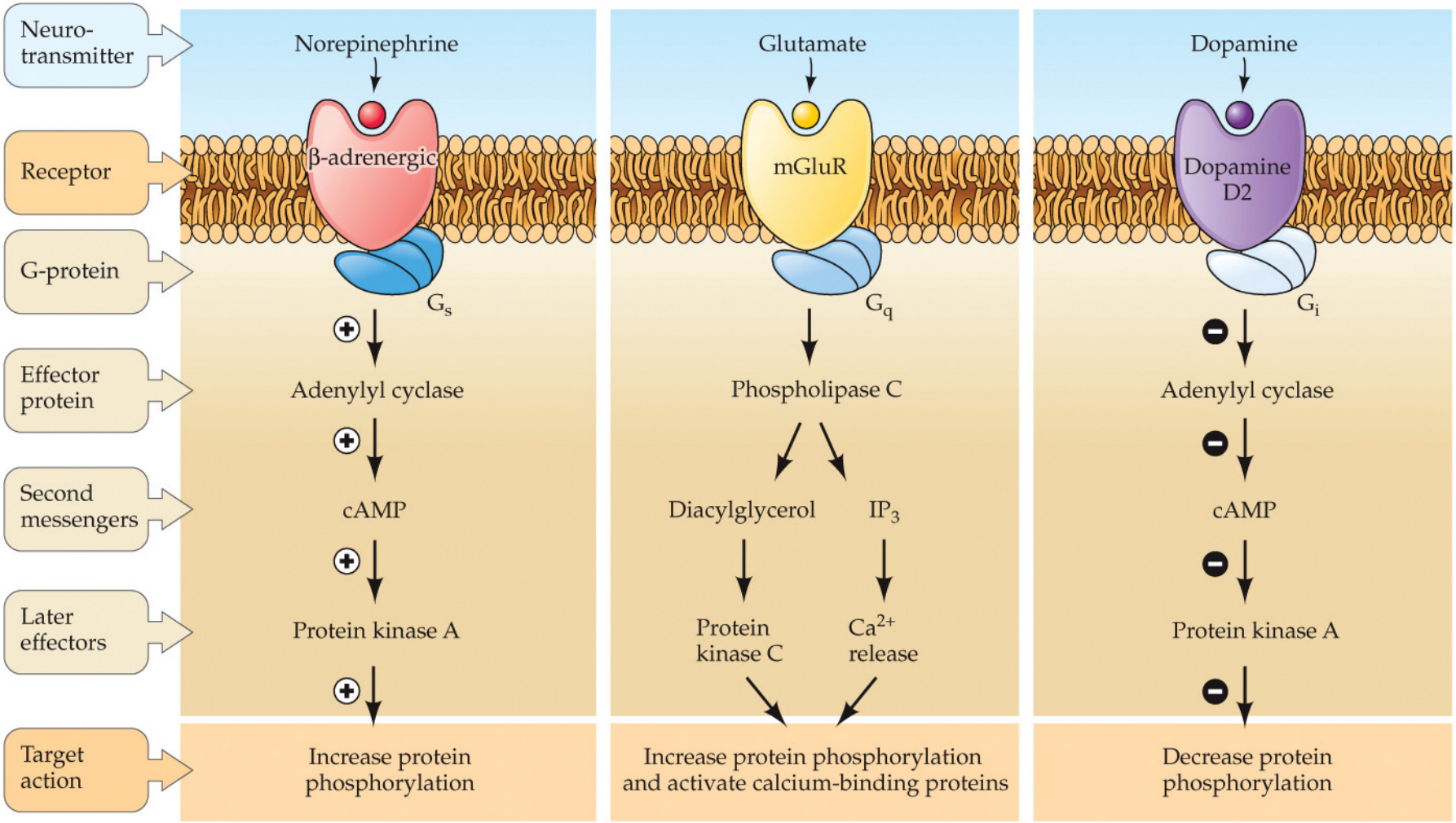


From Chien et al. (2010) *Science* 330: 1091–1095.

From Rasmussen et al. (2007) *Nature* 450: 383–387, Rasmussen et al. (2007, 2011) *Nature* 477: 549–555, and Betke et al. (2012) *Prog. Neurobiol.* 96: 304–321.

