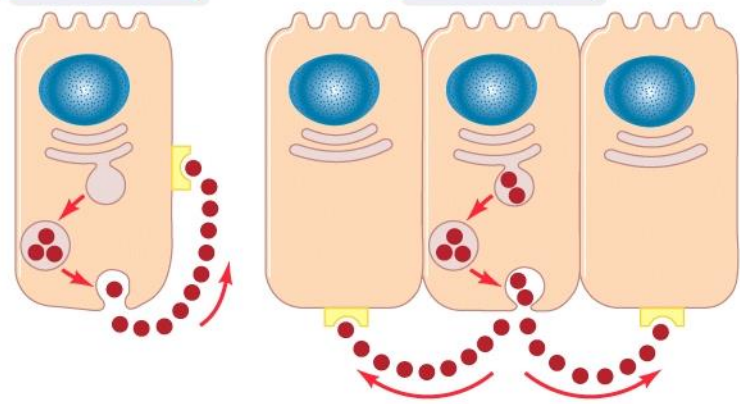


(a)

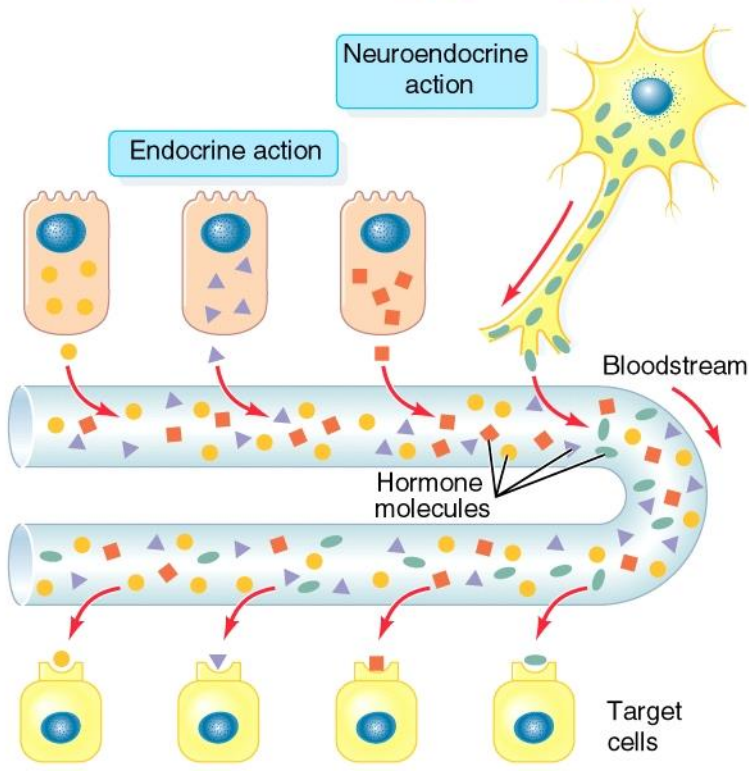
Autocrine action

Paracrine action

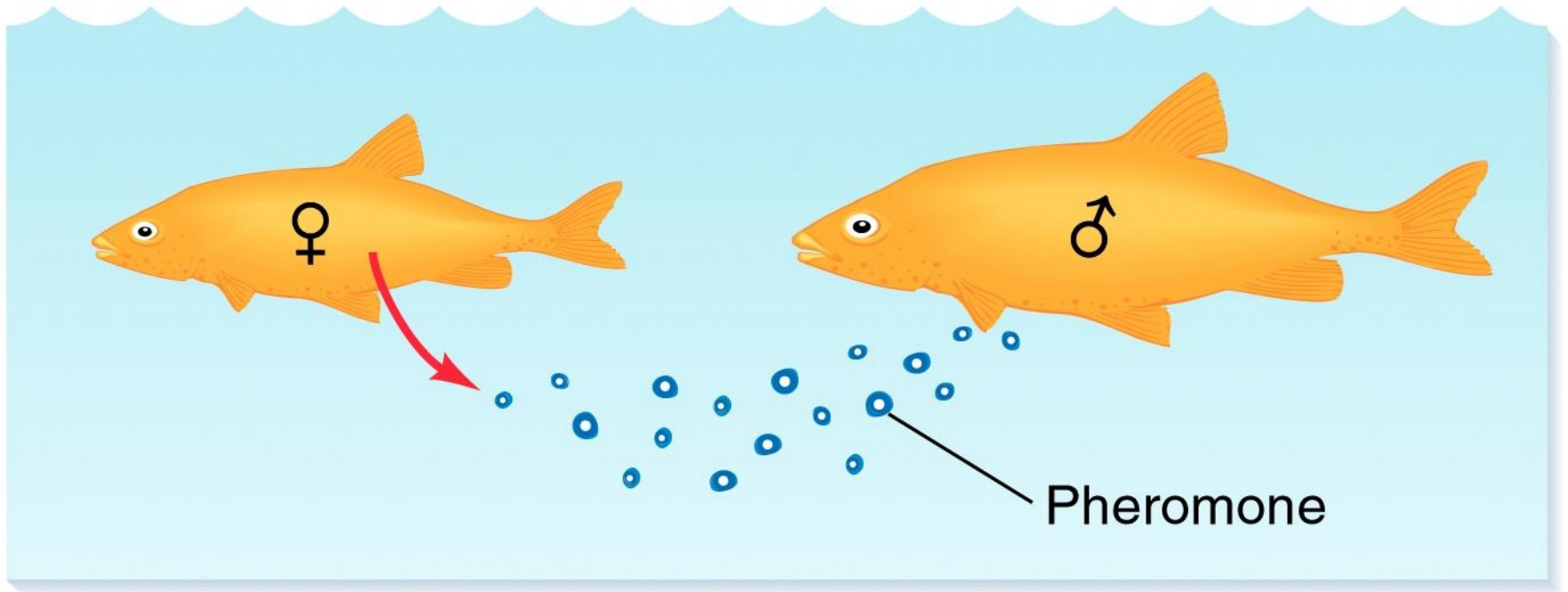


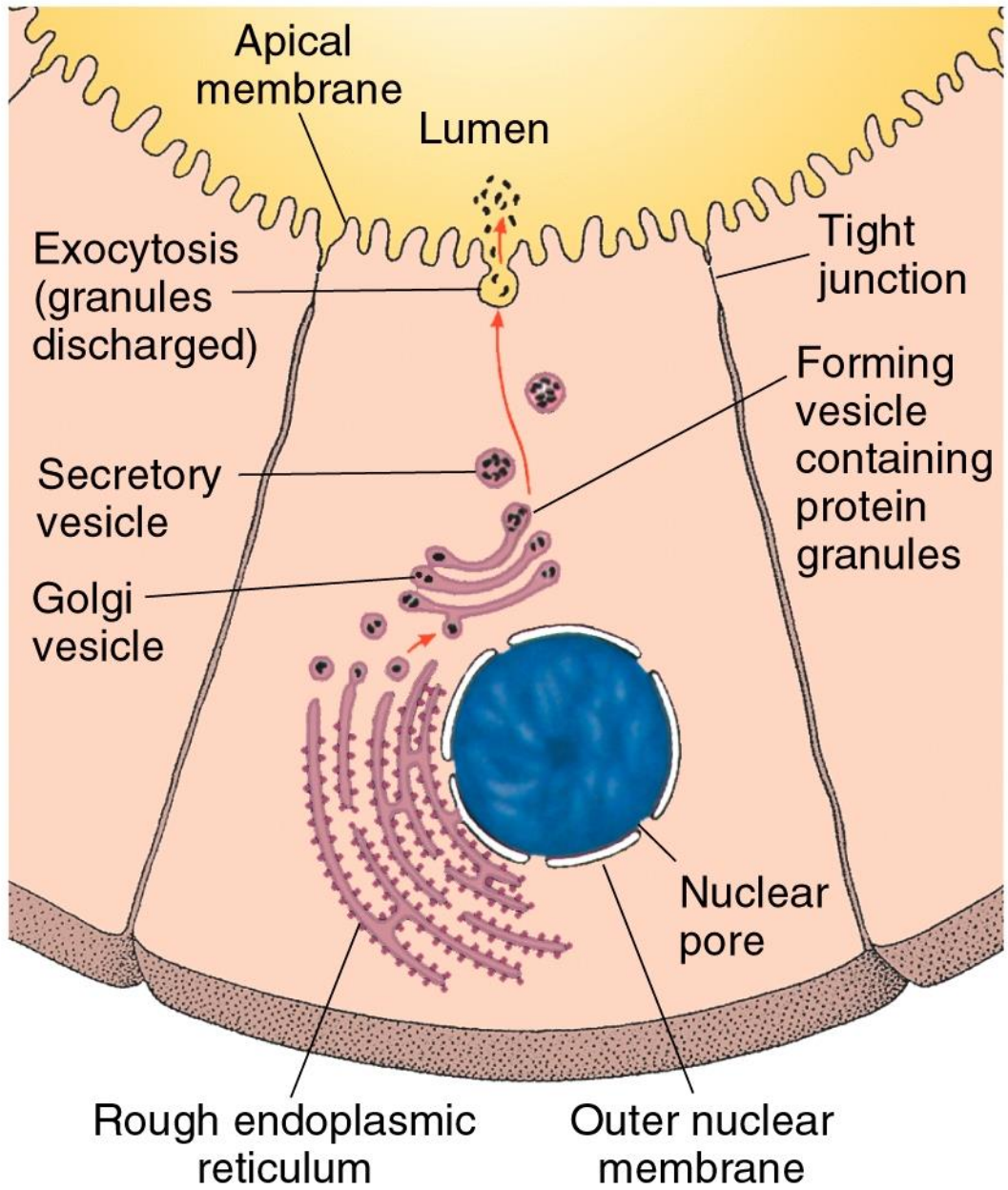
Neuroendocrine action

Endocrine action



(b)





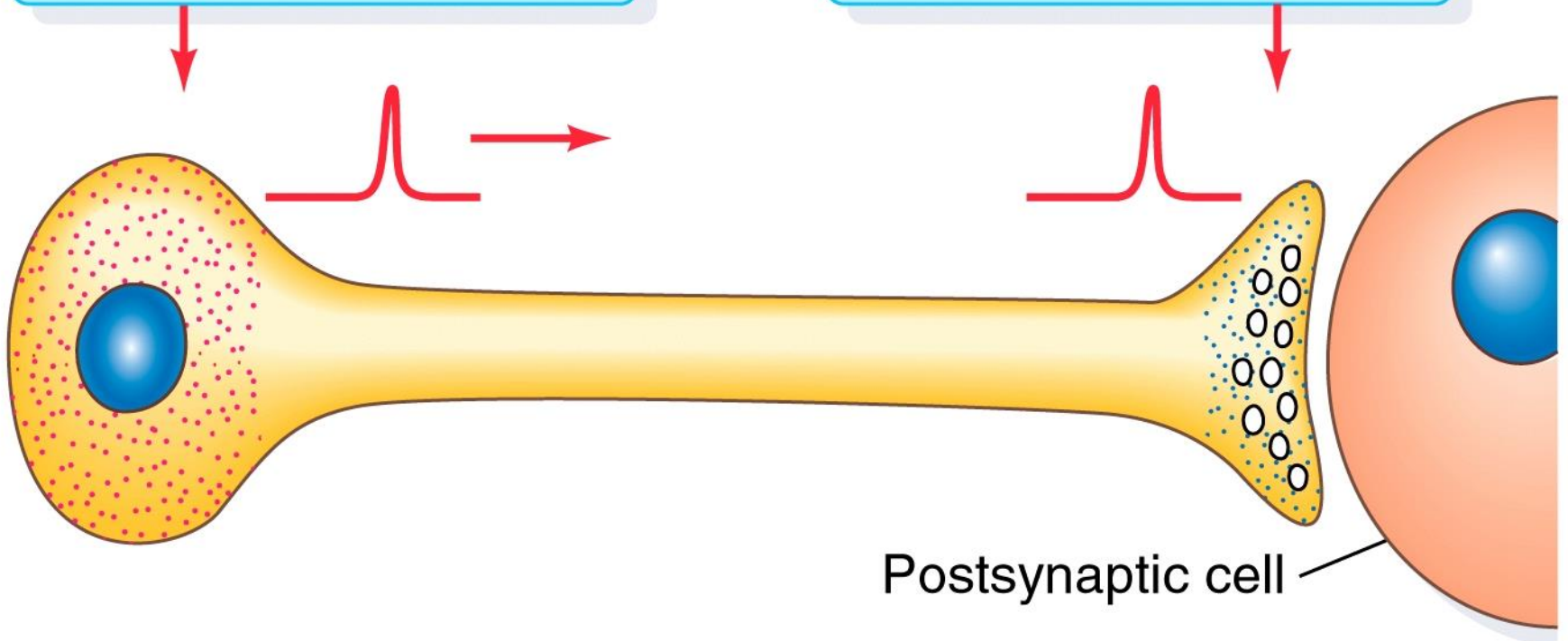
(a) Neuron

Stimulus induces

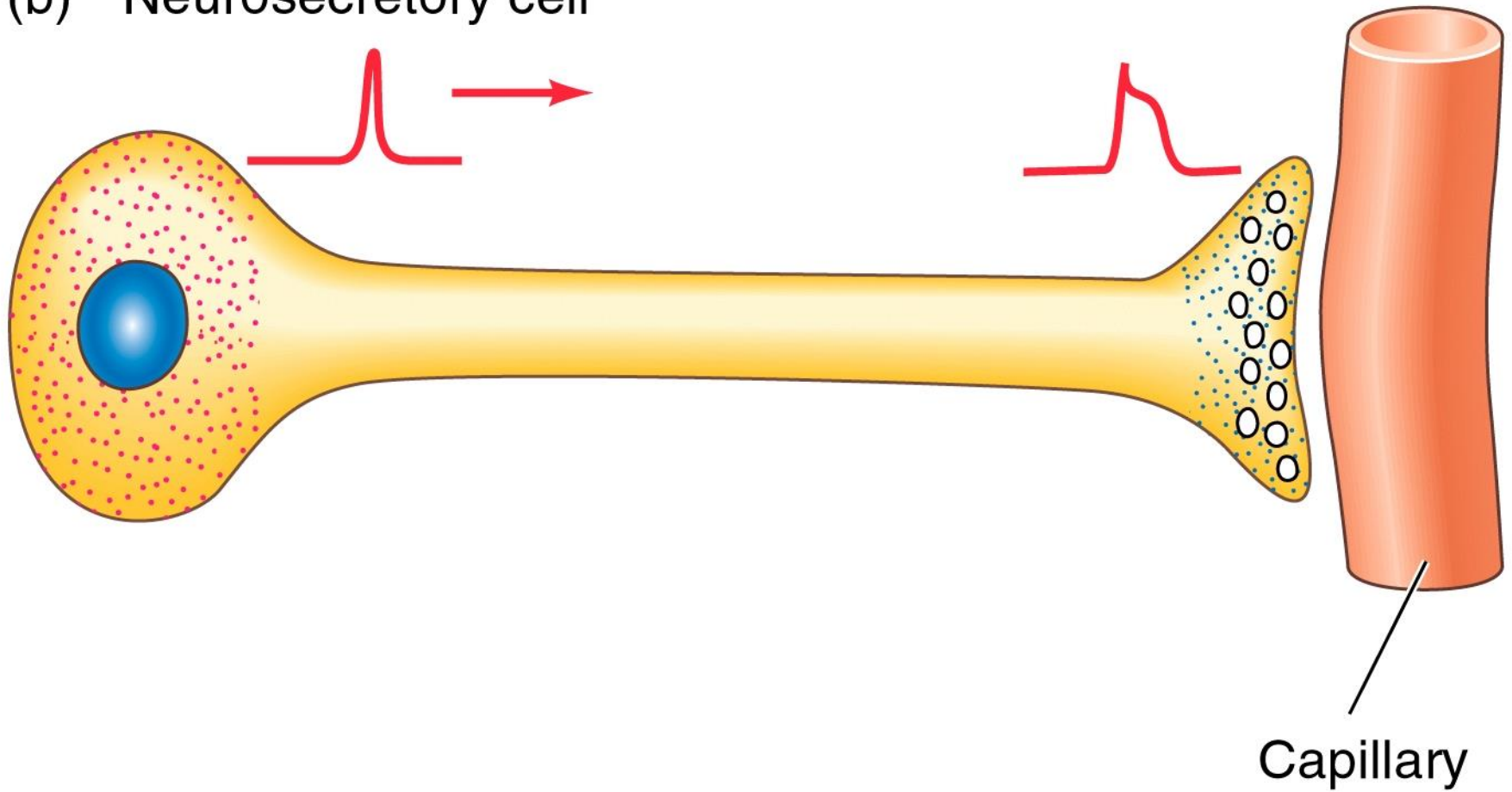
- (1) permeability increase
- (2) Na^+ , Ca^{2+} influx
- (3) depolarization

Secretion follows

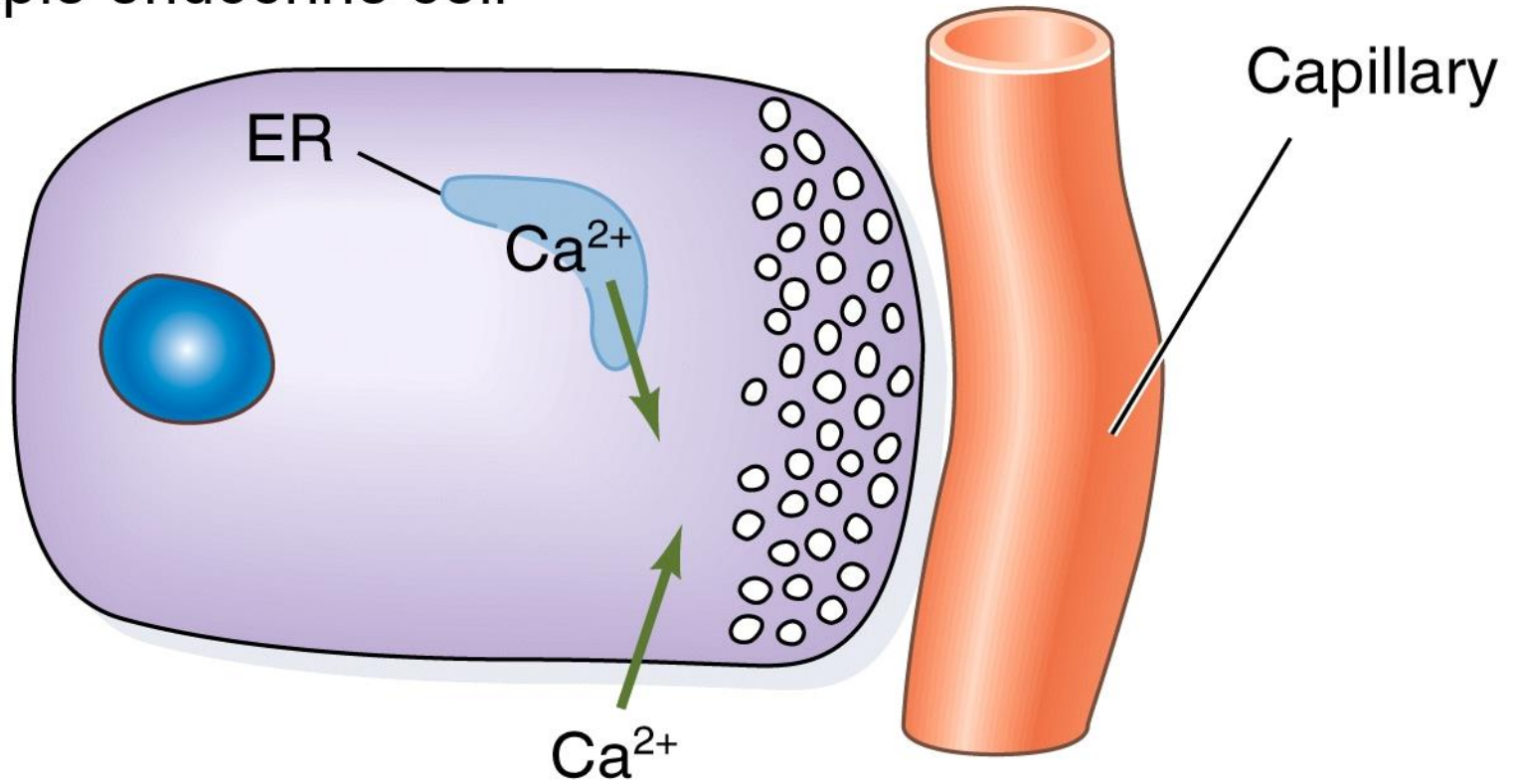
- (1) depolarization
- (2) permeability increase
- (3) Ca^{2+} influx



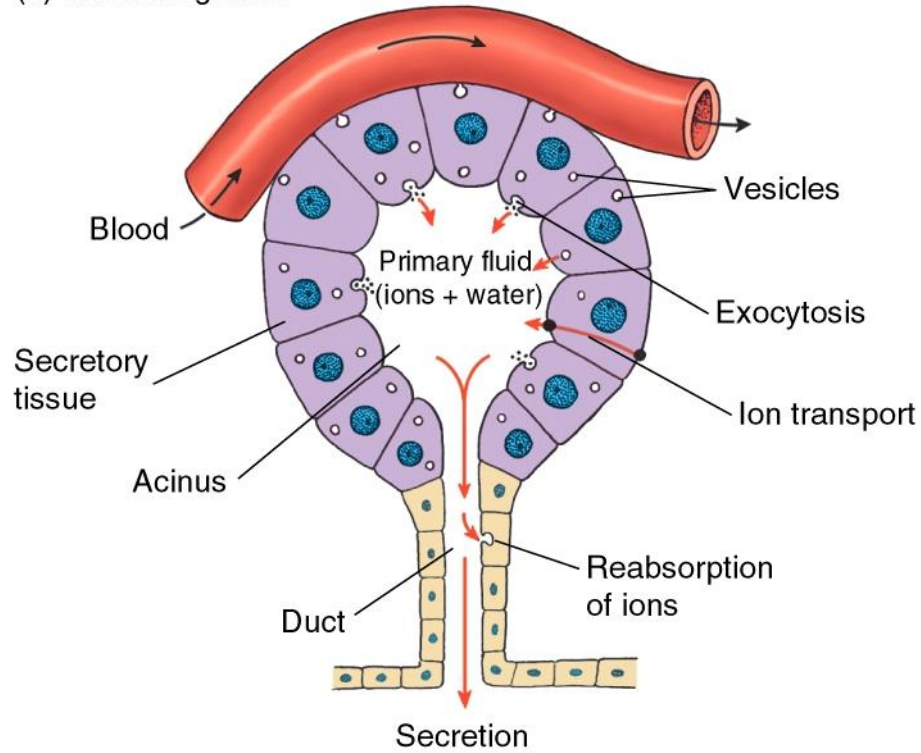
(b) Neurosecretory cell



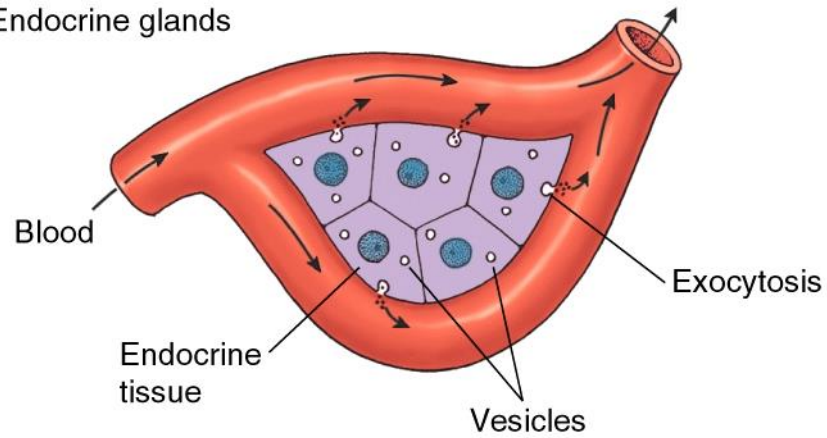
(c) Simple endocrine cell


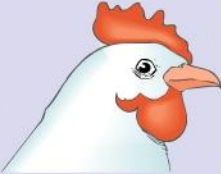
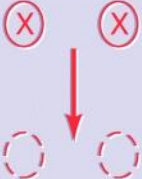
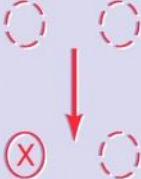
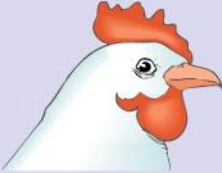