***NEUROSCIENCE 6e*, Figure 6.16**

Effector pathways associated with G-protein-coupled receptors



NEUROSCIENCE 6e, Figure 7.6

Effector protein is usually associated with the plasma membrane

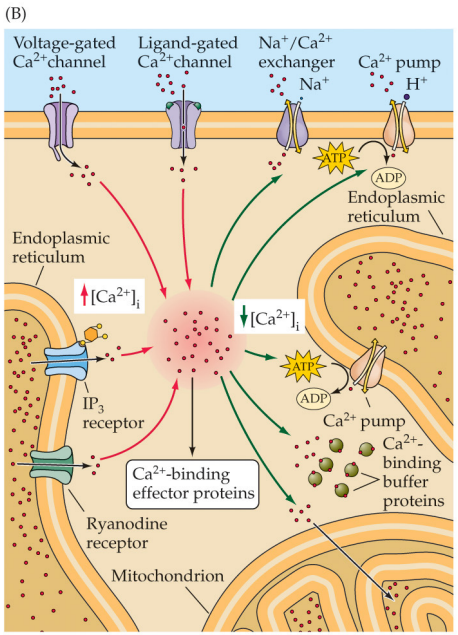
Neuronal second messengers

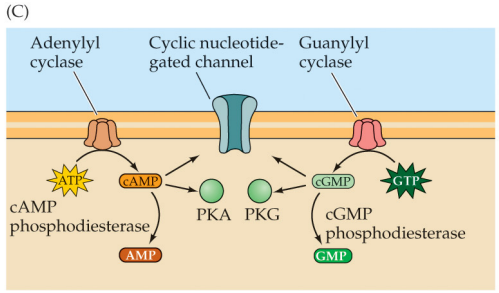
Phospholipase C

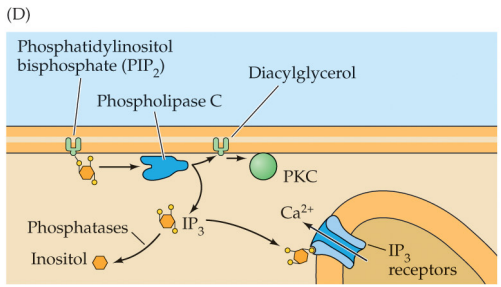
(A)

Second messenger	Sources	Intracellular targets	Removal mechanisms
Ca^{2+}	Plasma membrane: Voltage-gated Ca^{2+} channels; Various ligand-gated channels; Endoplasmic reticulum: IP_3 receptors; Ryanodine receptors	Calmodulin; Protein kinases; Protein phosphatases; Ion channels; Synaptotagmins; Many other Ca^{2+}-binding proteins	Plasma membrane: Na^+/Ca^{2+} exchanger; Ca^{2+} pump; Endoplasmic reticulum: Ca^{2+} pump; Mitochondria
Cyclic AMP	Adenylyl cyclase acts on ATP	Protein kinase A; Cyclic nucleotide-gated channels	cAMP phosphodiesterase
Cyclic GMP	Guanylyl cyclase acts on GTP	Protein kinase G; Cyclic nucleotide-gated channels	cGMP phosphodiesterase
IP_3	Phospholipase C acts on PIP_2	IP_3 receptors on endoplasmic reticulum	Phosphatases
Diacylglycerol	Phospholipase C acts on PIP_2	Protein kinase C	Various enzymes

Two immediate, one later

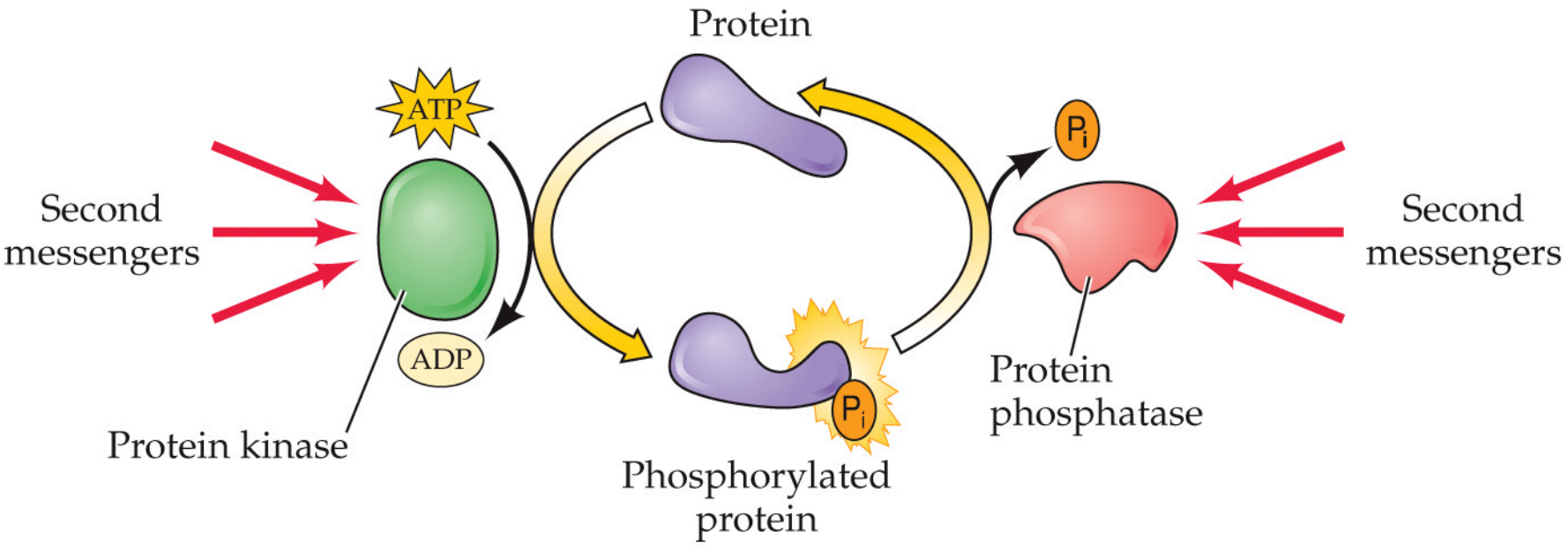






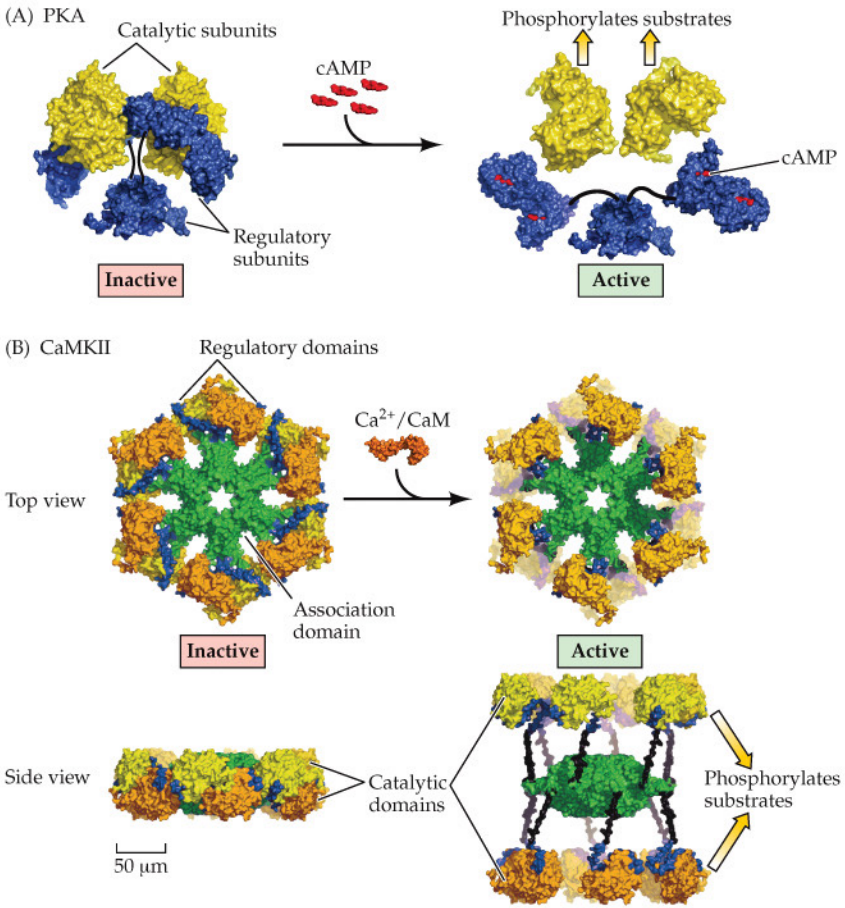
NEUROSCIENCE 6e, Figure 7.7

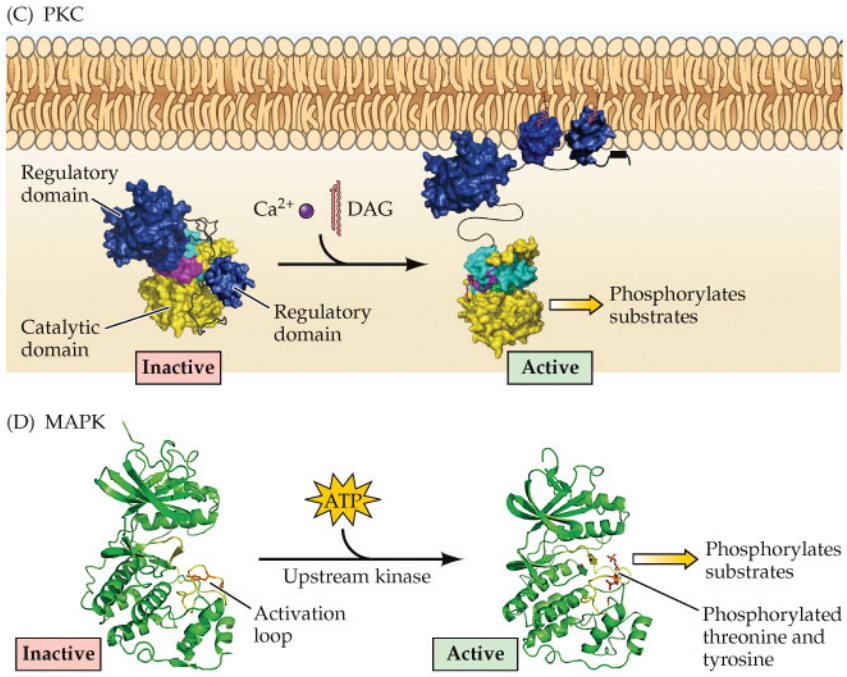
Regulation of cellular proteins by phosphorylation