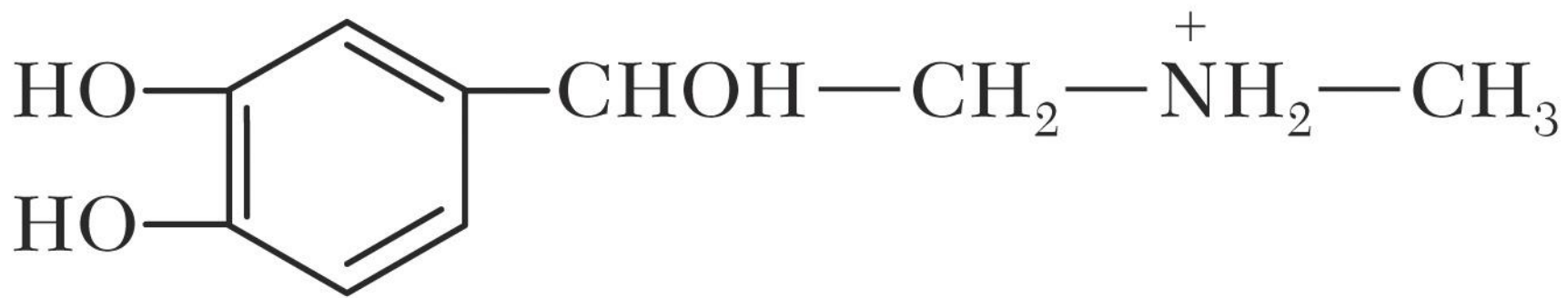
(a) Exocrine glands



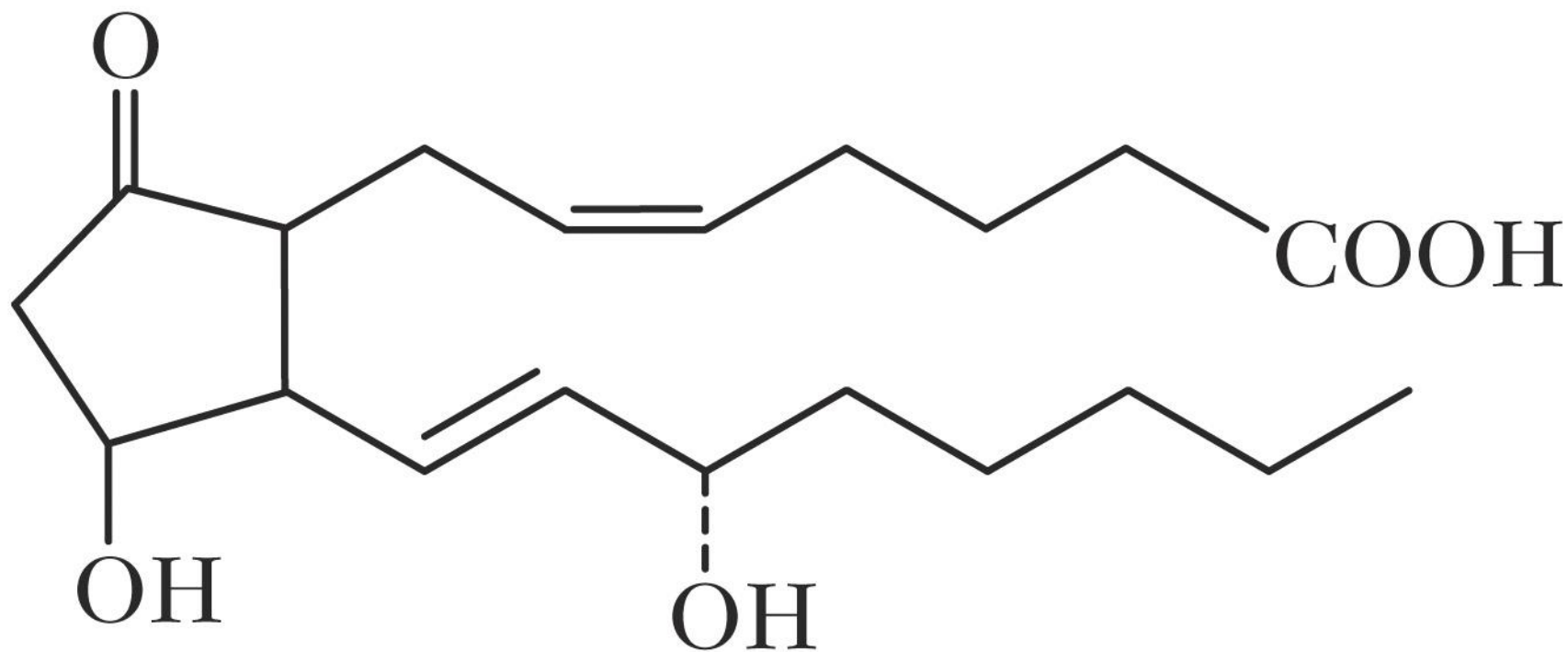
(b) Endocrine glands



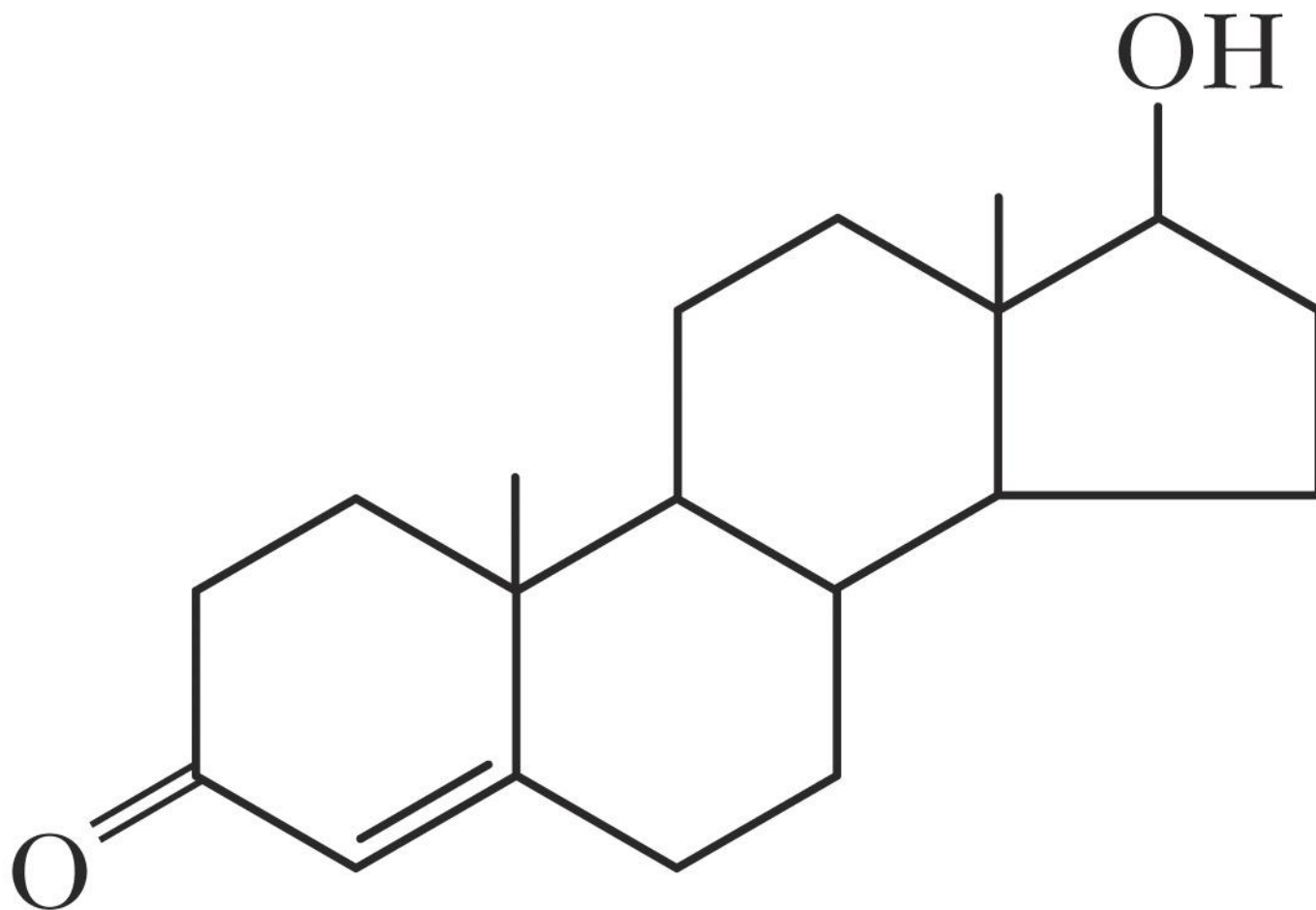
	1	2
Experimental groups	 <p>Normal cock</p>	 <p>Castrated cock</p>
Treatment	 <p>Both testes removed</p>	 <p>One testis replaced</p>
Results	 <p>Comb and wattles small</p> <p>No interest in hens</p> <p>Weak crow</p> <p>Listless fight behavior</p>	 <p>Comb and wattles normal</p> <p>Interest in hens</p> <p>Normal crow</p> <p>Aggressive fight behavior</p> <p>Testis larger than in controls</p>



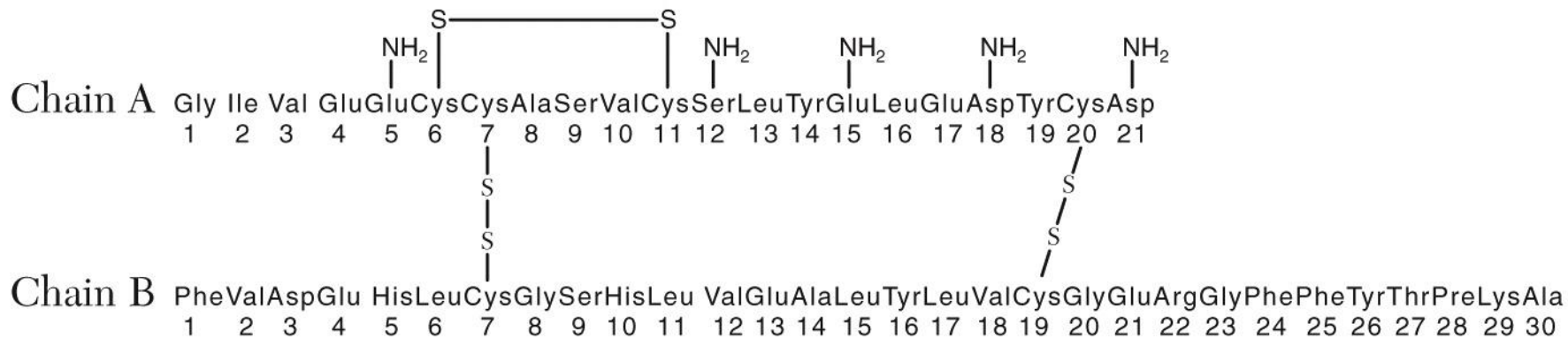
Epinephrine
(an amine)



Prostaglandin PGE₂
(an eicosanoid)



Testosterone
(a steroid)



Insulin (bovine)
(a peptide)

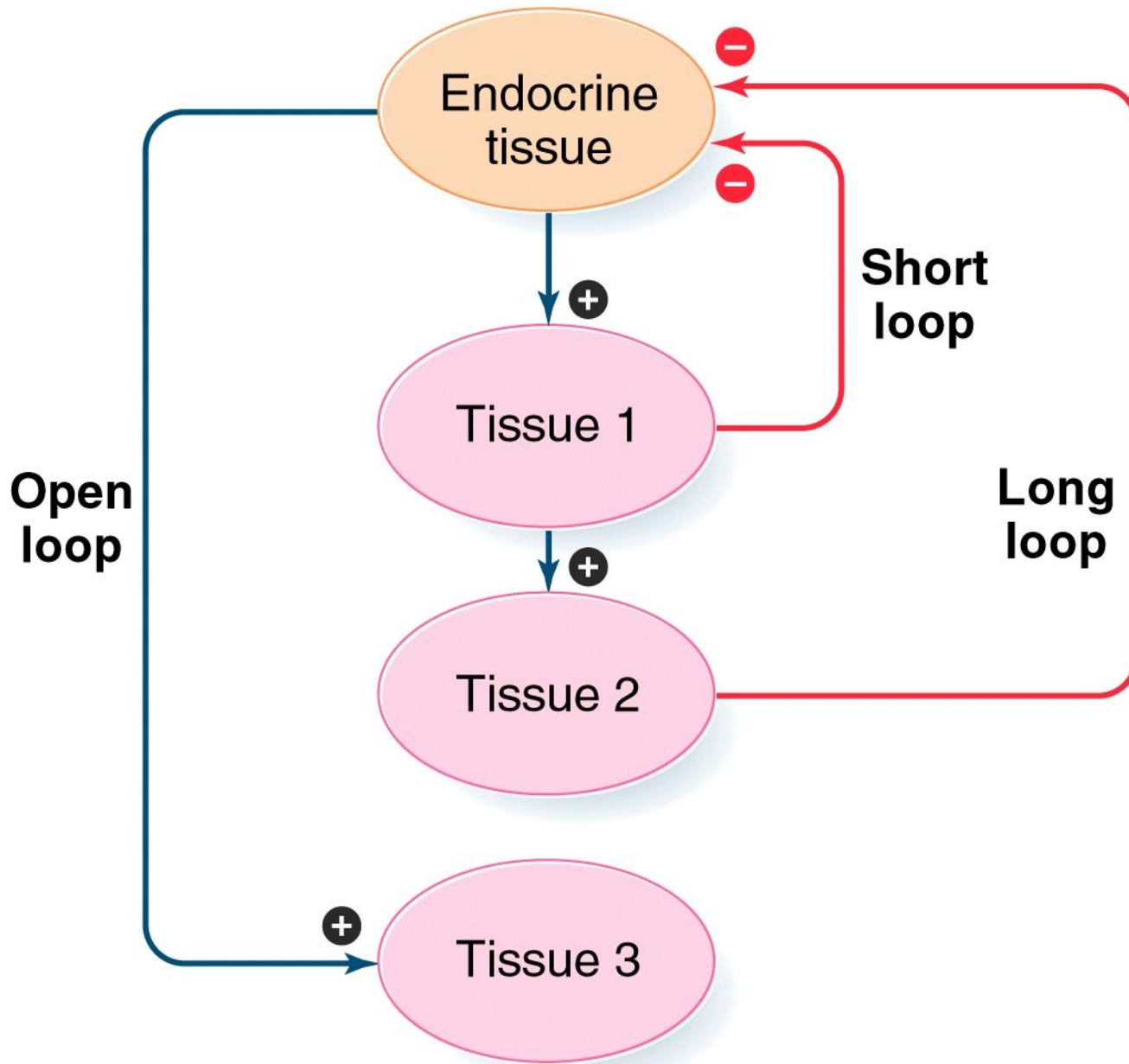


Table 9-1a Vertebrate endocrine glands and tissues

Gland/source	Hormone	Major physiological role*	
Adrenal gland	Steroidogenic tissue (cortex)	Aldosterone Cortisol and corticosterone	↑ Sodium retention ↑ Carbohydrate metabolism and sympathetic function
	Chromaffin tissue (medulla)	Epinephrine and norepinephrine	Multiple ↑ and ↓ effects on nerves, muscles, cellular secretions, and metabolism
Gastrointestinal tract	Cholecystokinin	↑ Secretion of enzymes by pancreatic acinar cell; ↑ gall-bladder contraction	
	Chymodenin	↑ Secretion of chymotrypsinogen from the exocrine pancreas	
	Gastric inhibitory peptide	↓ Gastric acid (HCl) secretion	
	Gastrin	↑ Gastric acid (HCl) secretion	
	Gastrin-releasing peptide	↑ Gastrin secretion; ↓ gastric acid (HCl) secretion	
	Motilin	↑ Gastric acid secretion and motility of intestinal villi	
	Neurotensin	Enteric neurotransmitter	
	Secretin	↑ Bicarbonate secretion by pancreatic acinar cells	
	Substance P	Enteric neurotransmitter	
Vasoactive intestinal peptide	↑ Intestinal secretion of electrolytes		

(continued on the next page)

GASTRIN-releasing peptide increases Gastric acid and HCl production

<https://step1.medbullets.com/gastrointestinal/106036/gastric-secretion>

Table 9-1b Vertebrate endocrine glands and tissues

Gland/source	Hormone	Major physiological role*
Heart (atrium)	Atrial natriuretic peptide (ANP)	↑ Salt and water excretion by kidney
Kidney	Calcitriol†	↑ Blood Ca^{2+} , bone formation, and intestinal absorption of Ca^{2+} and PO_4^{2-3}
	Erythropoietin (erythrocyte-stimulating factor)	↑ Production of red blood cells (erythropoiesis)
	Renin	↑ Conversion of angiotensinogen to angiotensin II
Ovary		
Preluteal follicle	Estradiol	↑ Female sexual development and behavior
	Estrogen	↑ Estrus and female secondary sexual characteristics; prepares reproductive system for fertilization and ovum implantation
Corpus luteum	Progesterone	↑ Growth of uterine lining and mammary glands, and maternal behavior
	Relaxin	↑ Relaxation of pubic symphysis and dilation of uterine cervix

(continued on the next page)

Table 9-1c Vertebrate endocrine glands and tissues

Gland/source	Hormone	Major physiological role*
Pancreas (islets of Langerhans)	Glucagon	↑ Blood glucose, gluconeogenesis, and glycogenolysis
	Insulin	↓ Blood glucose; ↑ protein, glycogen, and fat synthesis
	Pancreatic polypeptide	↑ ↓ Secretion of other pancreatic islet hormones
	Somatostatin	↓ Secretion of other pancreatic islets hormones
Parathyroid glands	Parathormone	↑ Blood Ca^{2+} ; ↓ blood PO_4^{-3}
Pineal (epiphysis)	Melatonin	↓ Gonadal development (antigonadotropic action)
Pituitary gland	See Table 9-2, 9-3	
Placenta	Chorionic gonadotropin (CG, choriogonadotropin)	↑ Progesterone synthesis by corpus luteum
	Placental lactogen	↑ Fetal growth and development (possibly); ↑ Mammary gland development in the mother
Plasma angiotensinogen‡	Angiotensin II	↑ Vasoconstriction and aldosterone secretion; ↑ Thirst and fluid ingestion (dipsogenic behavior)
Testes		
Leydig cells	Testosterone	↑ Male sexual development and behavior
Sertoli cells	Inhibin	↓ Pituitary FSH secretion
	Müllerian regression factor	↑ Müllerian duct regression (atrophy)

(continued on the next page)

Table 9-1d Vertebrate endocrine glands and tissues

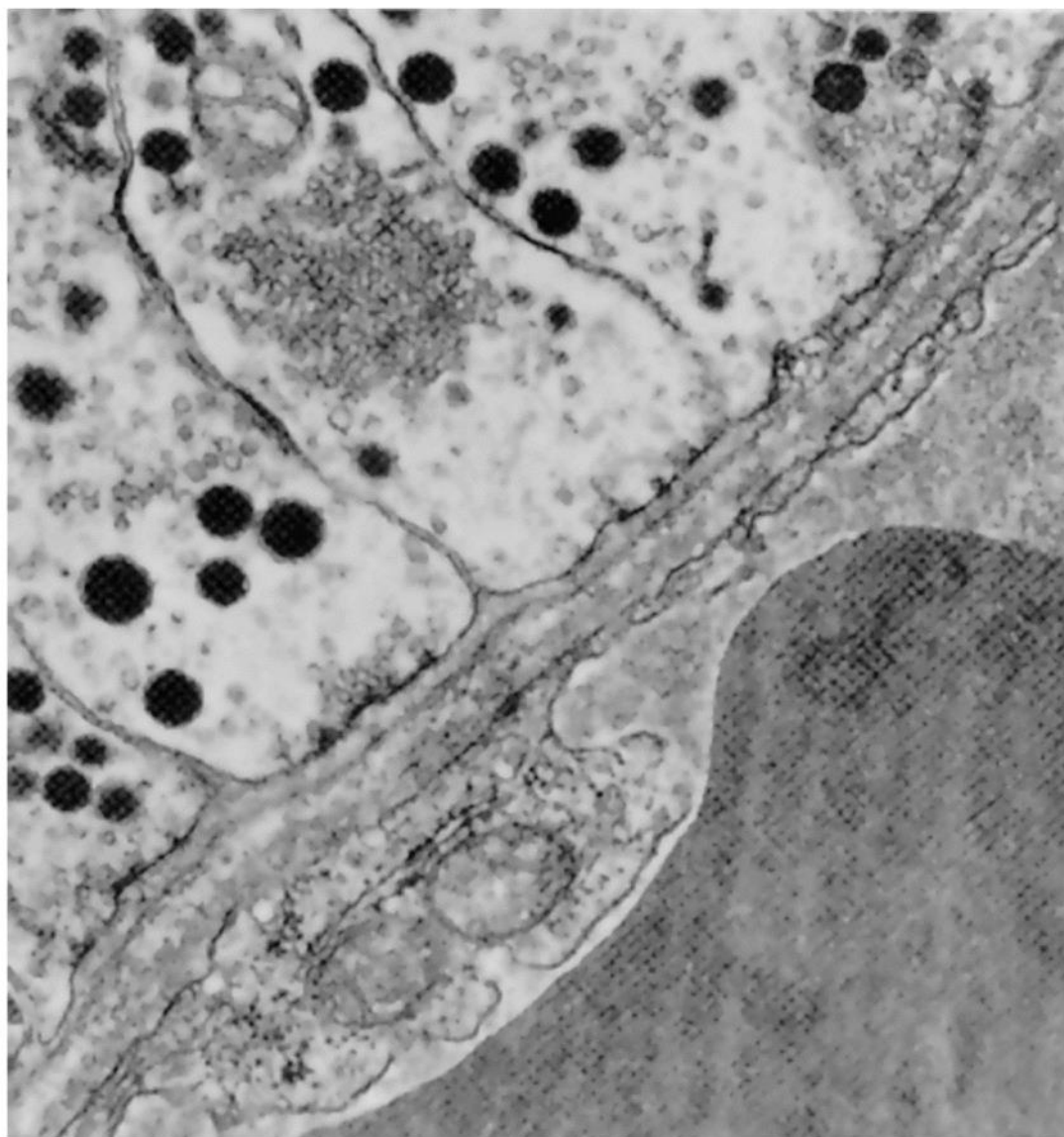
Gland/source	Hormone	Major physiological role*
Thymus gland	Thymic hormones	↑ Proliferation and differentiation of lymphocytes
Thyroid gland		
Follicular cells	Thyroxine and triiodothyronine	↑ Growth and differentiation; ↑ metabolic rate and oxygen consumption (calorigenesis)
Parafollicular cells (or ultimobranchial glands)	Calcitonin	↓ Blood Ca ²⁺
Most or all tissues	Leukotrienes	↑ ↓ Cyclic nucleotide formation
	Prostacyclins	↑ Cyclic nucleotide (cAMP) formation
	Prostaglandins	↑ Cyclic nucleotide (cAMP) formation
	Thromboxanes	↑ Cyclic nucleotide (cGMP?) formation
Selected tissues	Endorphins	Opiate-like activity
	Epidermal growth factor	↑ Epidermal cell proliferation
	Fibroblast growth factor	↑ Fibroblast proliferation
	Nerve growth factor	↑ Neurite development
	Somatomedins	↑ Cellular growth and proliferation

* ↑ means hormone stimulates or increases indicated effect; ↓ means hormone inhibits or decreases indicated effect.