NEUROSCIENCE 6e, Figure 7.8

Activation of protein kinases

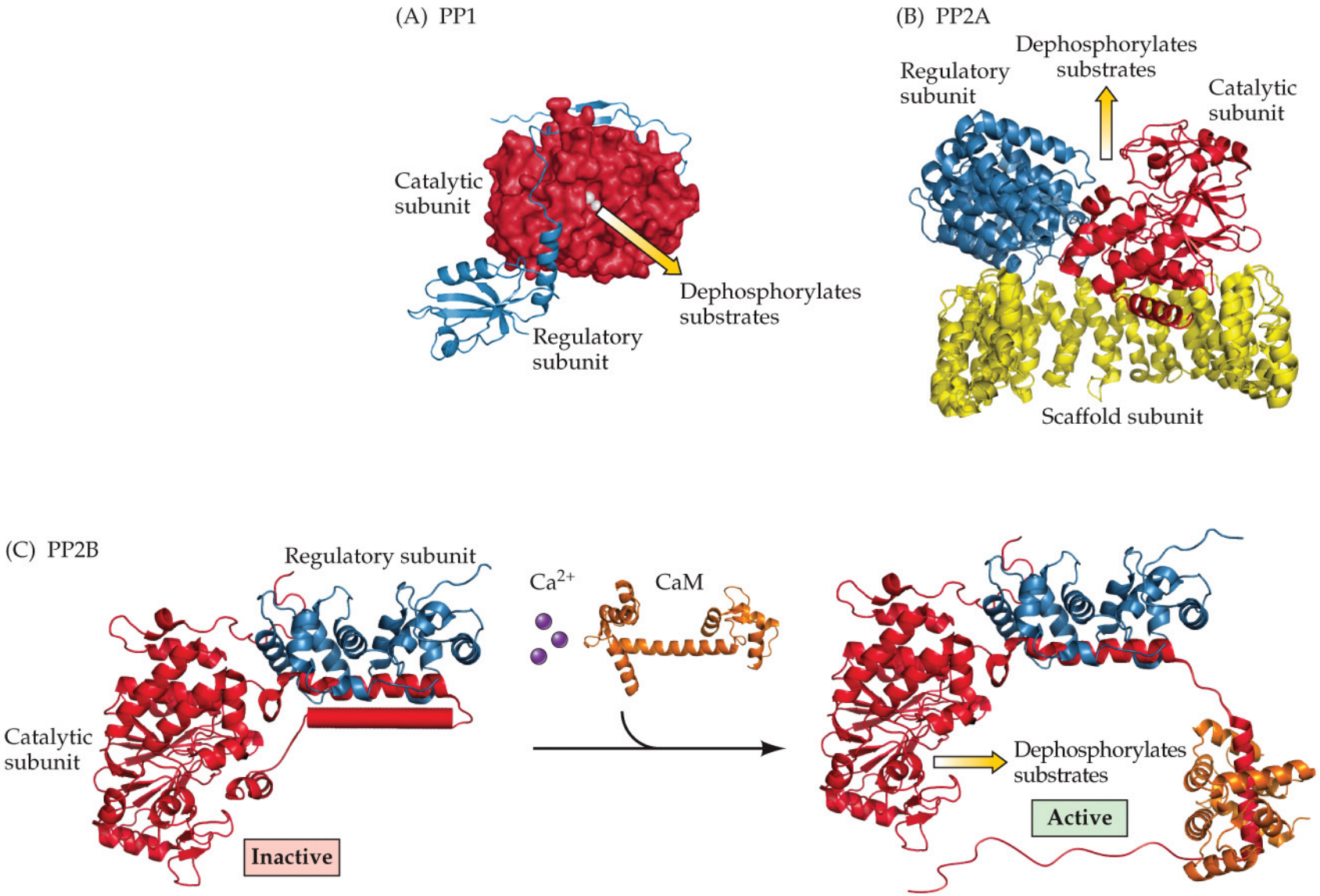




NEUROSCIENCE 6e, Figure 7.9

A from Berman et al. (2000) *Nucleic Acids Research* 28: 235–242. doi:10.1093/nar/28.1.236. B after Craddock et al. (2012) *PLoS Comput. Biol.* 8: e1002421. C after Leonard et al. (2011) *Cell* 144: 55–66. D from Turk (2007) *Biochem. J.* 402: 405–417.

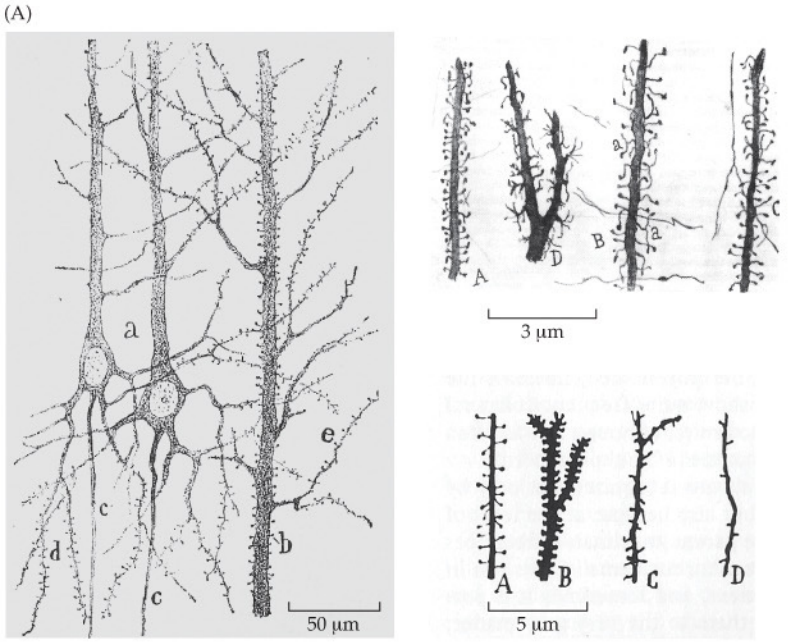
Types of protein phosphatases

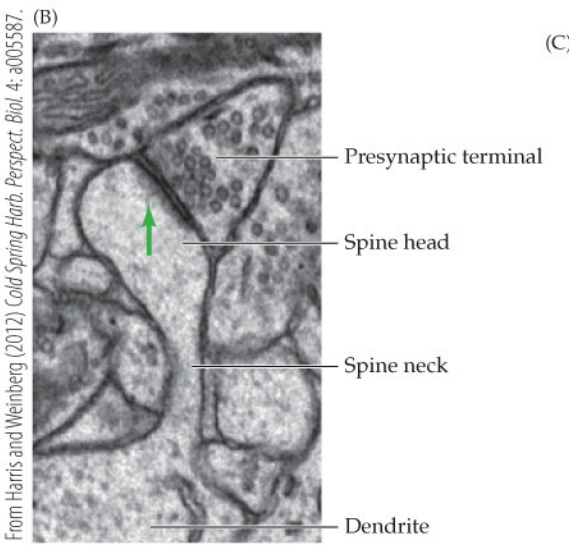


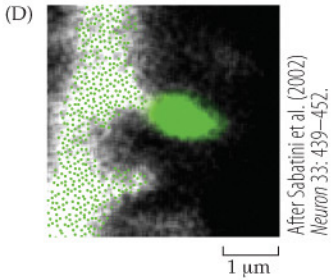
NEUROSCIENCE 6e, Figure 7.10

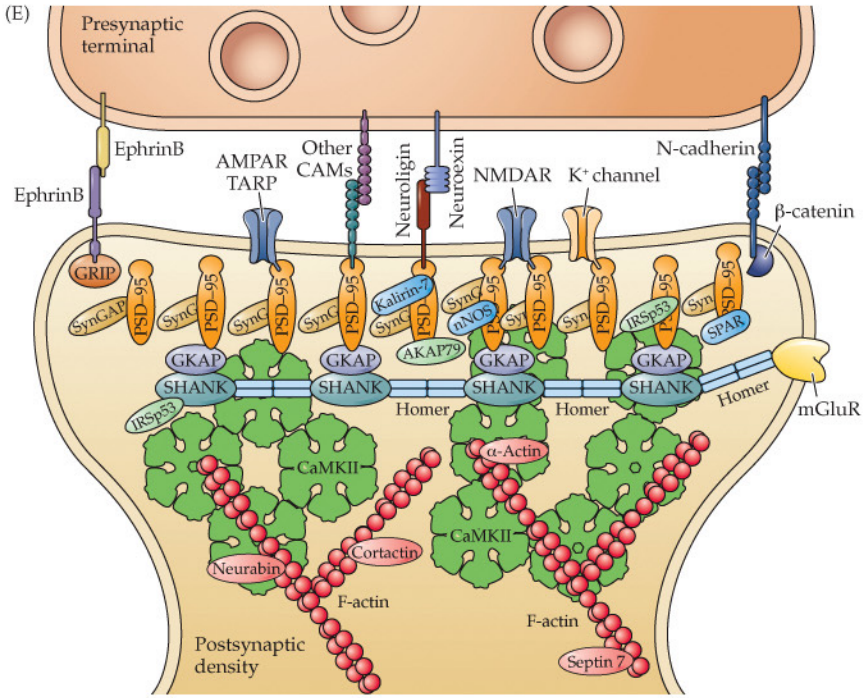
A from Bollen et al. (2010) *Trends Biochem. Sci.* 35: 450–458. B from Cho and Xu (2007) *Nature* 445: 53–57. C after Li et al. (2011) *Trends Cell Biol.* 21: 91–103.