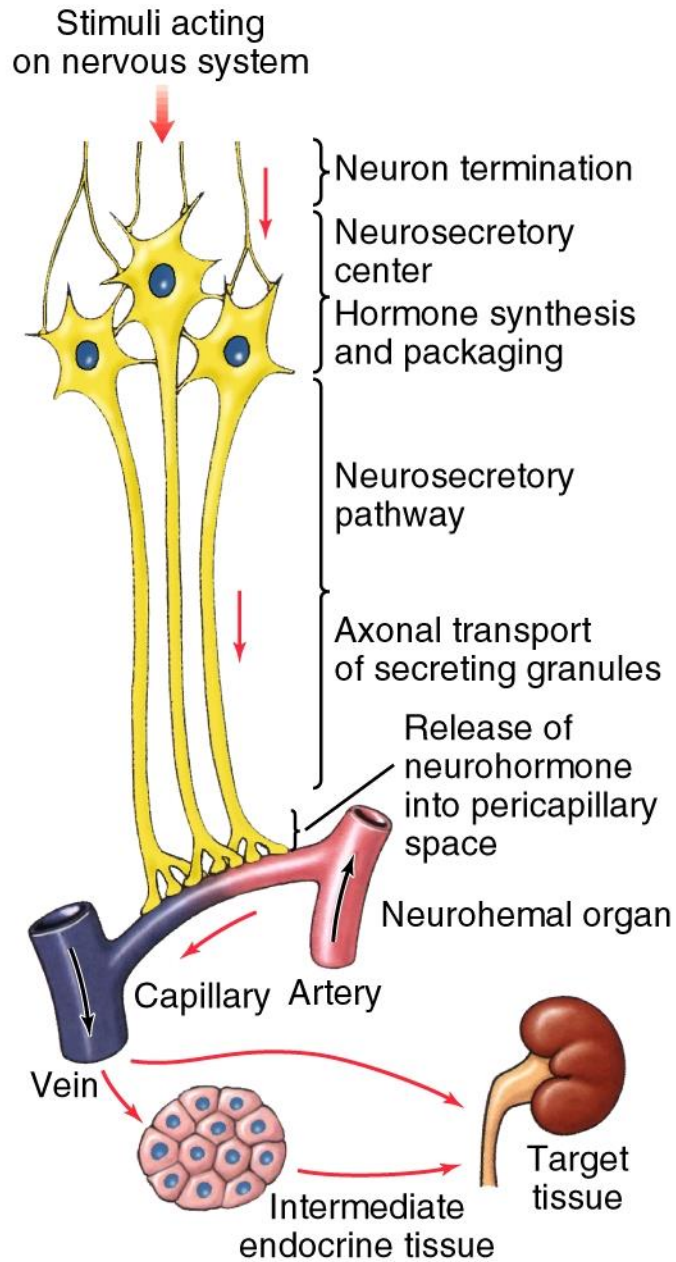
† The final steps in synthesis of calcitriol from vitamin D₃ occur in the kidney, but the skin and liver also play a role in its synthesis.

‡ Angiotensinogen is produced in the liver and circulates in the bloodstream, where it is cleaved by renin to form the active hormone angiotensin II.

Source: Adapted from Hadley, 2000.



2 μm



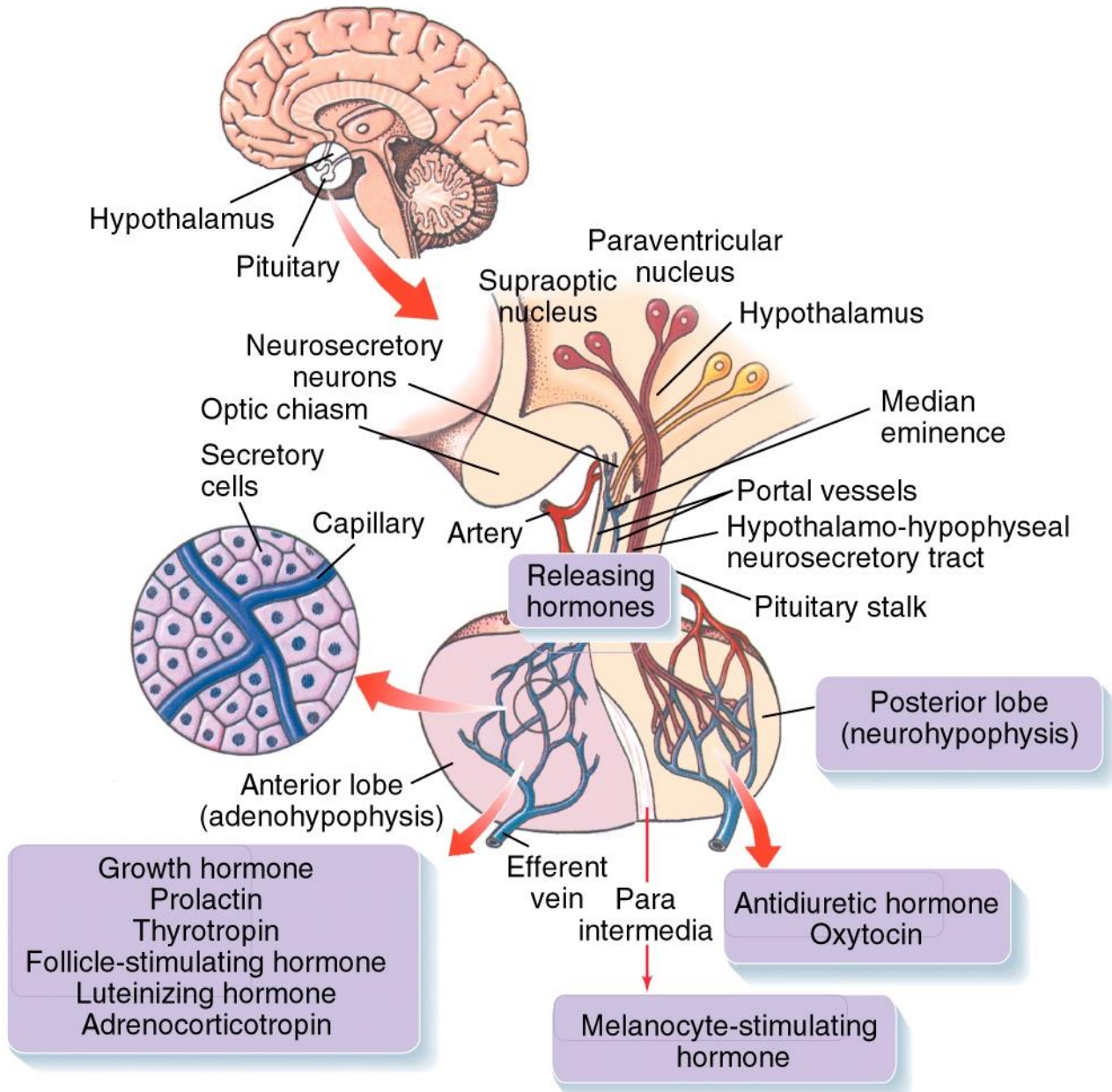


Table 9-2 Hypothalamic neurohormones that stimulate or inhibit release of adenohypophyseal hormones

Hormone	Structure	Primary action in mammals	Regulation*
Stimulatory			
Corticotropin-releasing hormone (CRH)	Peptide	Stimulates ACTH release	Stressful neuronal input increases secretion; ACTH inhibits secretion
GH-releasing hormone (GRH)	Peptide	Stimulates GH release	Hypoglycemia stimulates secretion
Gonadotropin-releasing hormone (GnRH)	Peptide	Stimulates release of FSH and LH	In male, low blood testosterone levels stimulate secretion; in female, neuronal input and decreased estrogen levels stimulate secretion; high blood FSH or LH inhibits secretion
TSH-releasing hormone (TRH)	Peptide	Stimulates TSH release and prolactin release	Low body temperatures induce secretion; thyroid hormone inhibits secretion
Inhibitory			
MSH-inhibiting hormone (MIH)	Peptide	Inhibits MSH release	Melatonin stimulates secretion
Prolactin-inhibiting hormone (PIH)	Amine	Inhibits prolactin release	High levels of prolactin increase secretion; estrogen, testosterone, and neuronal stimuli (suckling) inhibit secretion
Somatostatin (GH-inhibiting hormone, GIH)	Peptide	Inhibits release of GH and many other hormones (e.g., TSH, insulin, glucagon)	Exercise induces secretion; hormone is rapidly inactivated in body tissues

*ACTH = adrenocorticotrophic hormone; FSH = follicle-stimulating hormone; GH = growth hormone; LH = luteinizing hormone; MSH = melanocyte-stimulating hormone; TSH = thyroid-stimulating hormone.

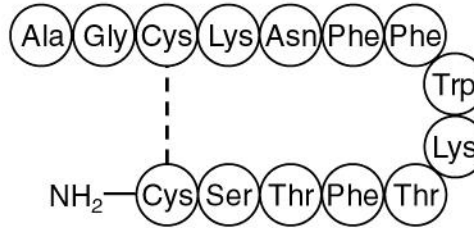
TSH-releasing hormone



Gonadotropin-releasing hormone



Somatostatin



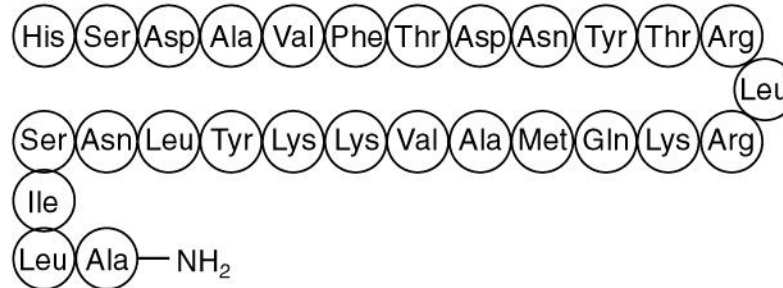
Leu-enkephalin



Substance P



Vasoactive intestinal peptide



Cholecystokinin (brain)



Table 9-3 Tropic hormones of the anterior pituitary gland

Hormone	Structure	Target tissue	Primary action in mammals	Regulation*
Adrenocorticotrophic hormone (ACTH)	Peptide	Adrenal cortex	Increases synthesis and secretion of steroid hormones by adrenal cortex	Cortical-releasing hormone (CRH) stimulates release; ACTH slows release of CRH
Follicle-stimulating hormone (FSH)	Glycoprotein	Ovarian follicles (female); seminiferous tubules (male)	In female, stimulates maturation of ovarian follicles; in male, increases sperm production	GnRH stimulates release; inhibin and steroid sex hormones inhibit release
Luteinizing hormone (LH)	Glycoprotein	Ovarian interstitial cells (female); testicular interstitial cells (male)	In female, induces final maturation of ovarian follicles, estrogen secretion, ovulation, corpus luteum formation, and progesterone secretion; in male, increases synthesis and secretion of androgens	GnRH stimulates release; inhibin and steroid sex hormones inhibit release
Thyroid-stimulating hormone (TSH)	Glycoprotein	Thyroid gland	Increases synthesis and secretion of thyroid hormones	TRH induces secretion; thyroid hormones and somatostatin slow release

*See Table 9-2 for key to abbreviations.

Neural stimuli:
stress

Neural stimuli:
suckling and
parturition

Increased
plasma
osmolarity

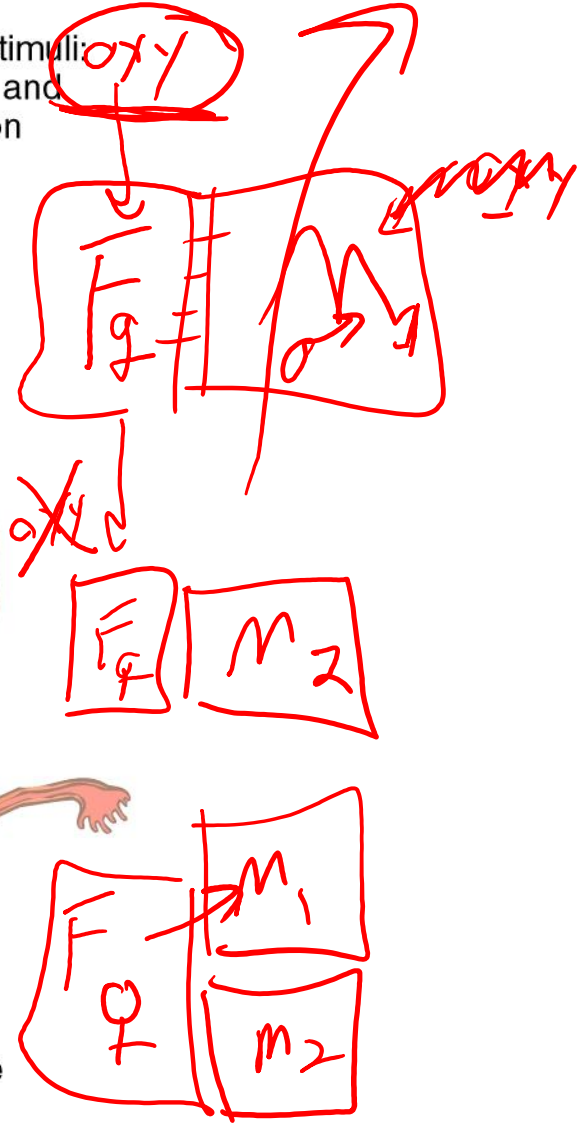
Oxytocin

ADH

MAMMARY GLANDS
Milk ejection

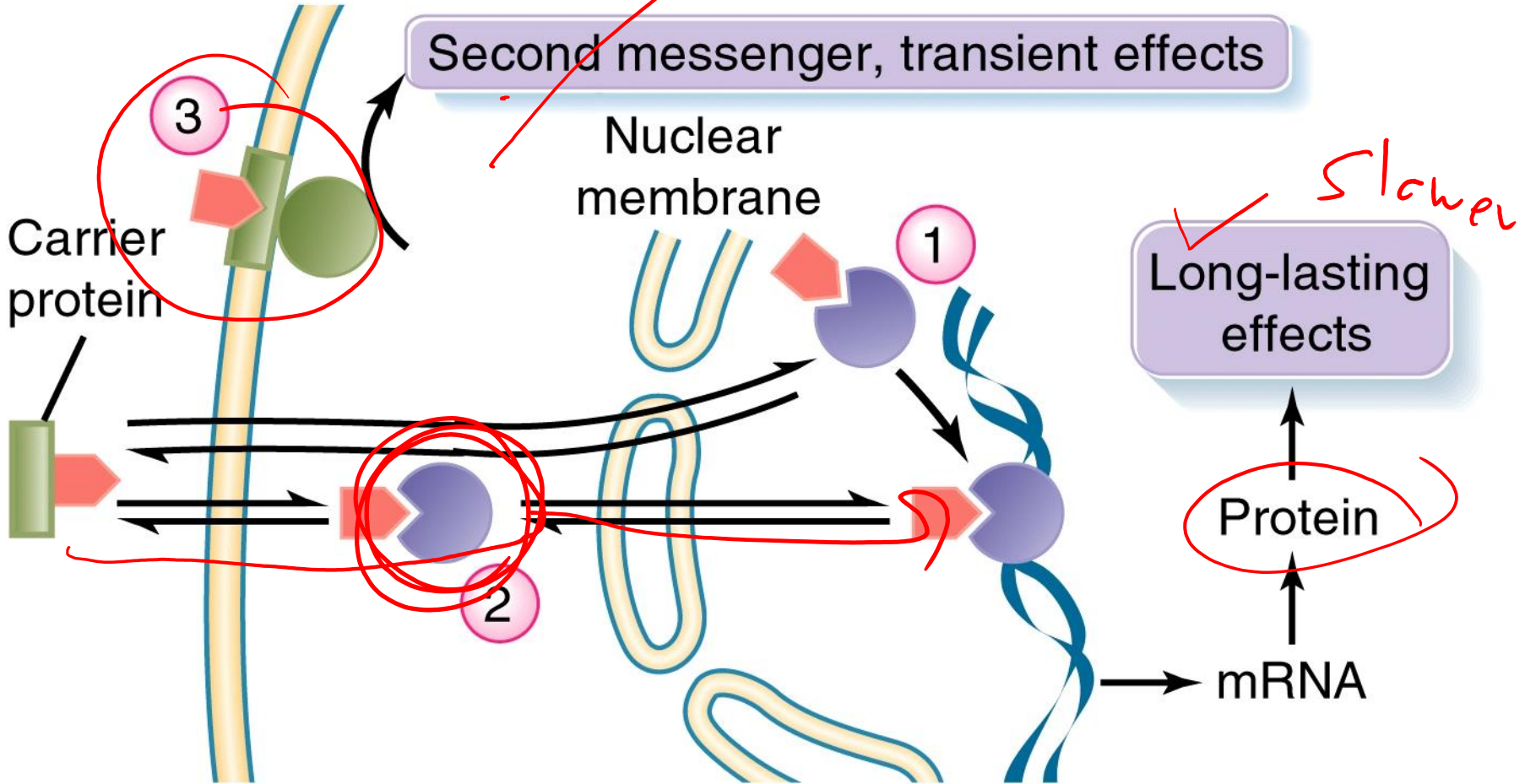
KIDNEY
Increased renal
tubular resorption
of water

UTERUS
Smooth muscle
contractions
during and after
childbirth



(a) Lipid-soluble hormone

Fast



Second messenger, transient effects

Nuclear membrane

Long-lasting effects

Protein

mRNA

Carrier protein

3

1

2

(b) Lipid-insoluble hormone

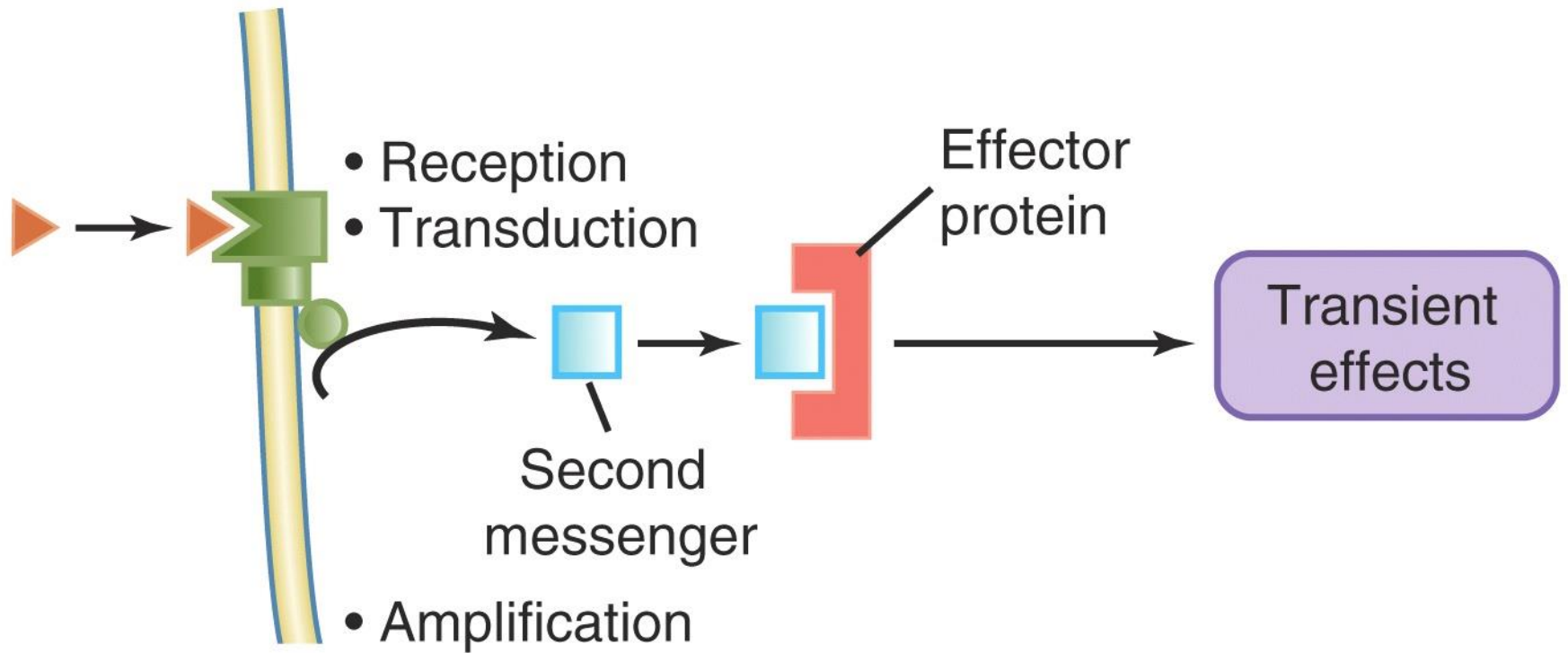
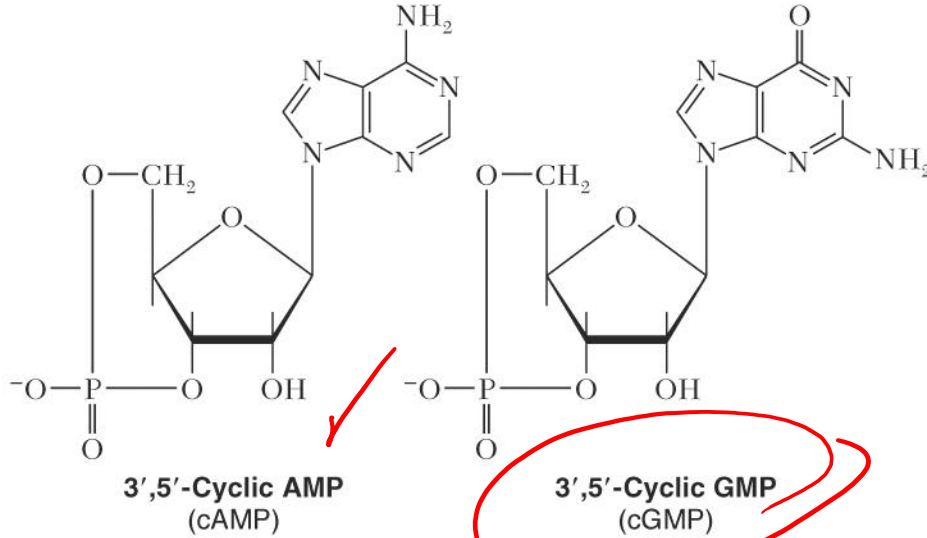


Table 9-5 Comparison of lipid-soluble and lipid-insoluble hormones

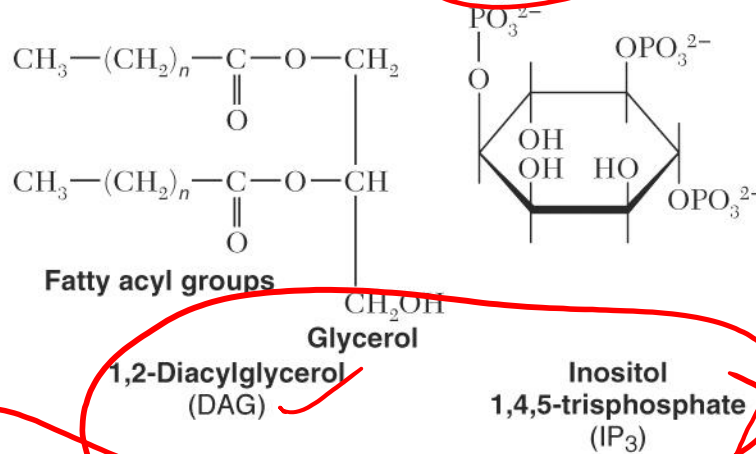
Property	Lipid-soluble		Lipid-insoluble	
	Steroids	Thyroid hormones	Peptides and proteins	Catecholamines
Feedback regulation of synthesis	Yes	Yes	Yes	Yes
Binding to carrier proteins	Yes	Yes	Rarely	No
Lifetime in blood plasma	Hours	Days	Minutes	Seconds
Time course of action	Hours to days	Days	Minutes to hours	Seconds or less
Receptor location	Cytosolic or nuclear	Nuclear	Plasma membrane	Plasma membrane
Mechanism of action	Receptor-hormone complex stimulates or inhibits gene expression		Hormone binding triggers second-messenger or activates intrinsic catalytic activity	Hormone binding causes change in membrane potential or triggers second-messenger pathway

Source: Adapted from Smith et al., 1983, p. 358. Used with permission of McGraw-Hill.