Dendritic Spines



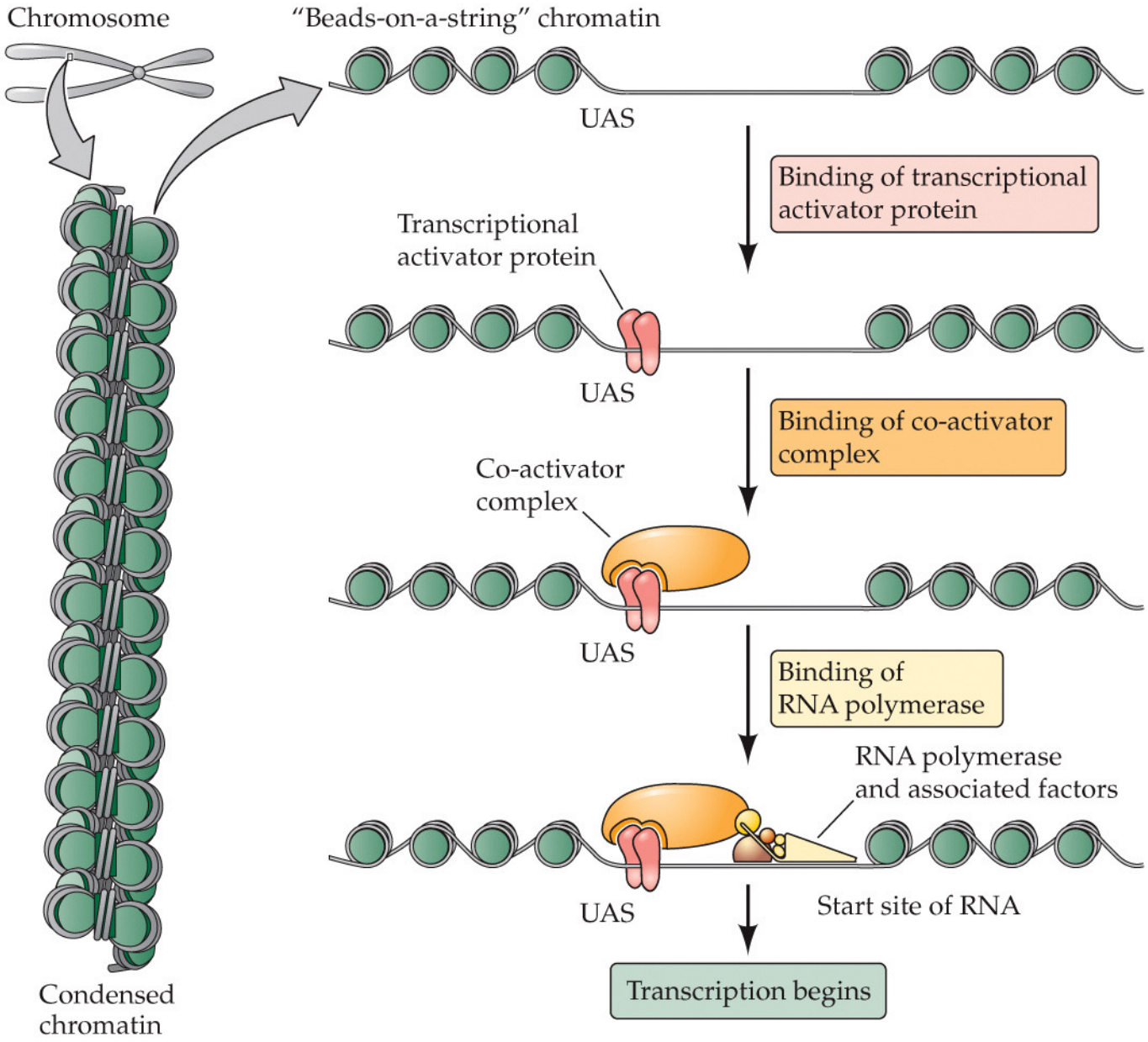






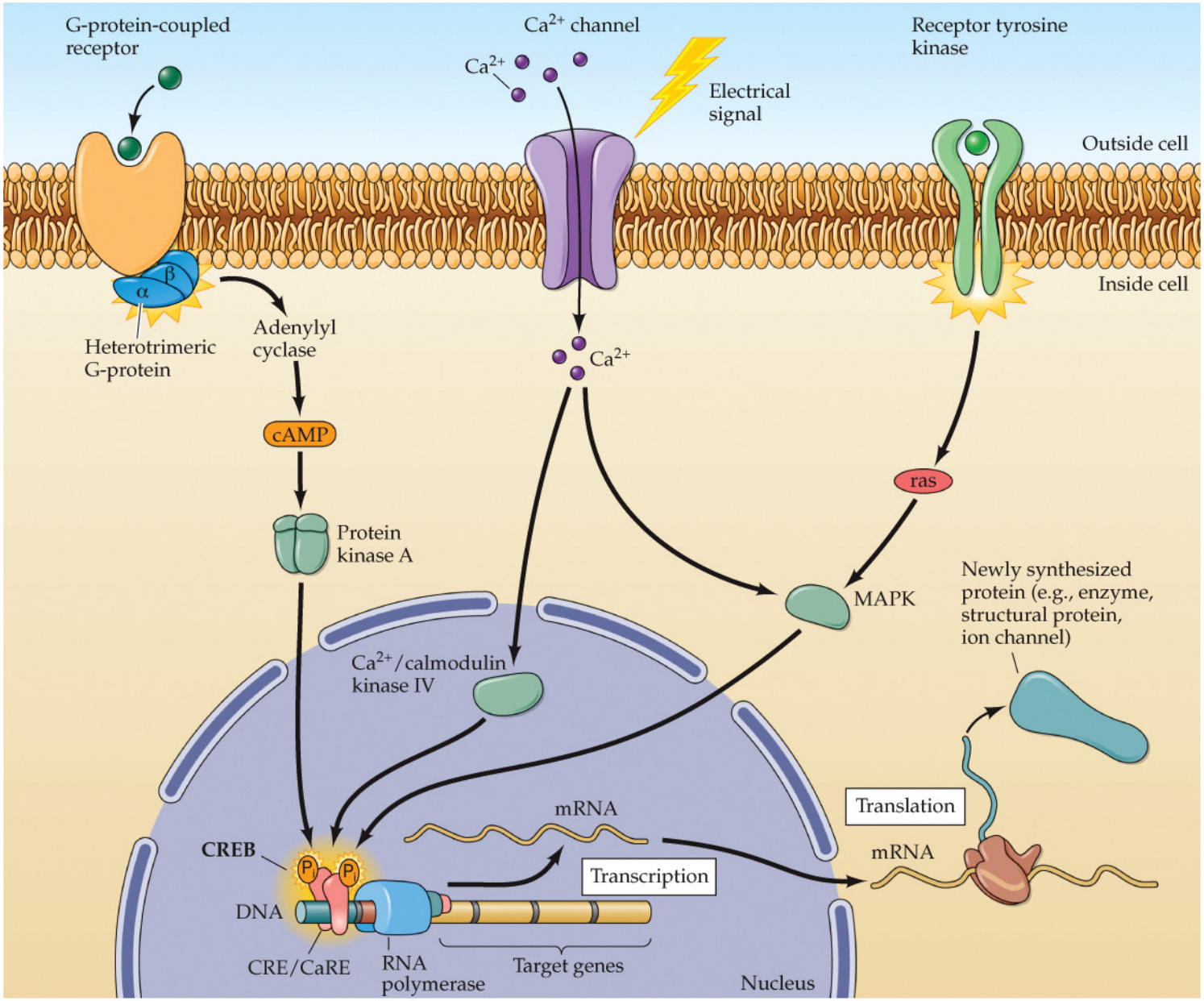
NEUROSCIENCE 6e, Box 7B

Steps in the transcription of DNA into RNA



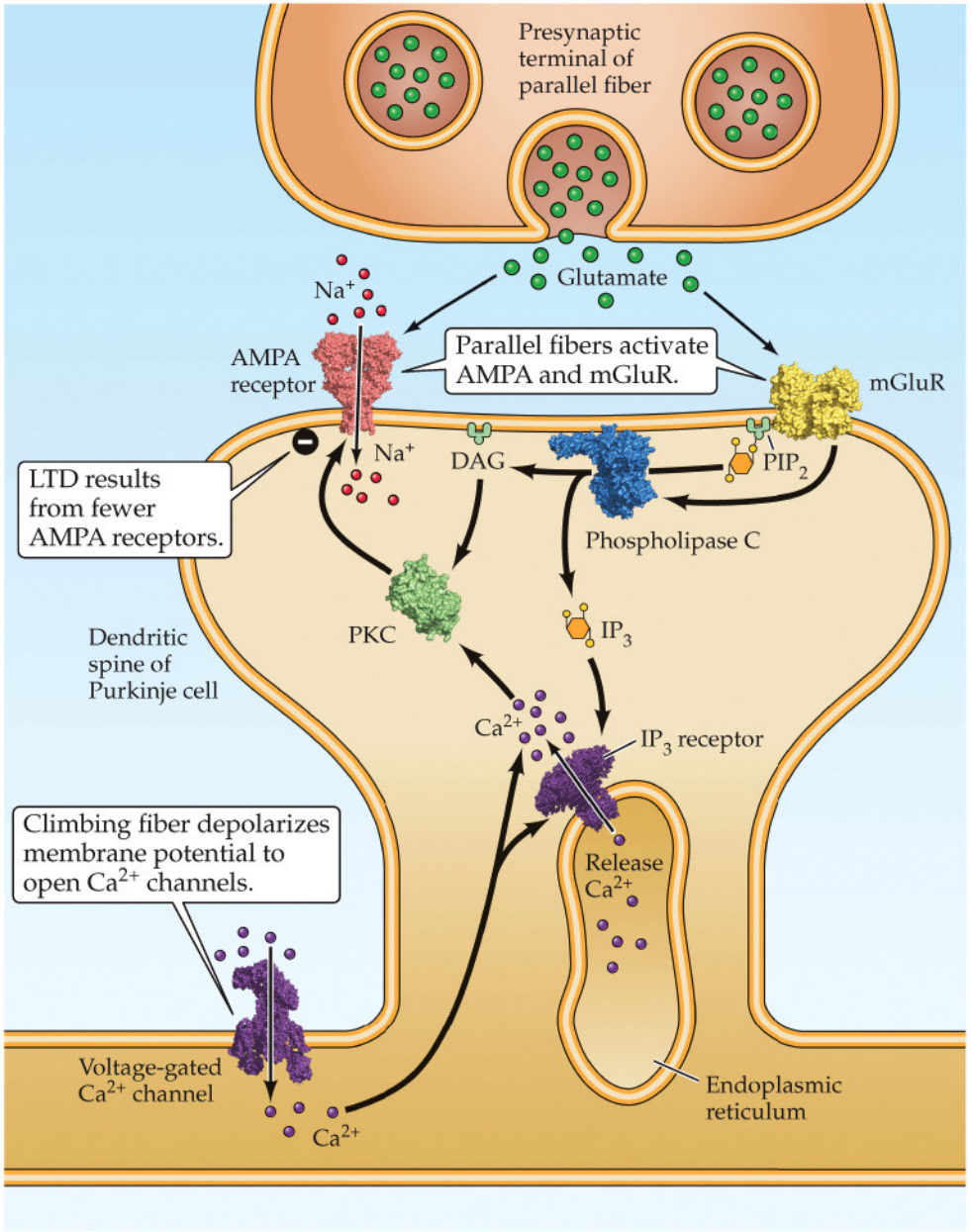
NEUROSCIENCE 6e, Figure 7.11

Transcriptional regulation by CREB



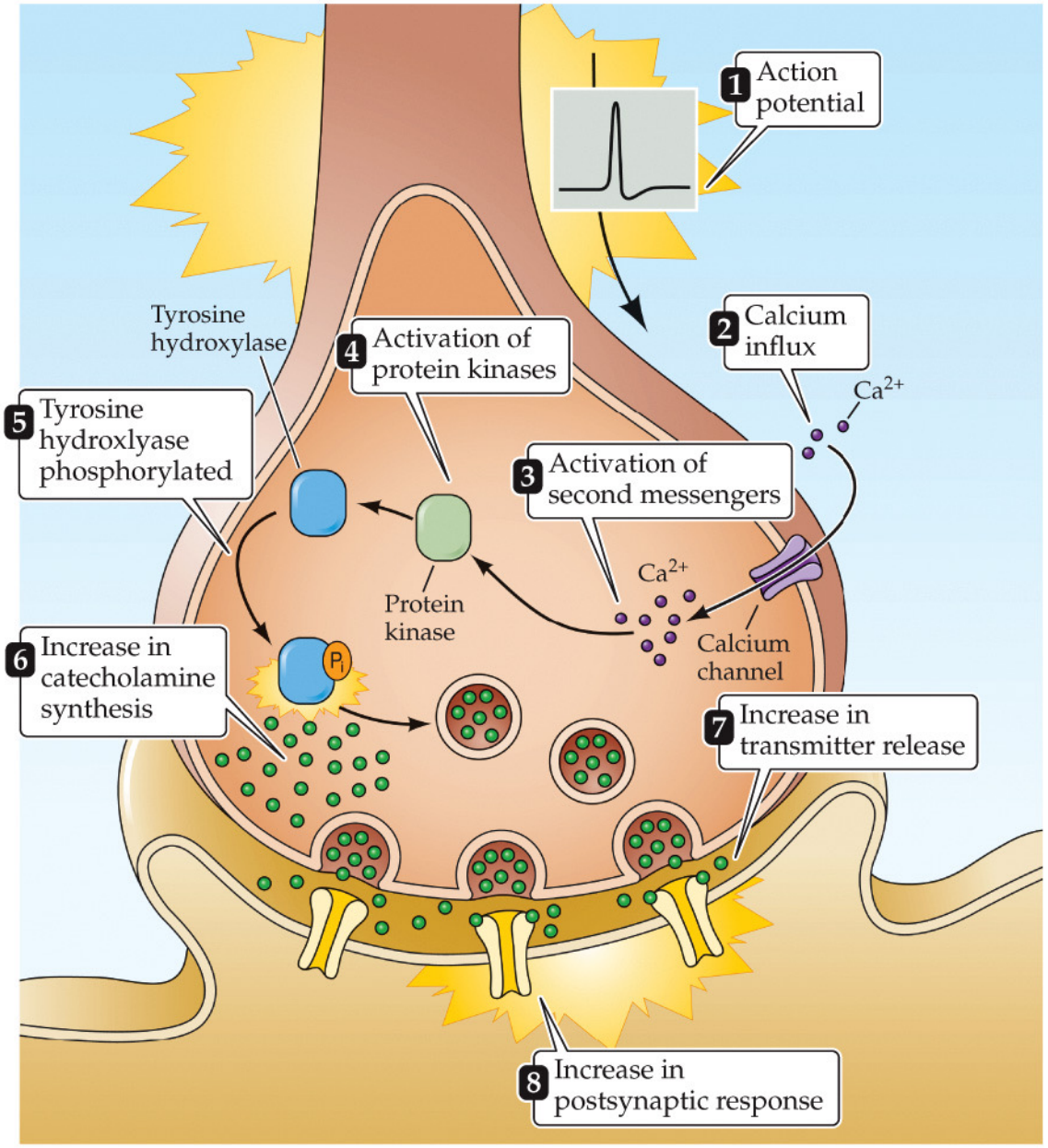
NEUROSCIENCE 6e, Figure 7.12

Signaling at cerebellar parallel fiber synapses during long-term synaptic depression



NEUROSCIENCE 6e, Figure 7.14

Regulation of tyrosine hydroxylase by protein phosphorylation



NEUROSCIENCE 6e, Figure 7.15