CYCLIC NUCLEOTIDES



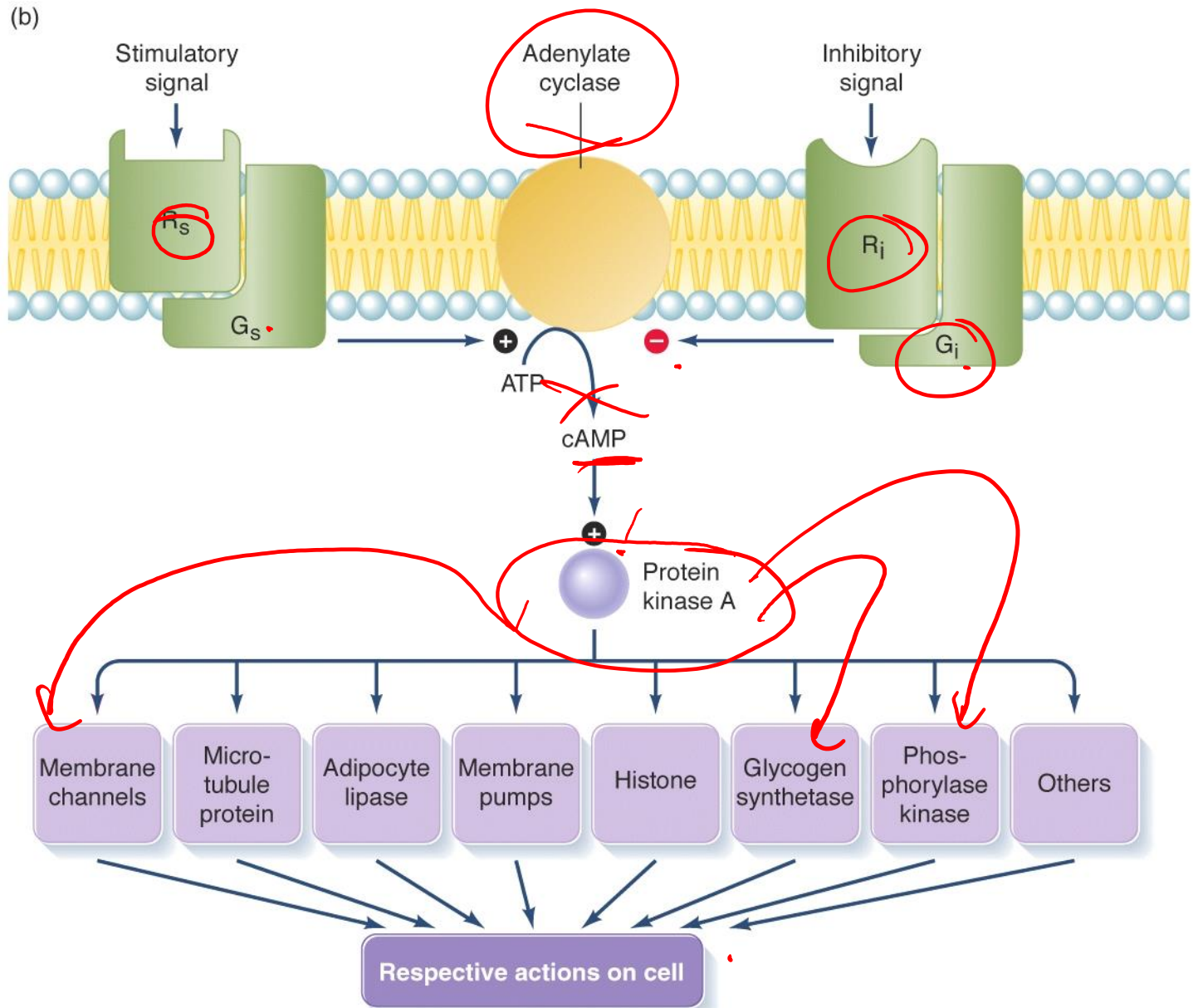
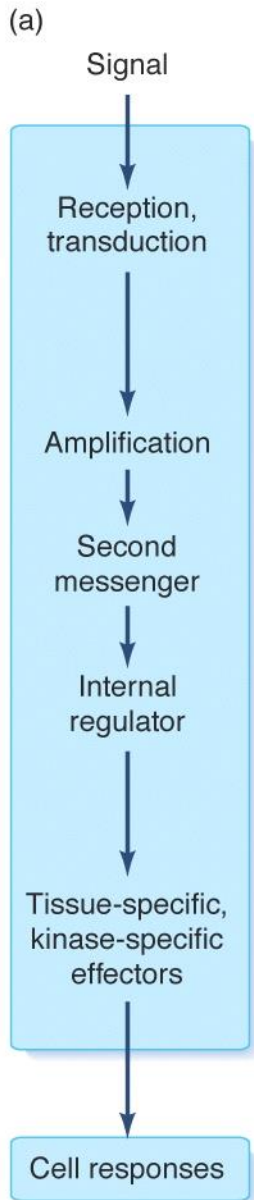
INOSITOL PHOSPHOLIPIDS



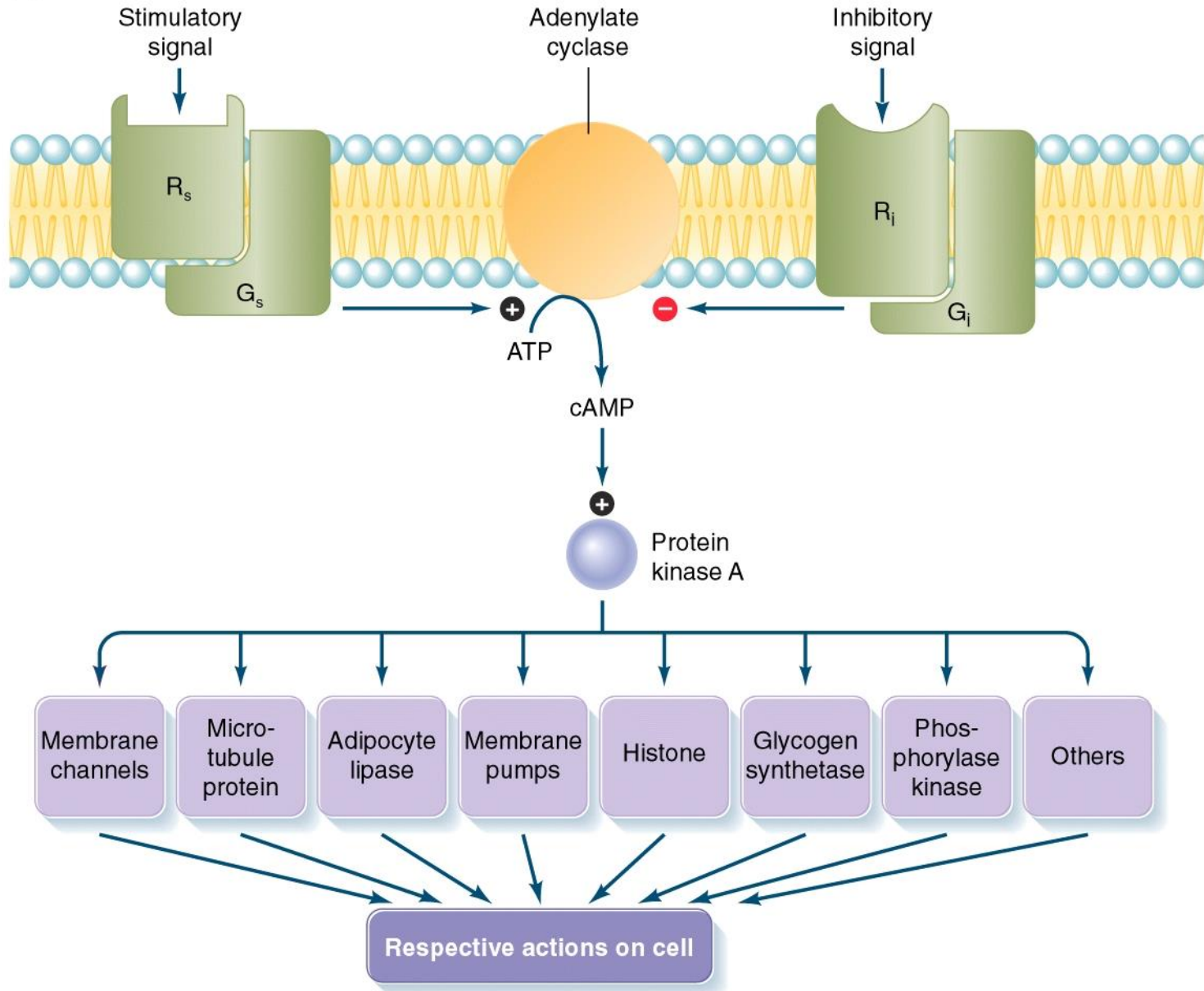
CALCIUM ION

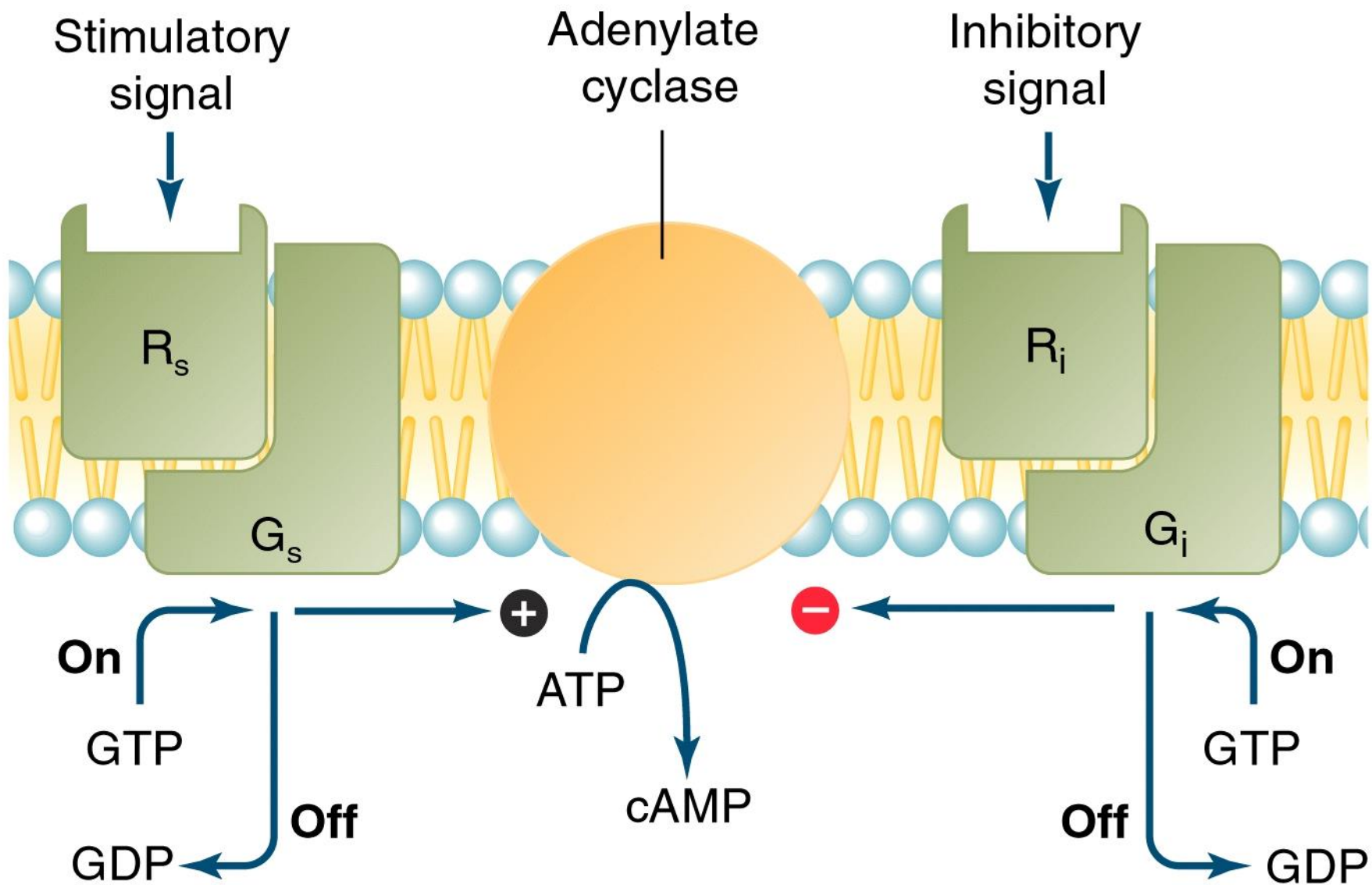


~~ATP~~
IP₃
cytoplasm



(b)





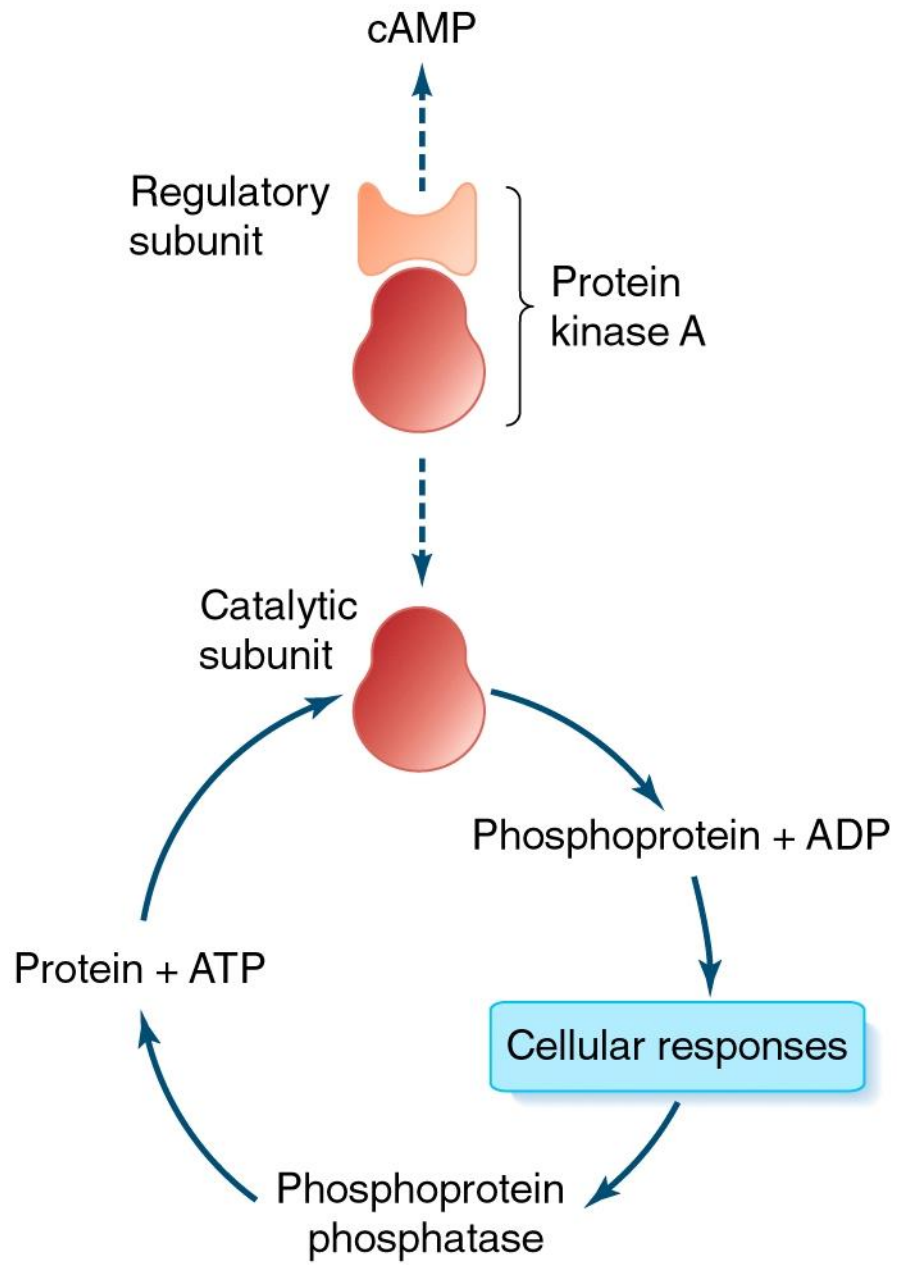
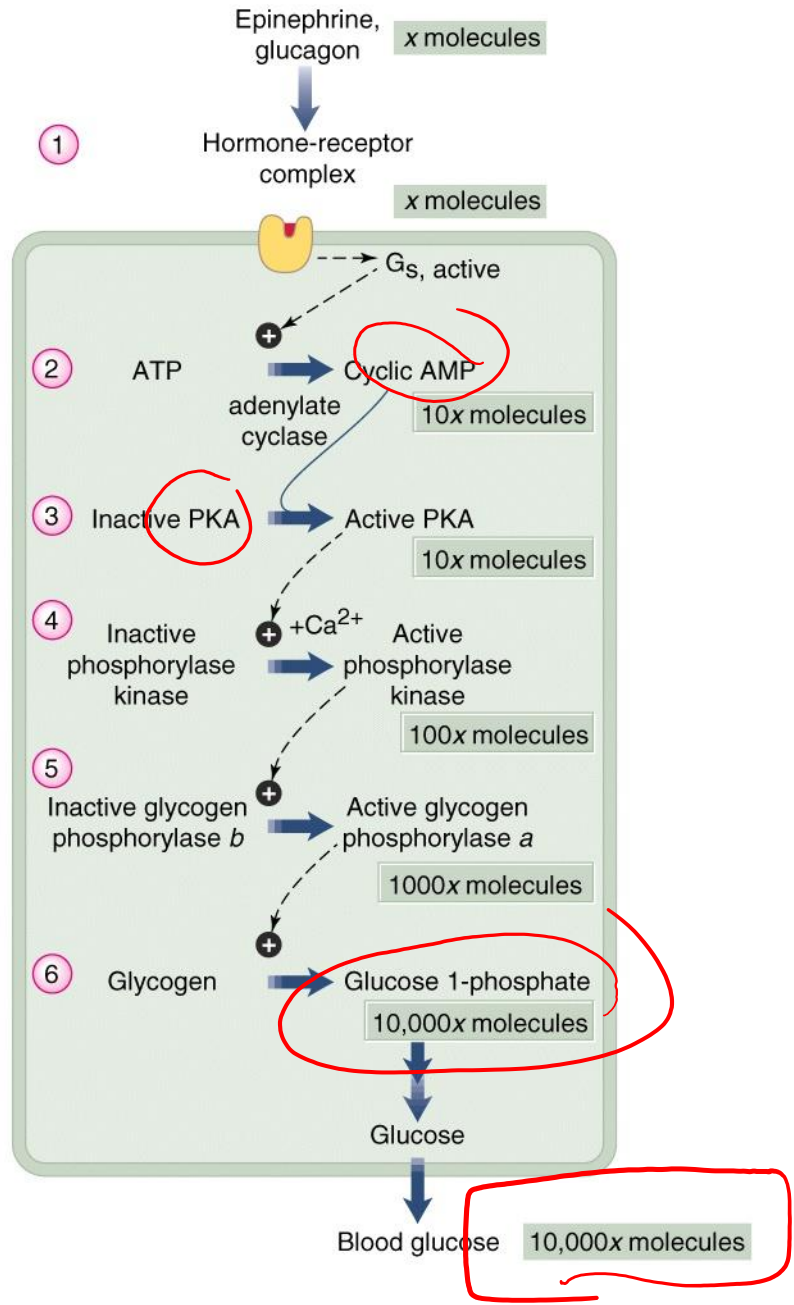
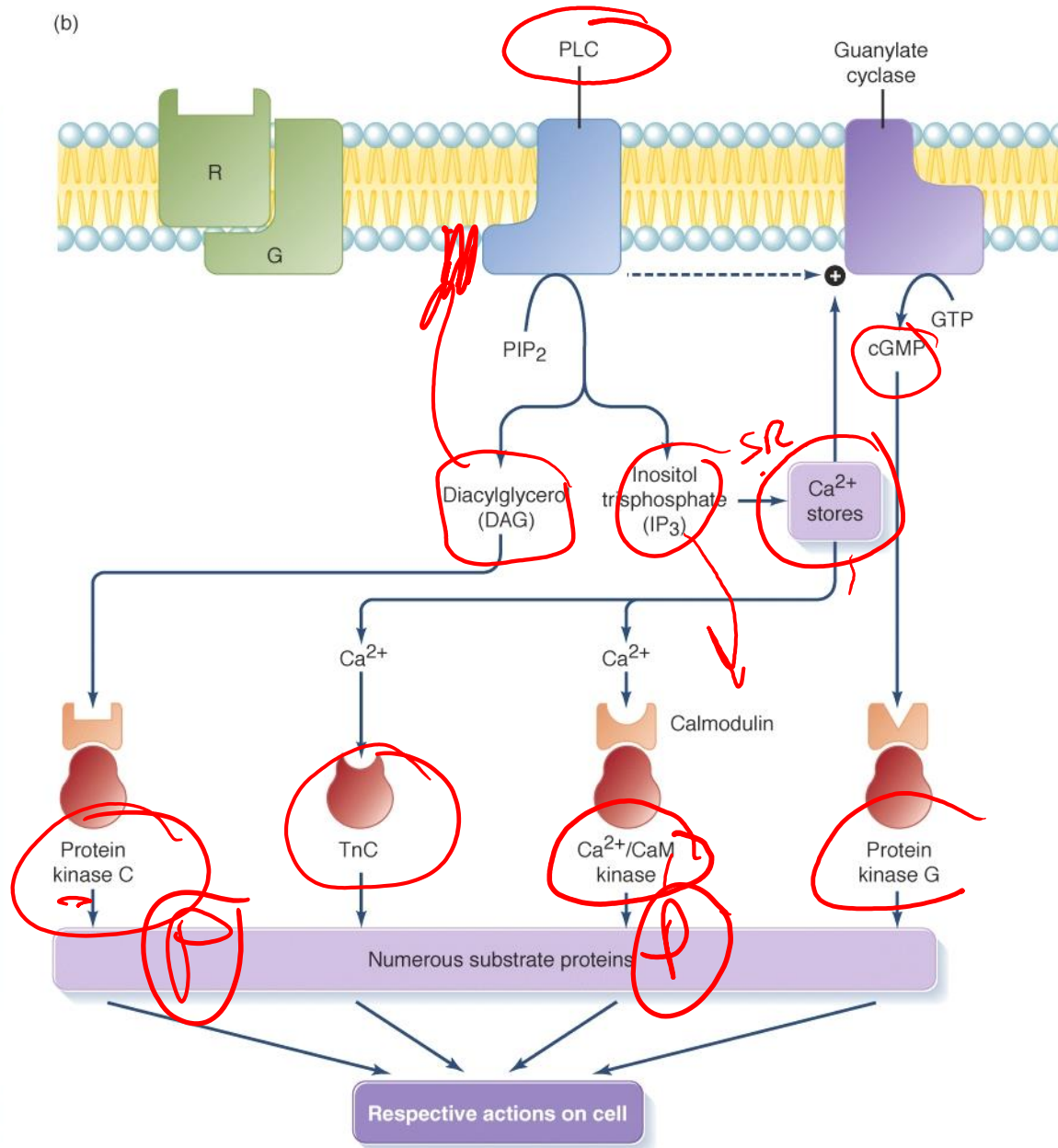
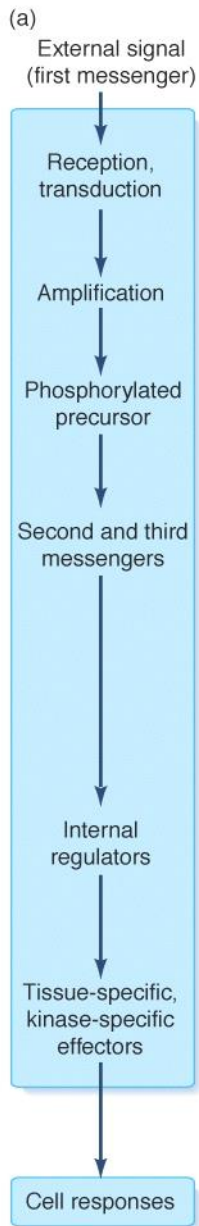


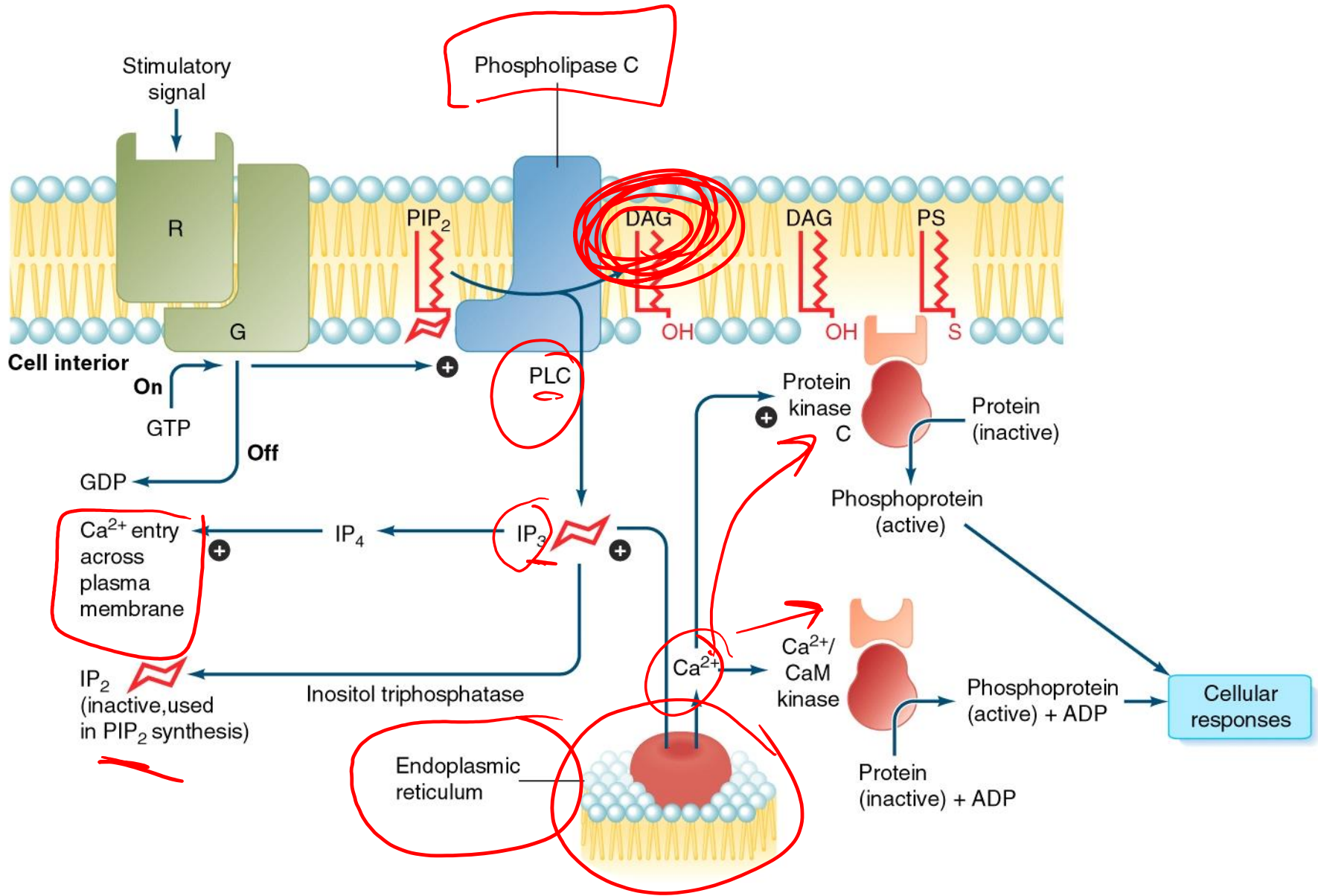
Table 9-6 Some hormone-induced responses mediated by the cAMP pathway

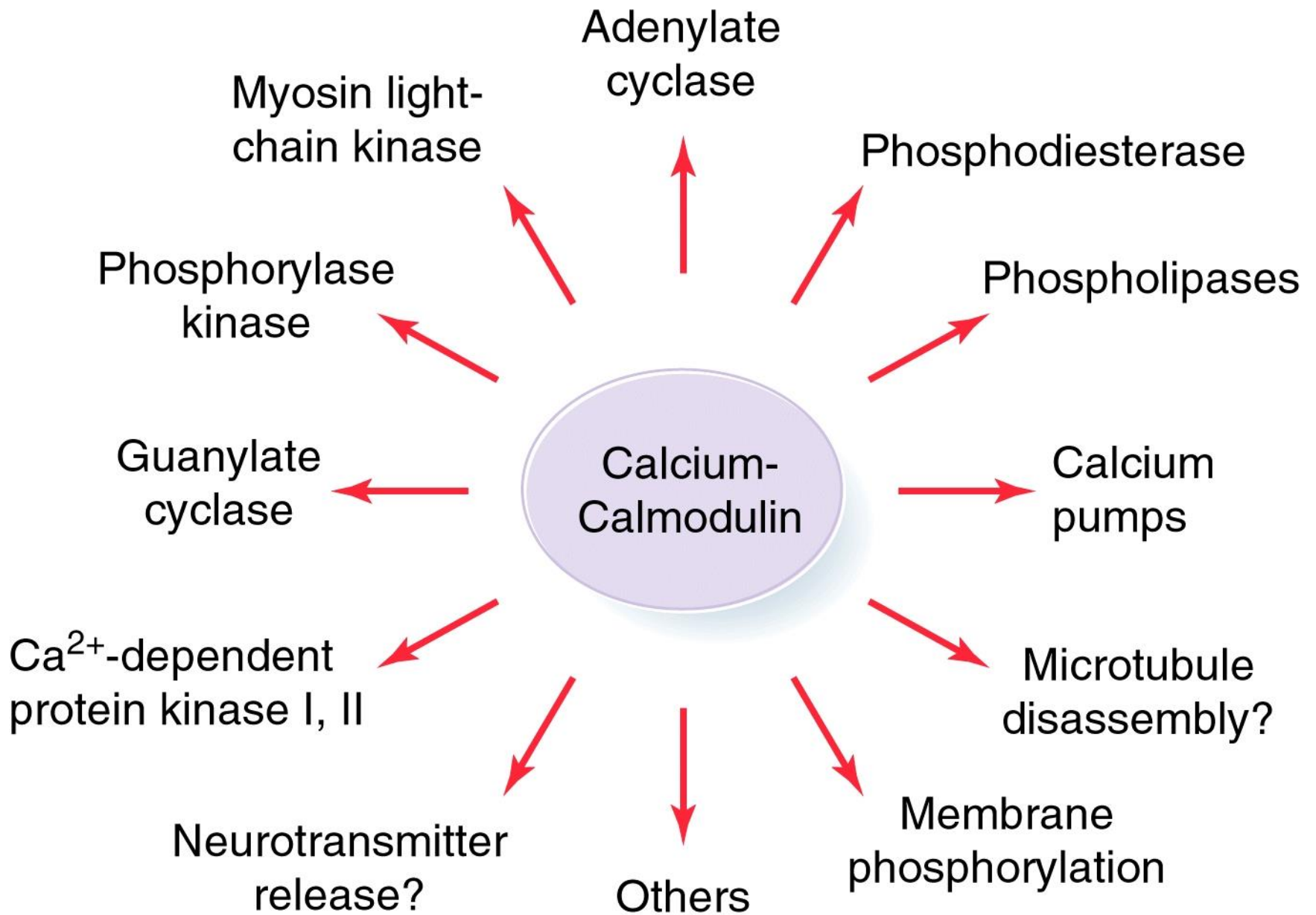
Signal	Tissue	Cellular response
Stimulatory		
Epinephrine (β -adrenoreceptors)	Skeletal muscle	Breakdown of glycogen
	Fat cells	Increased breakdown of lipids
	Heart	Increased heart rate and force of contraction
	Intestine	Fluid secretion
	Smooth muscle	Relaxation
Thyroid-stimulating hormone (TSH)	Thyroid gland	Thyroxine secretion
ADH (vasopressin)	Kidney	Reabsorption of water
Glucagon	Liver	Breakdown of glycogen
Serotonin	Salivary gland (blowfly)	Fluid secretion
Prostaglandin I ₂	Blood platelets	Inhibition of aggregation and secretion
Inhibitory		
Epinephrine (α_2 -adrenoreceptors)	Blood platelets	Stimulation of aggregation and secretion
	Fat cells	Decreased lipid breakdown
Adenosine	Fat cells	Decreased lipid breakdown

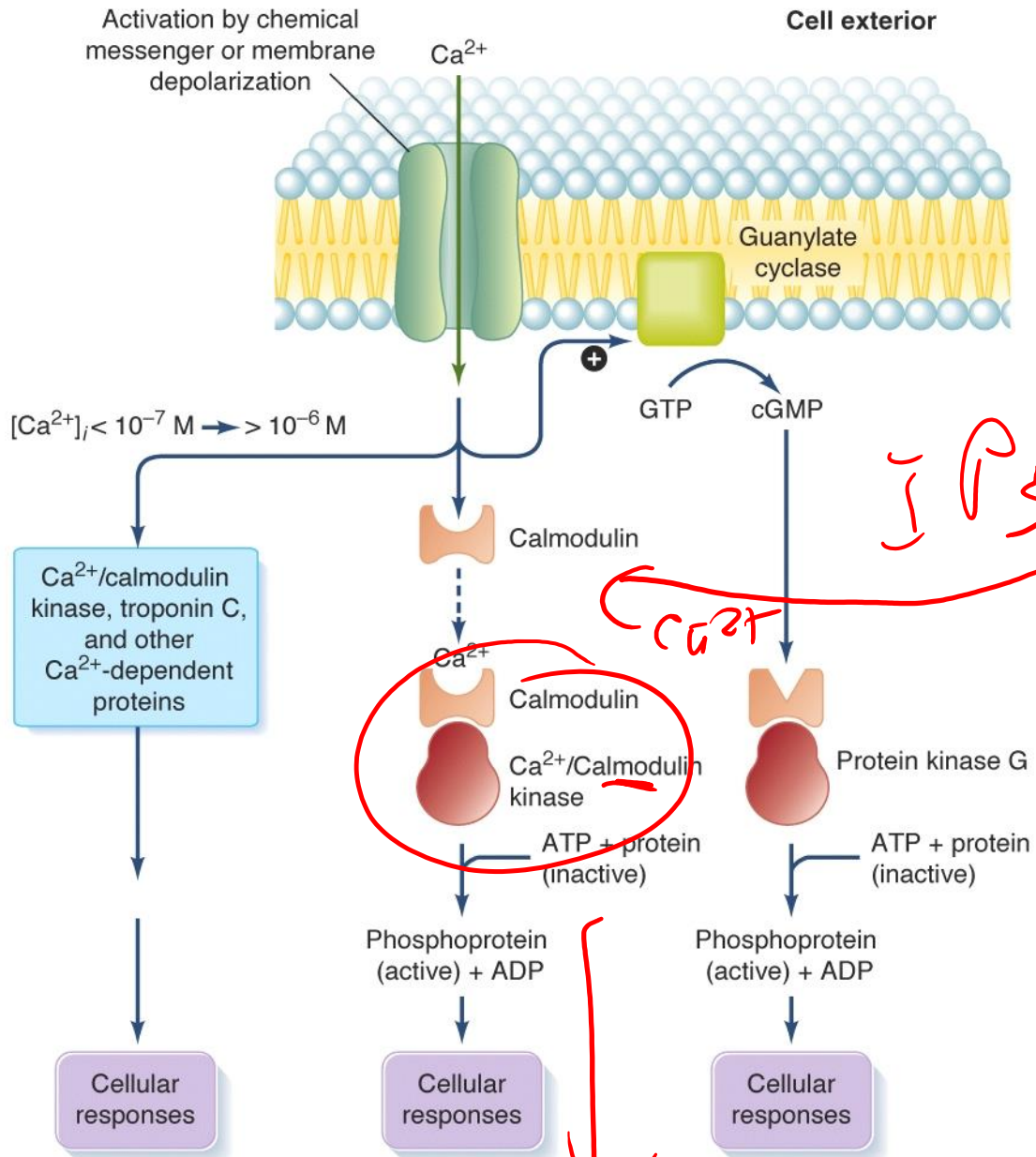
Source: Berridge, 1985.











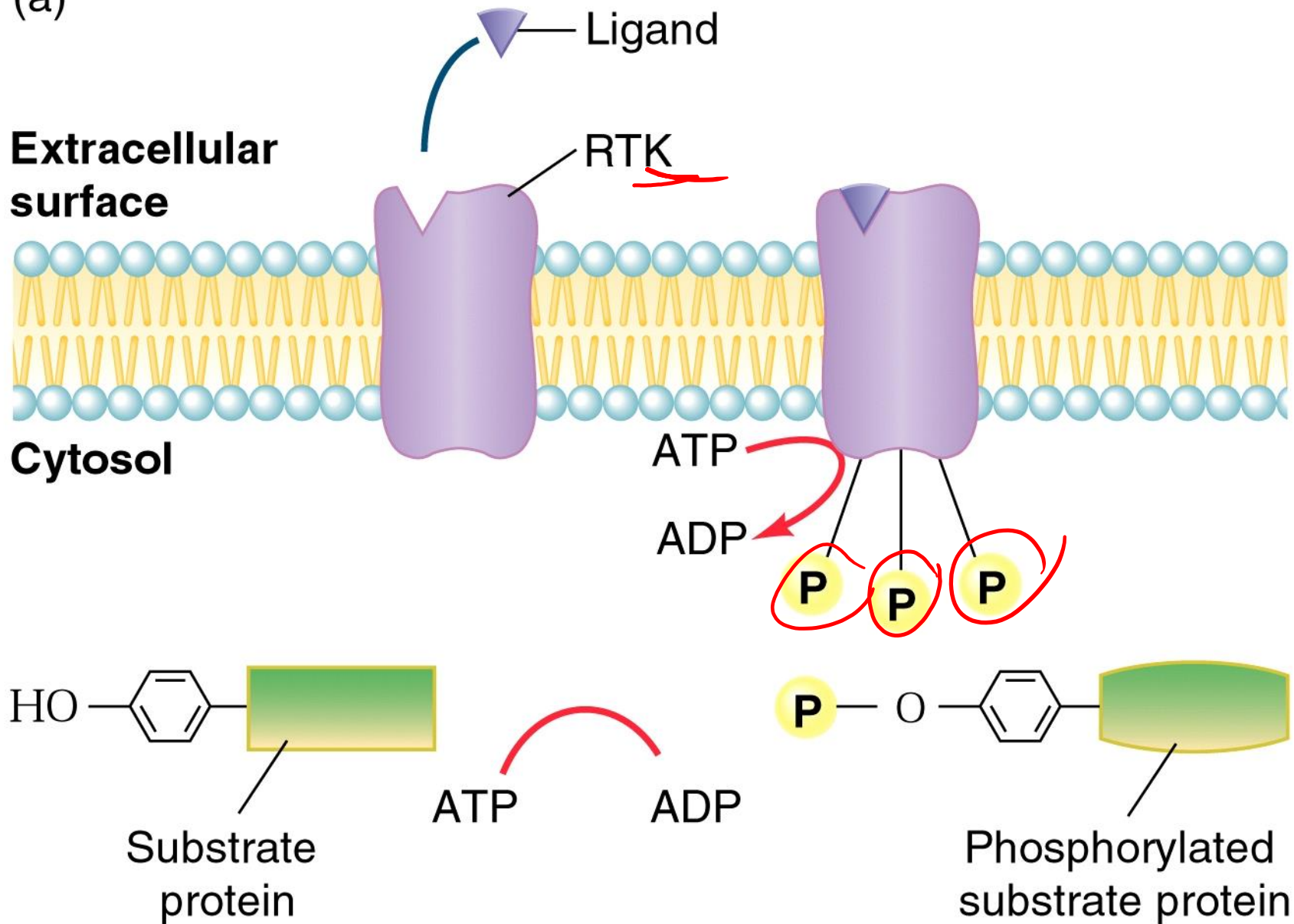
IP3

Ca²⁺

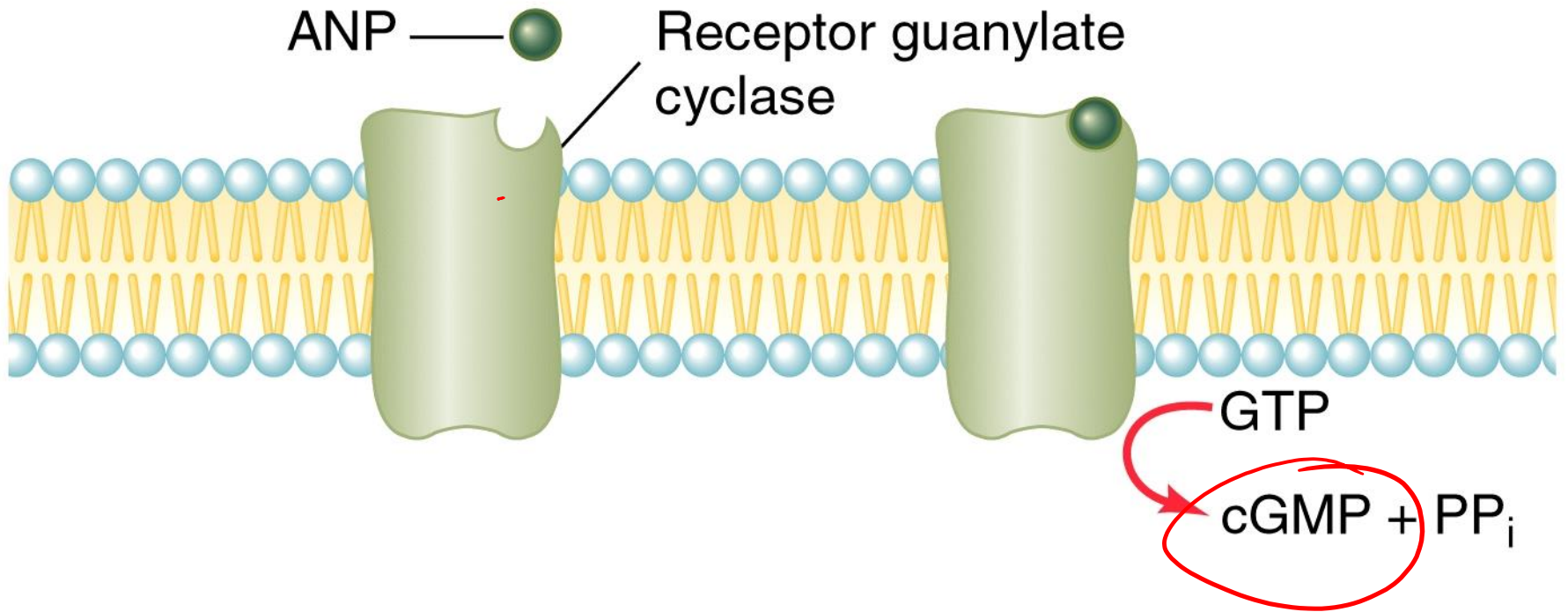
IP3

↓

(a)



(b)



Left Adrenal Gland

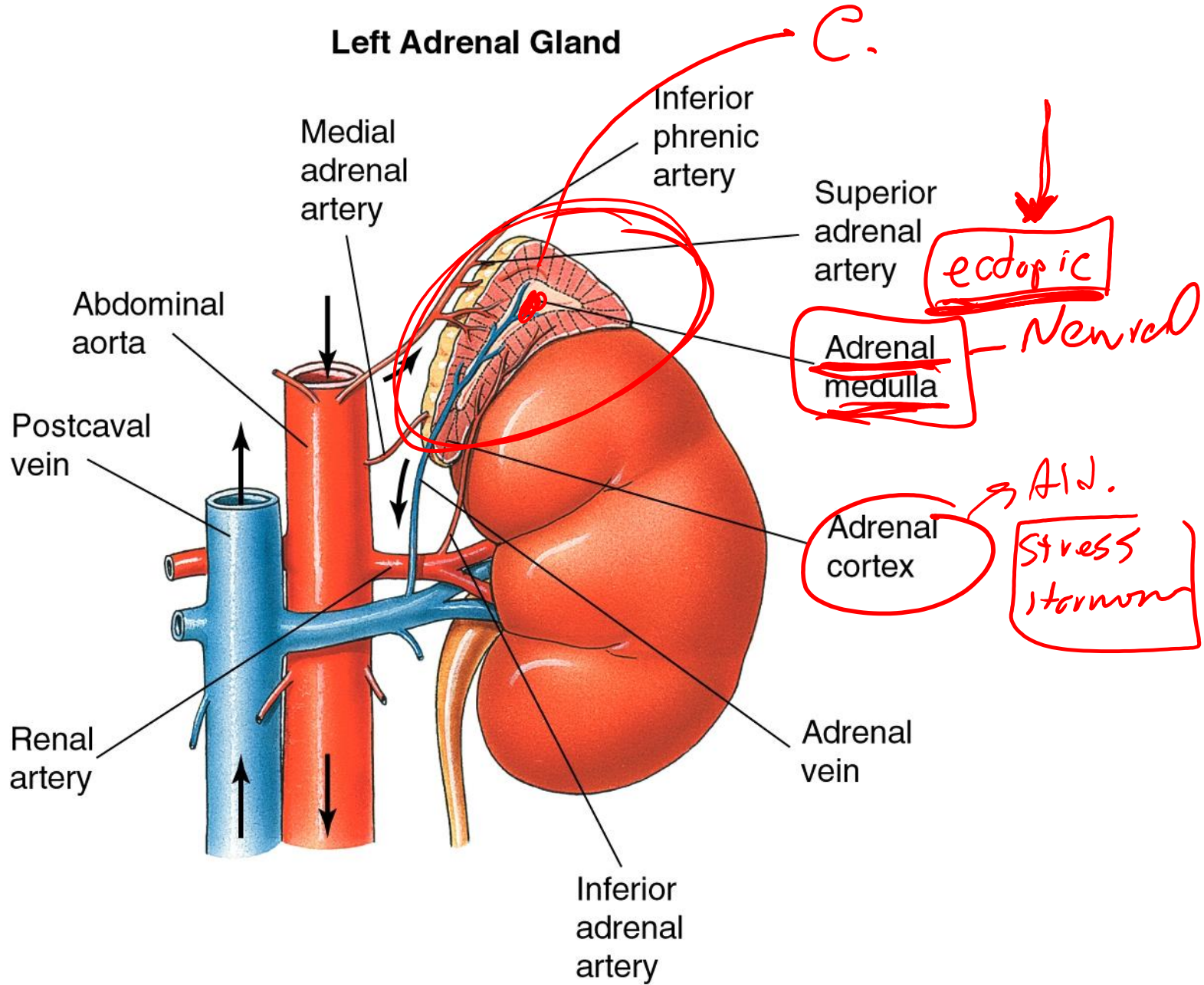


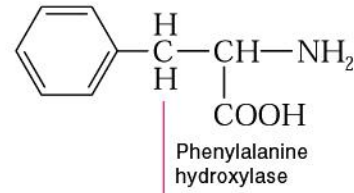
Table 9-7 Metabolic and developmental hormones

Hormone	Tissue of origin	Structure	Target tissue	Primary action	Regulation
Glucagon	Pancreas (alpha cells)	Peptide	Liver, adipose tissue	Stimulates glycogenolysis and release of glucose from liver; promotes lipolysis	Low serum glucose increases secretion; somatostatin inhibits release
Glucocorticoids (e.g., cortisol)	Adrenal cortex	Steroid	Liver, adipose tissue	Stimulate mobilization of amino acids from muscle and gluconeogenesis in liver to raise blood glucose; increase transfer of fatty acids from adipose tissue to liver; exhibit anti-inflammatory action	Physiological stress increases secretion; biological clock via CRH and ACTH controls diurnal changes in secretion
Growth hormone (GH)	Anterior pituitary	Peptide	All tissues	Stimulates RNA synthesis, protein synthesis, and tissue growth; increases transport of glucose and amino acids into cells; increase lipolysis and antibody formation	Reduced plasma glucose and increased plasma amino acid levels stimulate release via GRH; somatostatin inhibits release

Table 9-7 Metabolic and developmental hormones

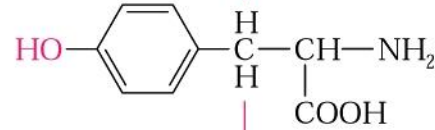
Hormone	Tissue of origin	Structure	Target tissue	Primary action	Regulation
Insulin	Pancreas (beta cells)	Peptide	All tissues except most neuronal tissue	Increases glucose and amino acid uptake by cells	High plasma glucose and amino acid levels and presence of glucagon increase secretion; somatostatin inhibits secretion
Norepinephrine and epinephrine	Adrenal medulla (chromaffin cells)	Catecholamine	Most tissues	Increase cardiac activity; induce vasoconstriction; increase glycolysis, hyperglycemia, and lipolysis	Sympathetic stimulation via splanchnic nerves increases secretion
Thyroxine	Thyroid	Tyrosine derivative	Most cells, but especially those of muscle, heart, liver, and kidney	Increases metabolic rate, thermogenesis, growth, and development; promotes amphibian metamorphosis	TSH induces release

Phenylalanine



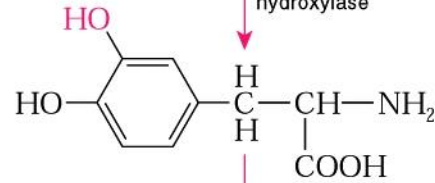
Phenylalanine hydroxylase

Tyrosine



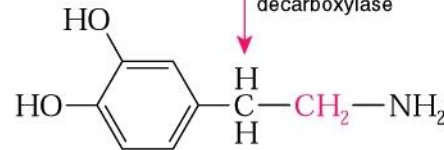
Tyrosine hydroxylase

Dopa



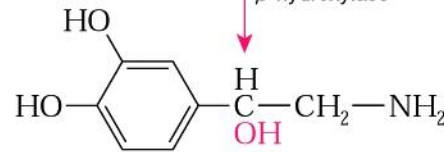
Dopa decarboxylase

Dopamine



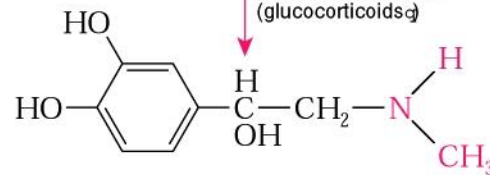
Dopamine β-hydroxylase

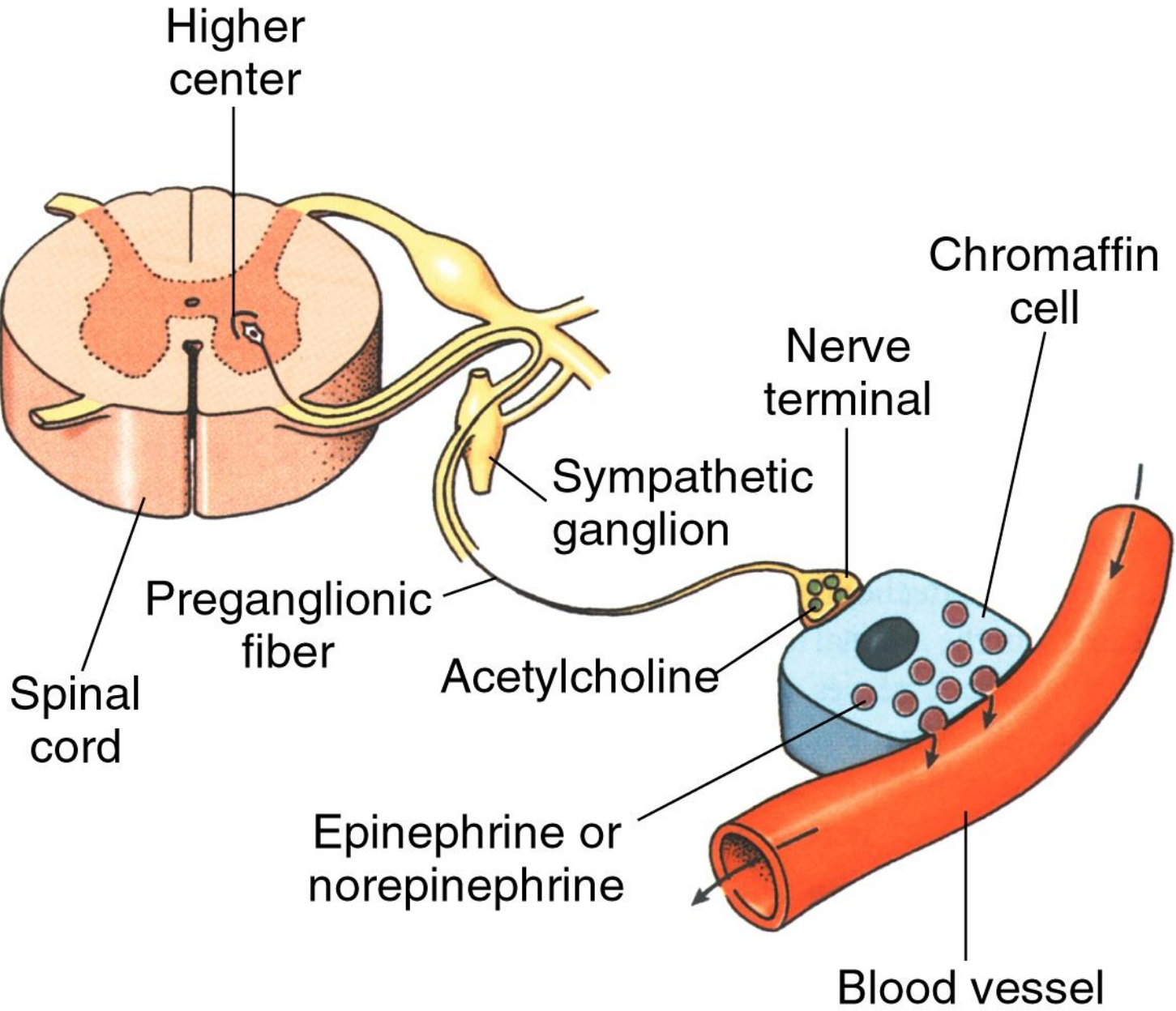
Norepinephrine

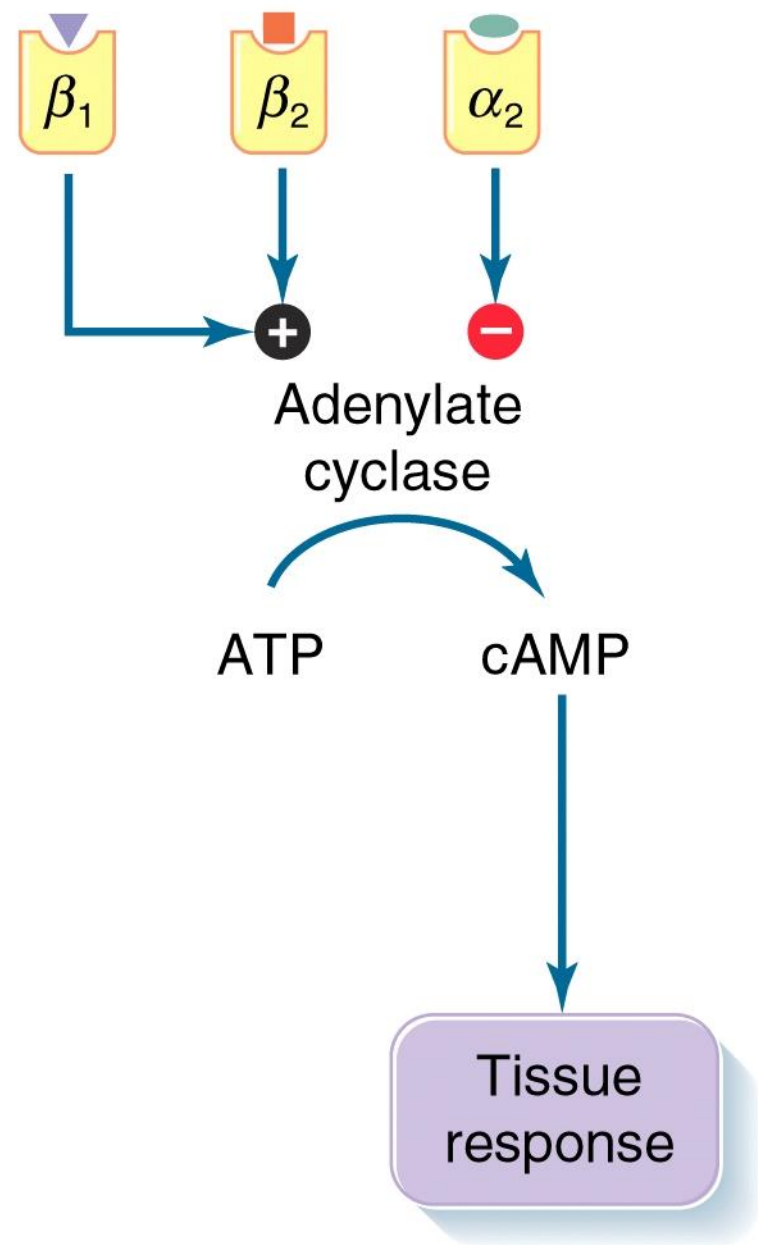
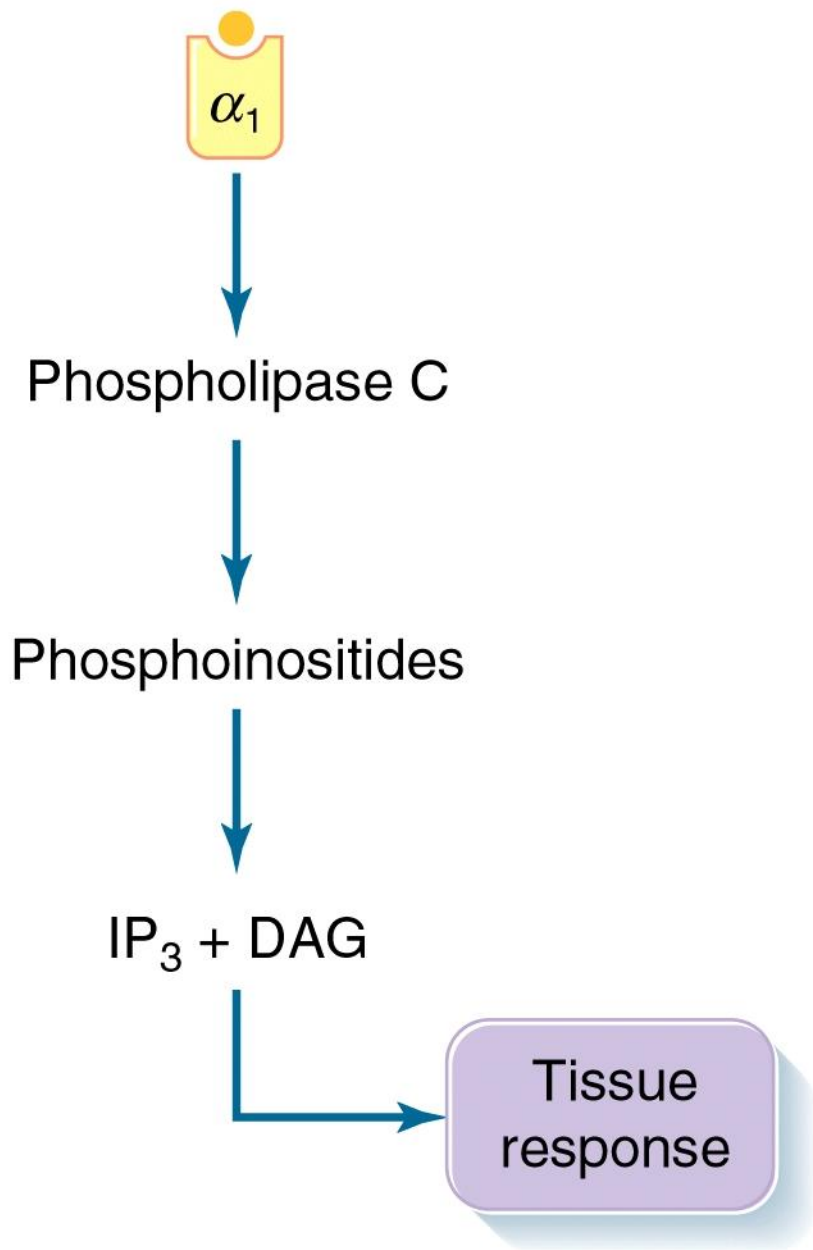


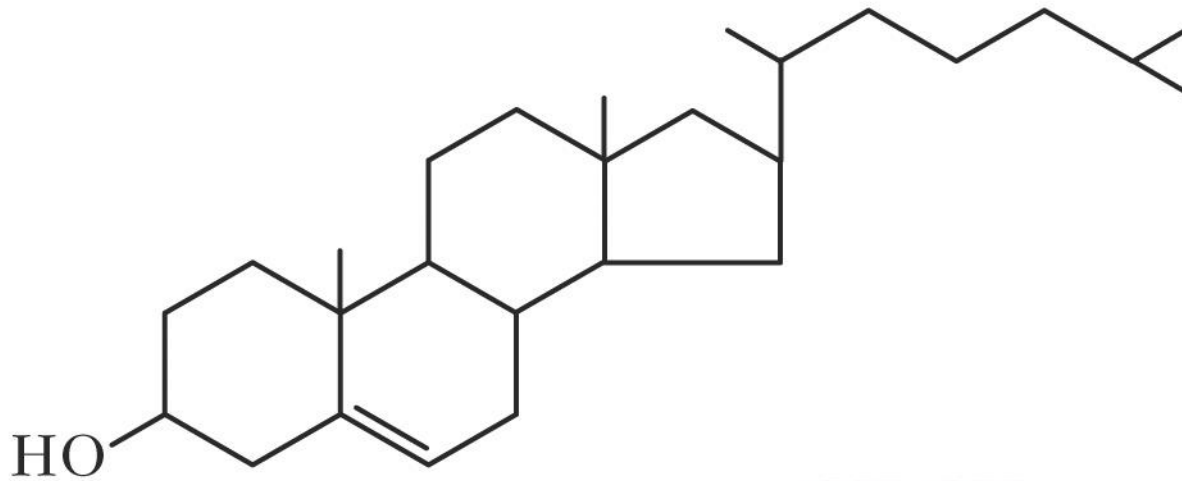
Phenylethanolamine N-methyltransferase (glucocorticoids)

Epinephrine

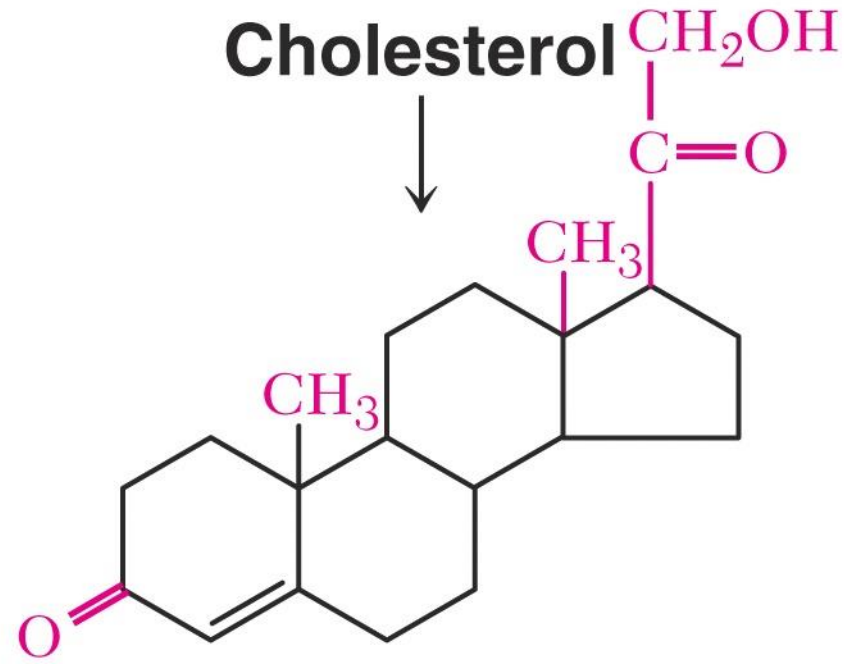




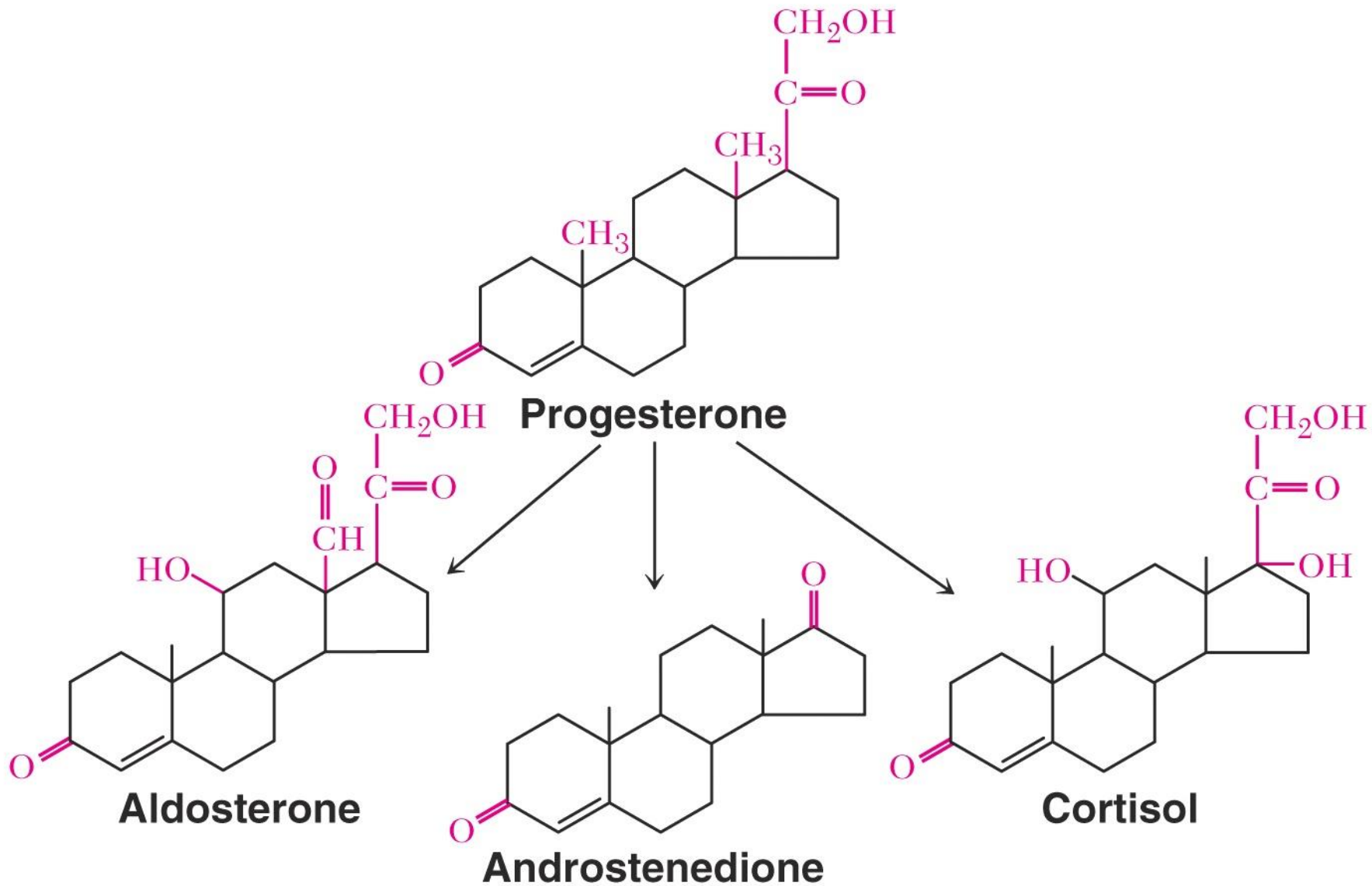


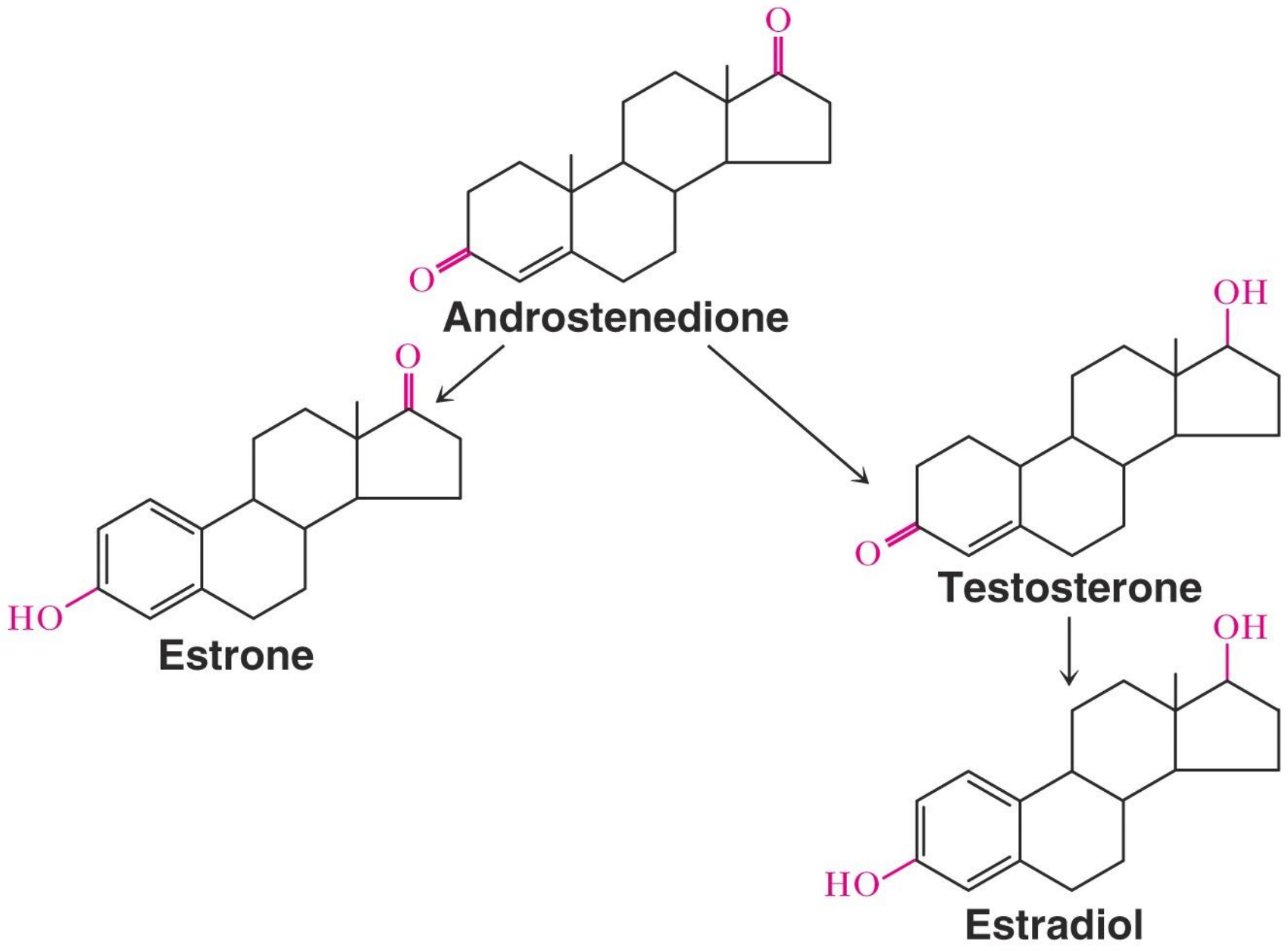


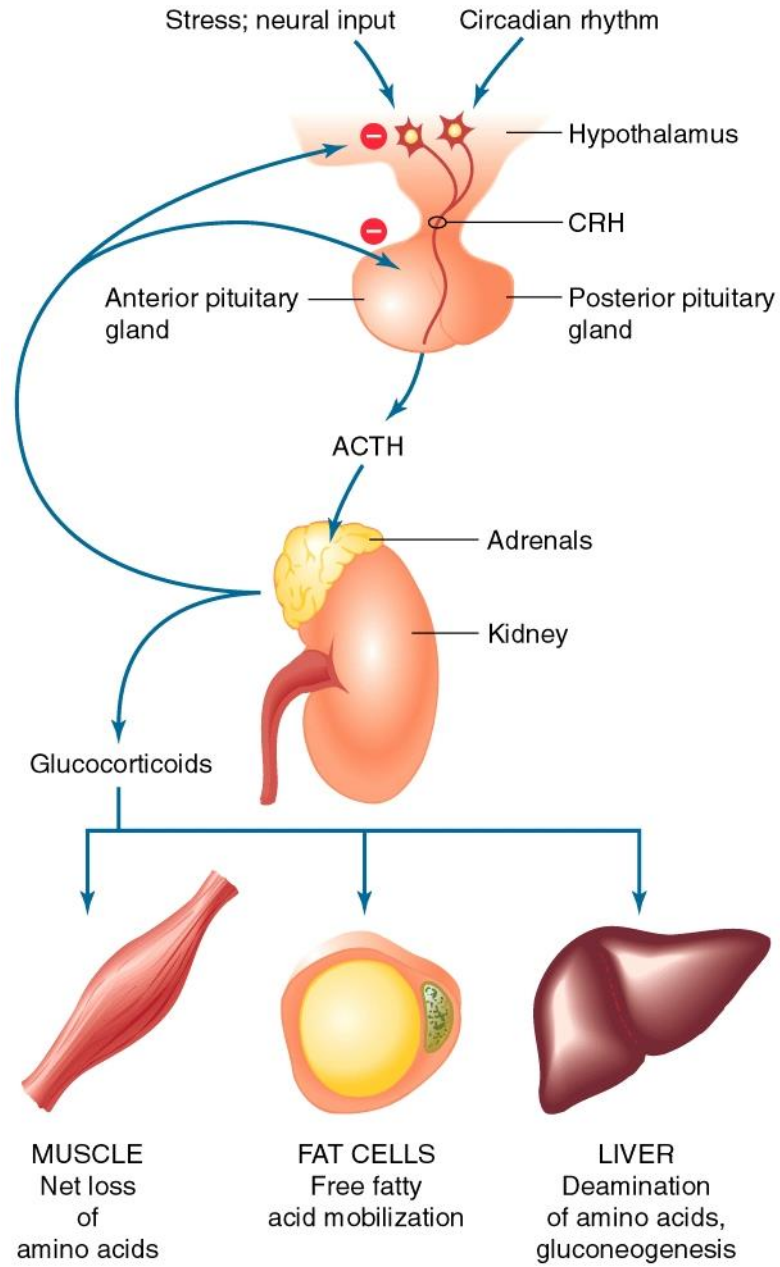
Cholesterol CH_2OH

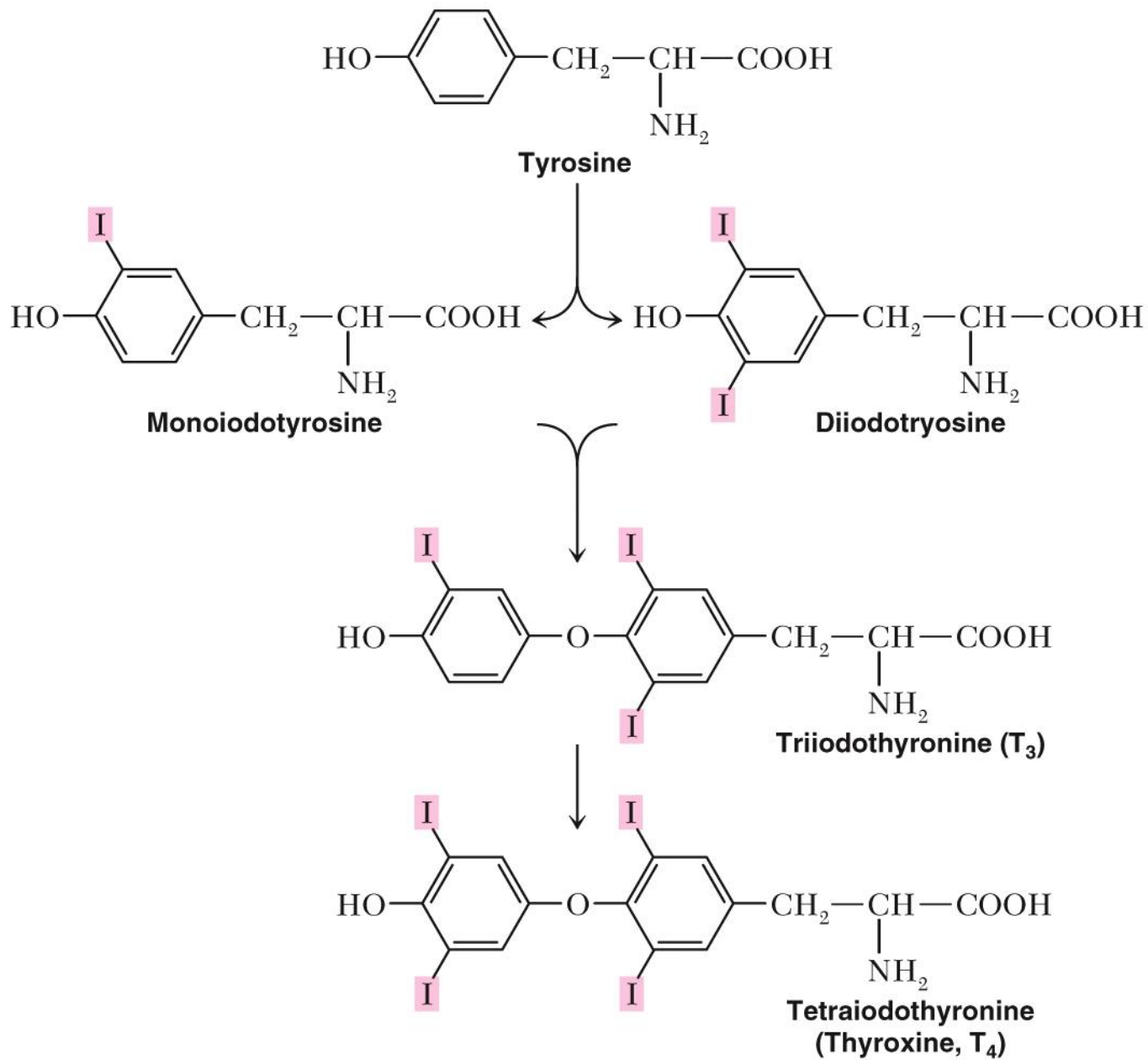


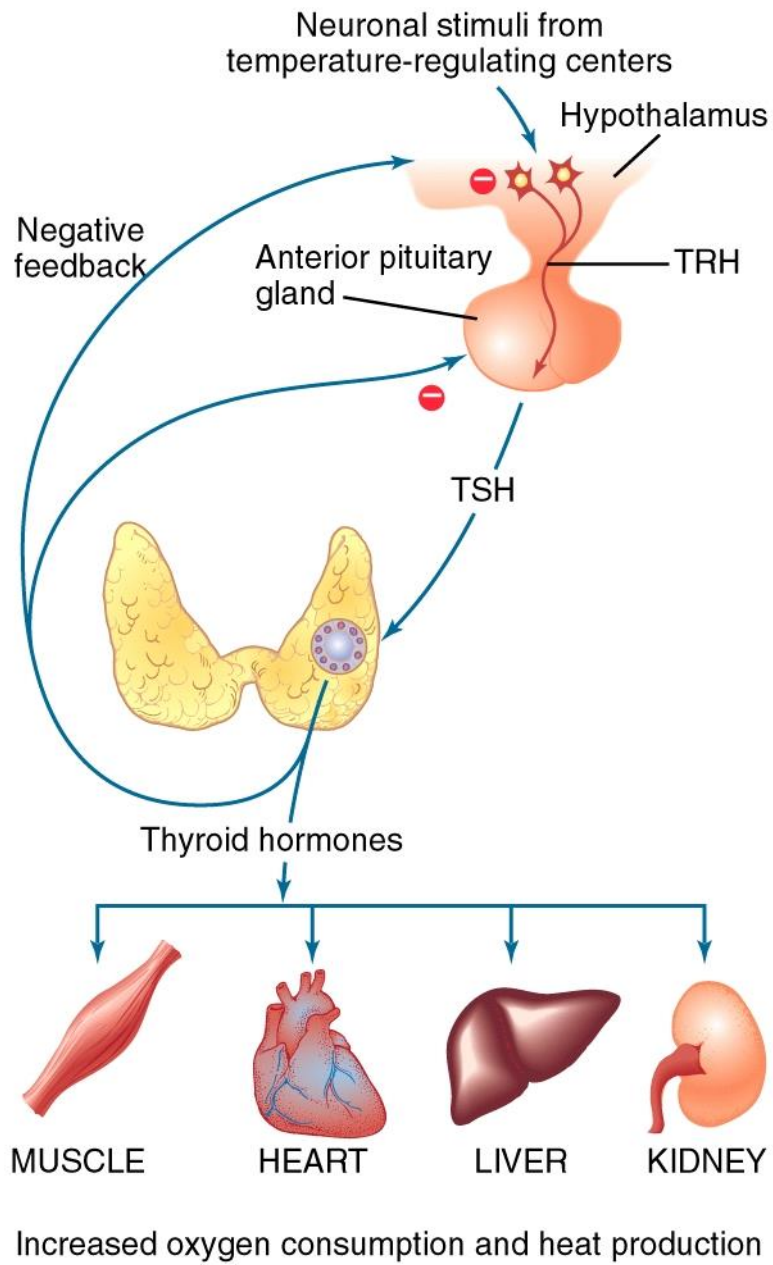
Progesterone











Neuronal stimuli from temperature-regulating centers

Hypothalamus

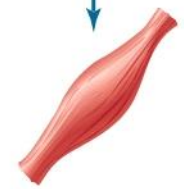
Negative feedback

Anterior pituitary gland

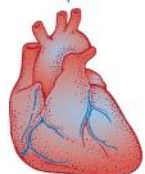
TRH

TSH

Thyroid hormones



MUSCLE



HEART

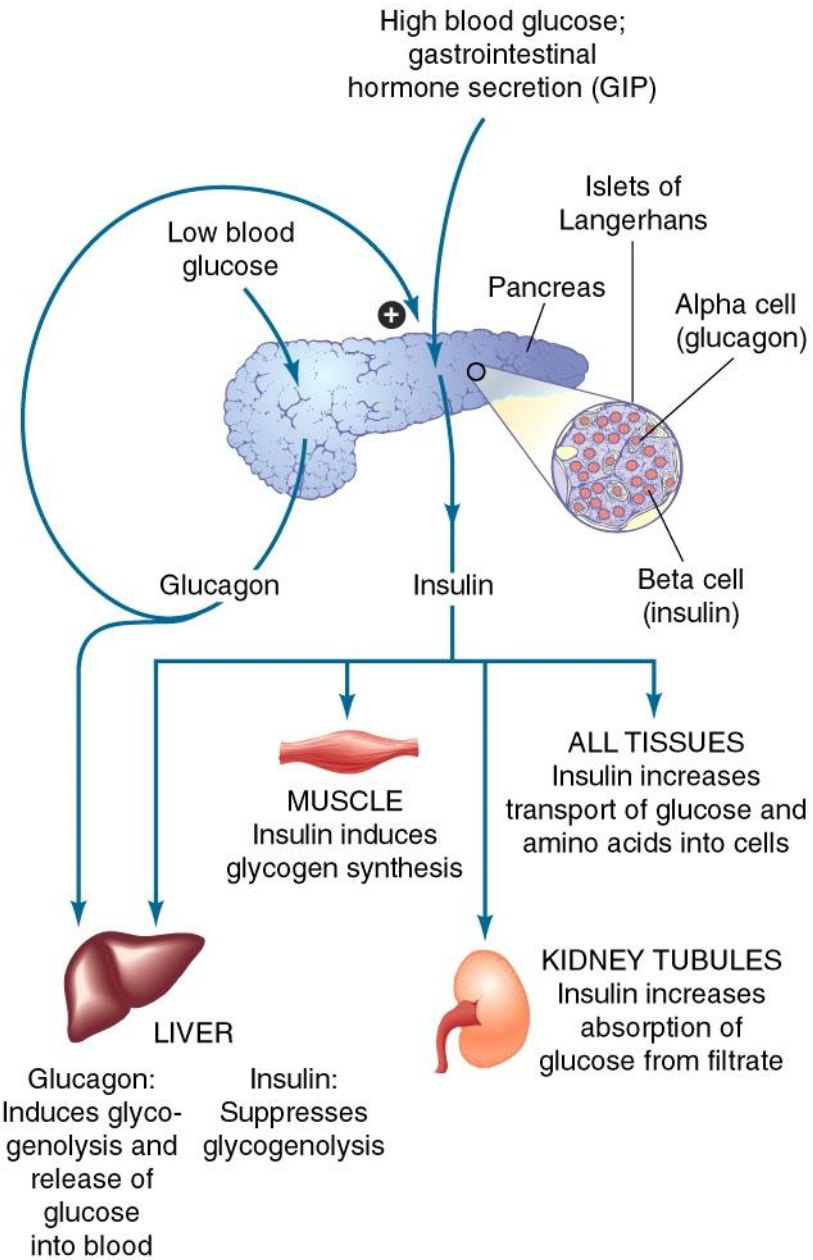


LIVER



KIDNEY

Increased oxygen consumption and heat production



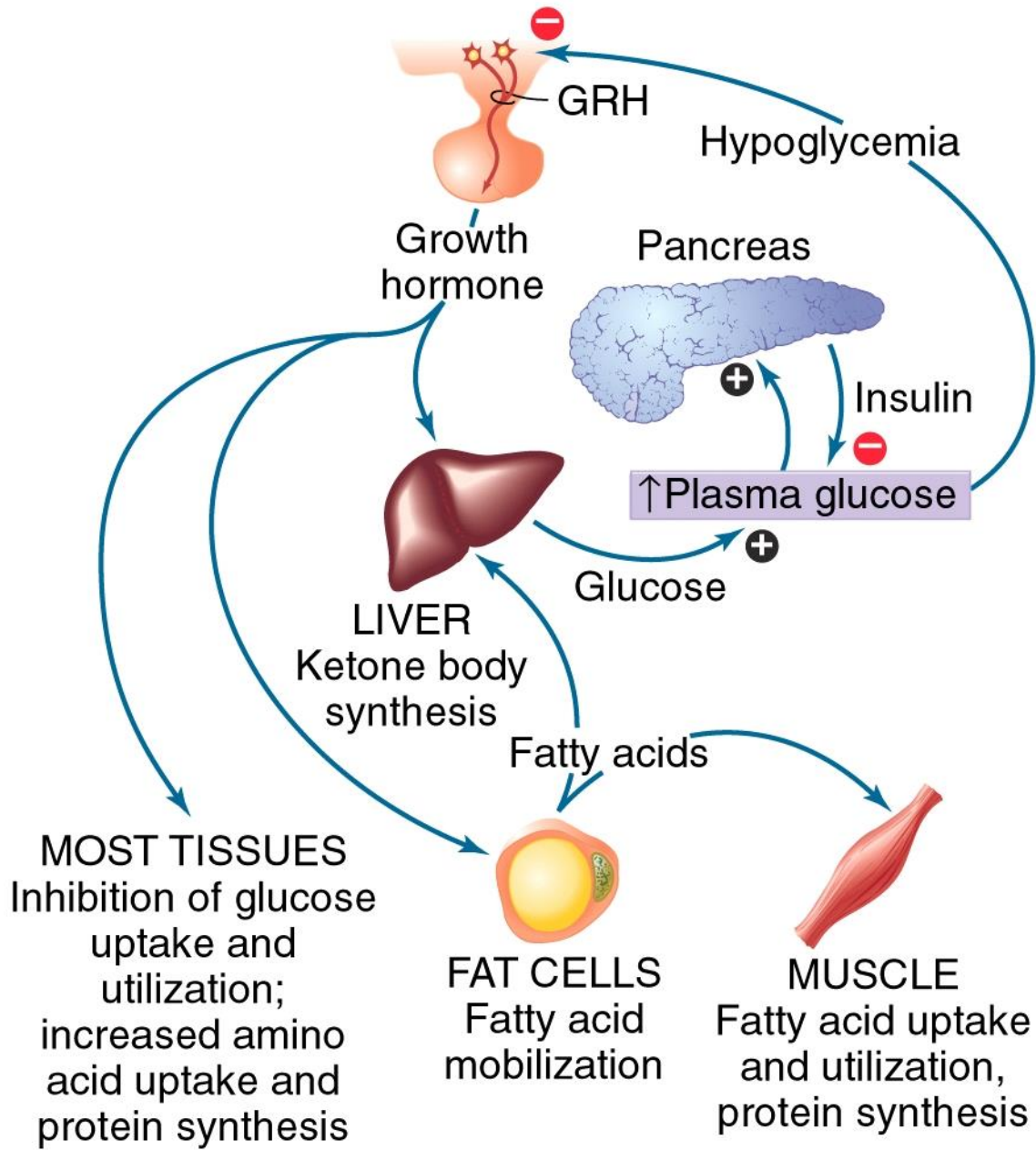


Table 9-8 Mammalian hormones involved in regulating water and electrolyte balance

Hormone	Tissue of origin	Structure	Target tissue	Primary action	Regulation
Antidiuretic hormone (ADH, vasopressin)	Posterior pituitary	Nonapeptide	Kidneys	Increases water reabsorption	Increased plasma osmotic pressure or decreased blood volume stimulates release
Atrial natriuretic peptide (ANP)	Heart (atrium)	Peptide	Kidneys	Reduces Na ⁺ and water reabsorption	Increased venous pressure stimulates release
Calcitonin	Thyroid (parafollicular cells)	Peptide	Bones, kidneys	Decreases release of Ca ²⁺ from bone; increases renal Ca ²⁺ and PO ₄ ³⁻ excretion	Increased plasma Ca ²⁺ stimulates secretion
Mineralocorticoids (e.g., aldosterone)	Adrenal cortex	Steroid	Distal kidney tubules	Promotes reabsorption of Na ⁺ from urinary filtrate	Angiotensin II stimulates secretion
Parathyroid hormone (PTH)	Parathyroid gland	Peptide	Bones, kidneys, intestine	Increases release of Ca ²⁺ from bone; with calcitriol increases intestinal Ca ²⁺ absorption; decreases renal Ca ²⁺ excretion	Decreased plasma Ca ²⁺ stimulates secretion

Modified in class

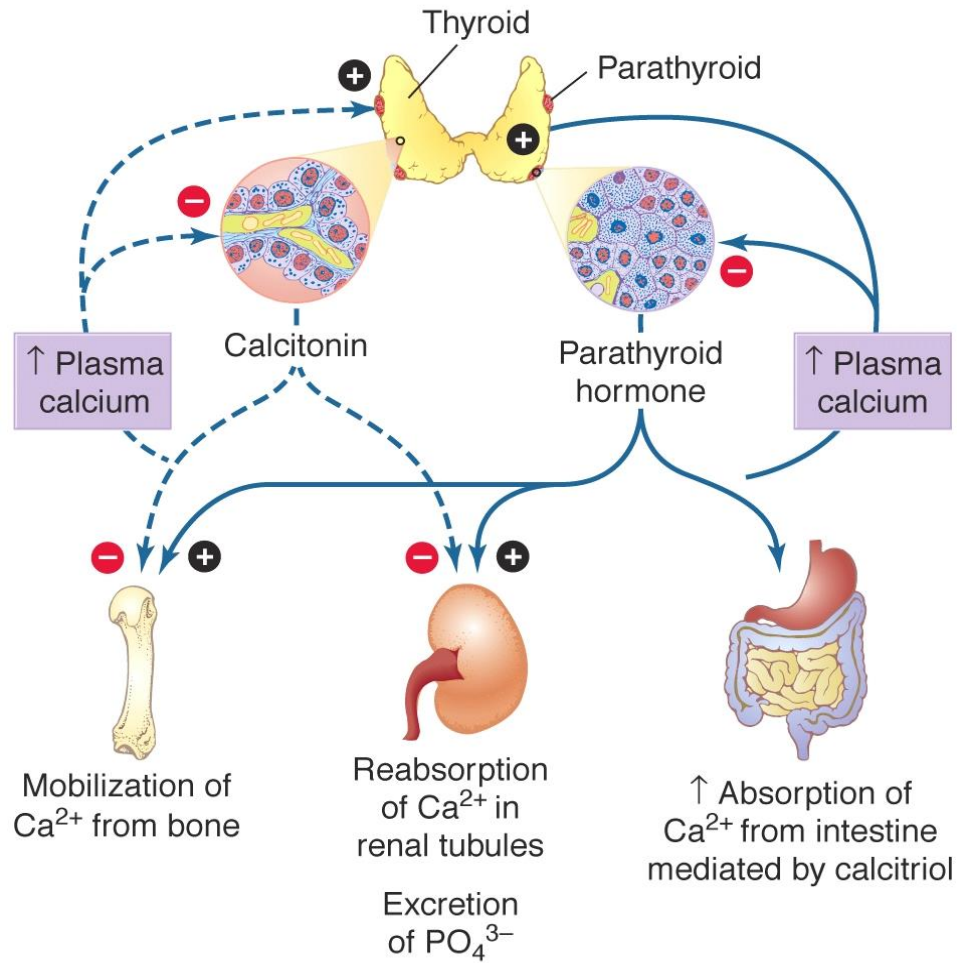
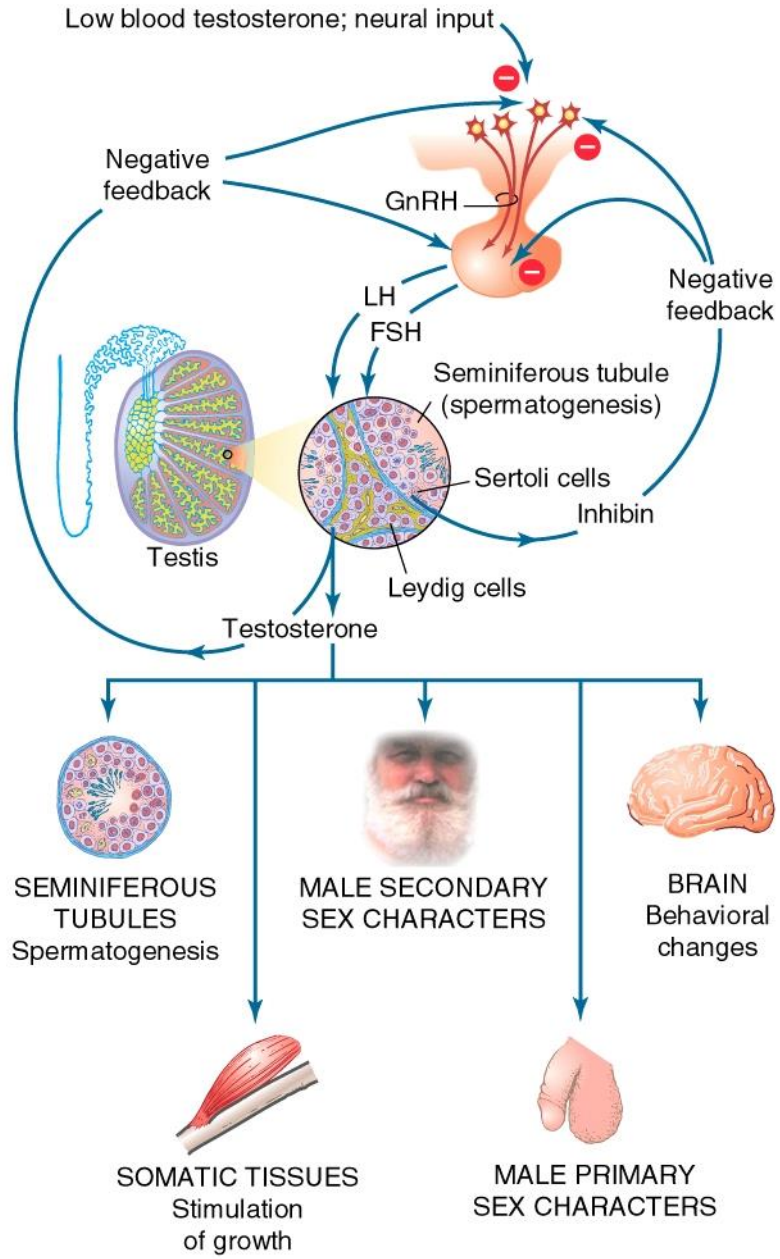
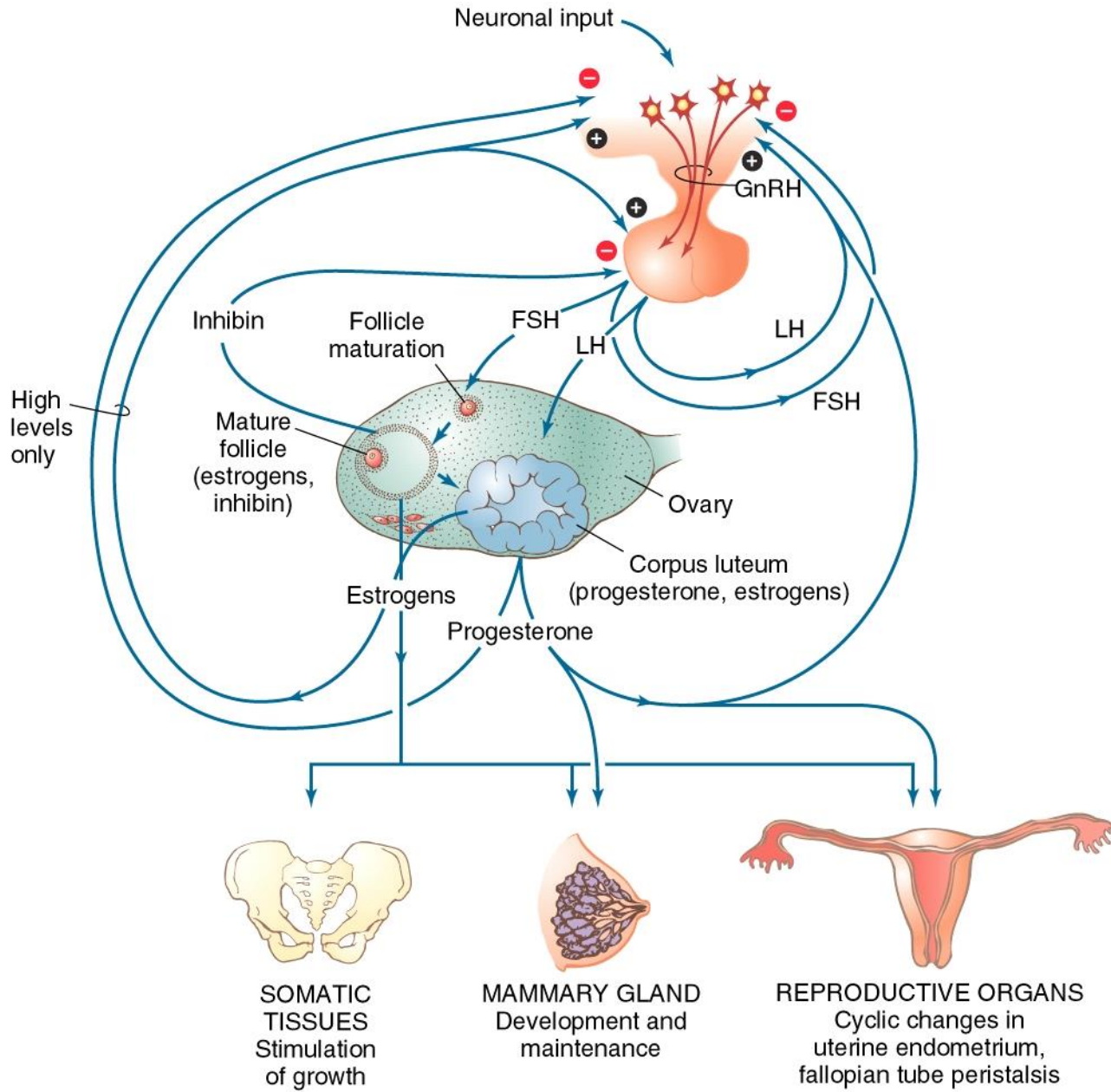
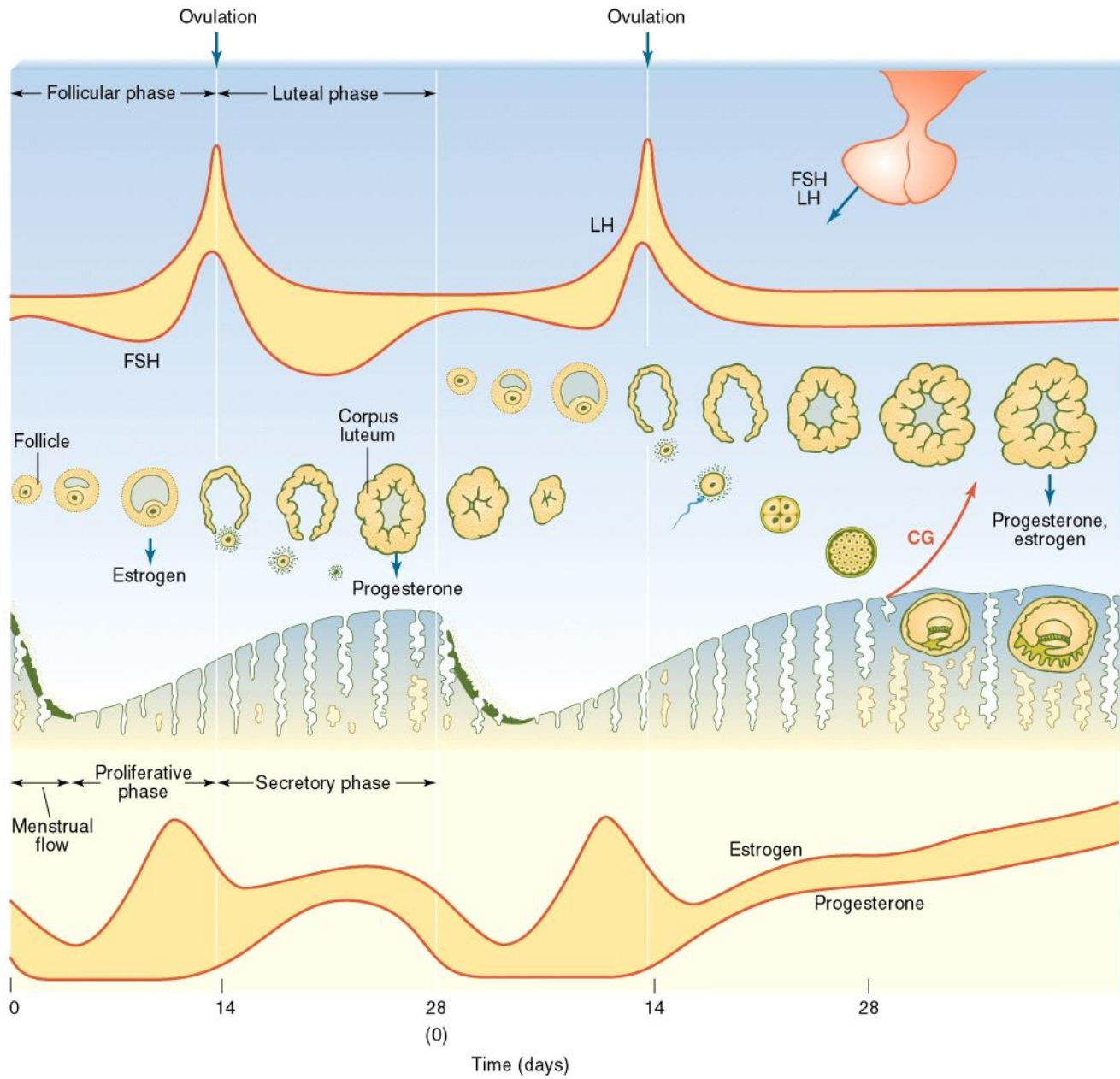


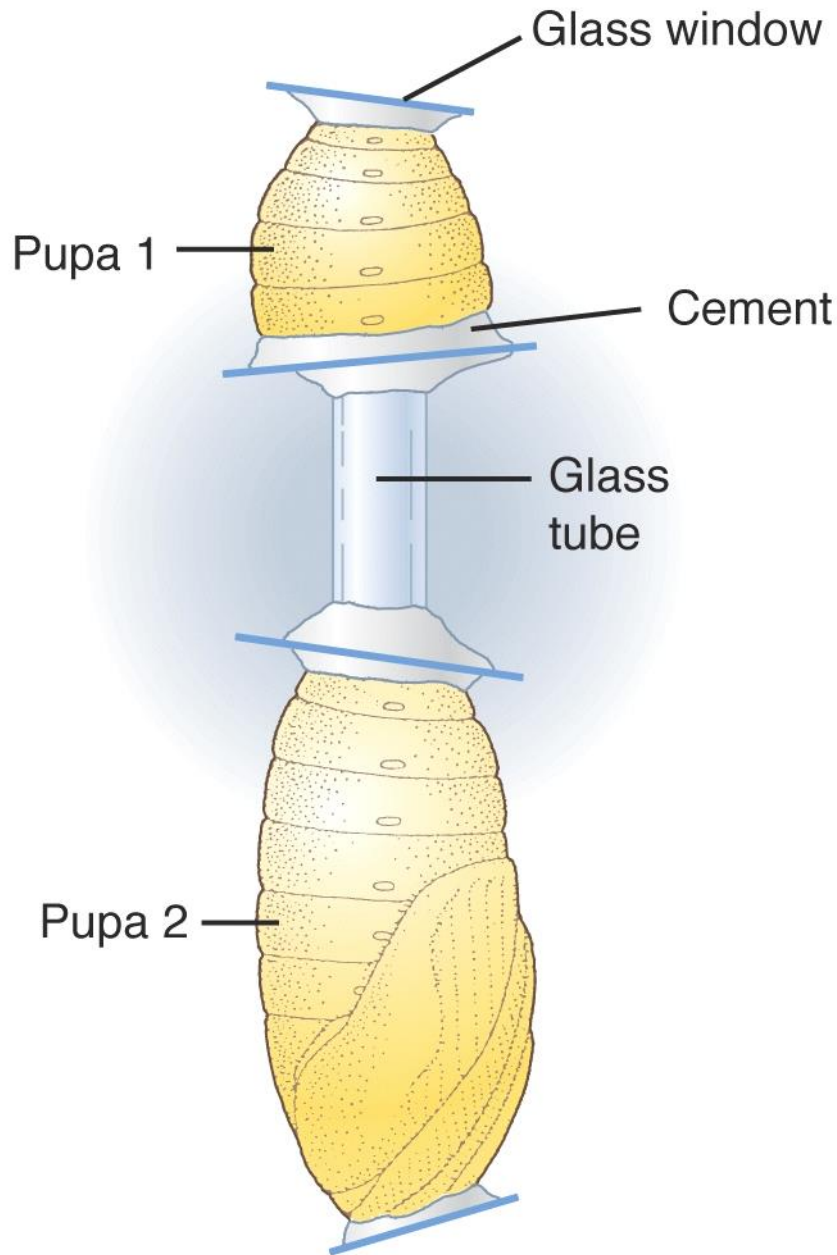
Table 9-9 Important mammalian reproductive hormones

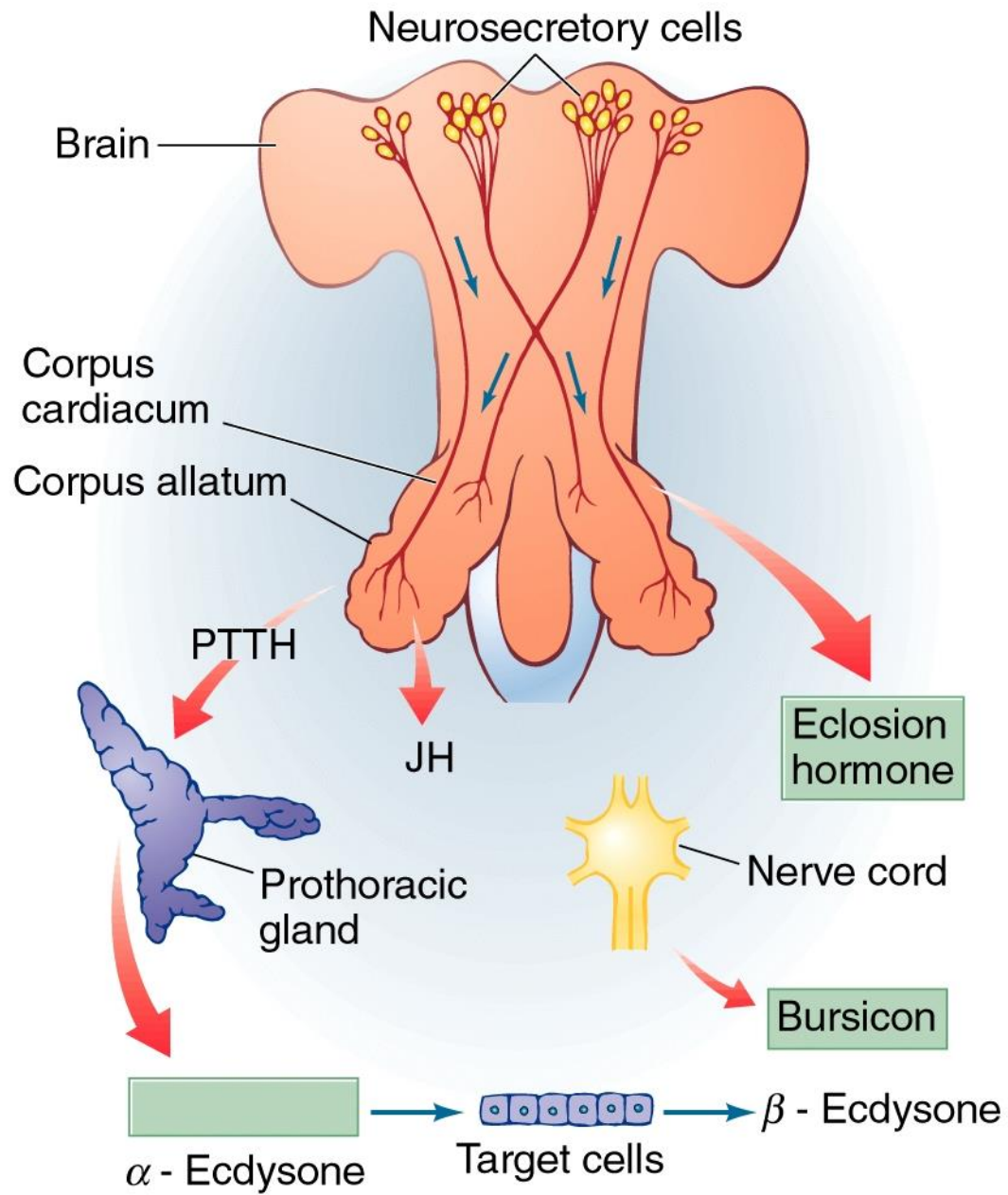
Hormone	Tissue of origin	Structure	Target tissue	Primary action	Regulation
Primary sex hormones					
Estradiol-17 β (estrogens)	Ovarian follicle, corpus luteum, adrenal cortex	Steroid	Most tissues	Promotes development and maintenance of female characteristics and behavior, oocyte maturation, and uterine proliferation	Increased FSH and LH levels stimulate secretion
Progesterone	Corpus luteum, adrenal cortex	Steroid	Uterus, mammary glands	Maintains uterine secretion; stimulates mammary duct formation	Increased LH and prolactin levels stimulate secretion
Testosterone (androgens)	Testes (Leydig cells), adrenal cortex	Steroid	Most tissues	Promotes development and maintenance of male characteristics and behavior and spermatogenesis	Increased LH level stimulates secretion
Other Hormones					
Oxytocin	Posterior pituitary	Nonapeptide	Uterus, mammary glands	Promotes smooth muscle contraction and milk ejection	Cervical distention and suckling stimulate release; high progesterone inhibits release
Prolactin (PL)	Anterior pituitary	Peptide	Mammary glands (alveolar cells)	Increases synthesis of milk proteins and growth of mammary glands; elicits maternal behavior	Continuous secretion of PL-inhibiting hormone (PIH) normally blocks release; increased estrogen and decreased PIH secretion permit release

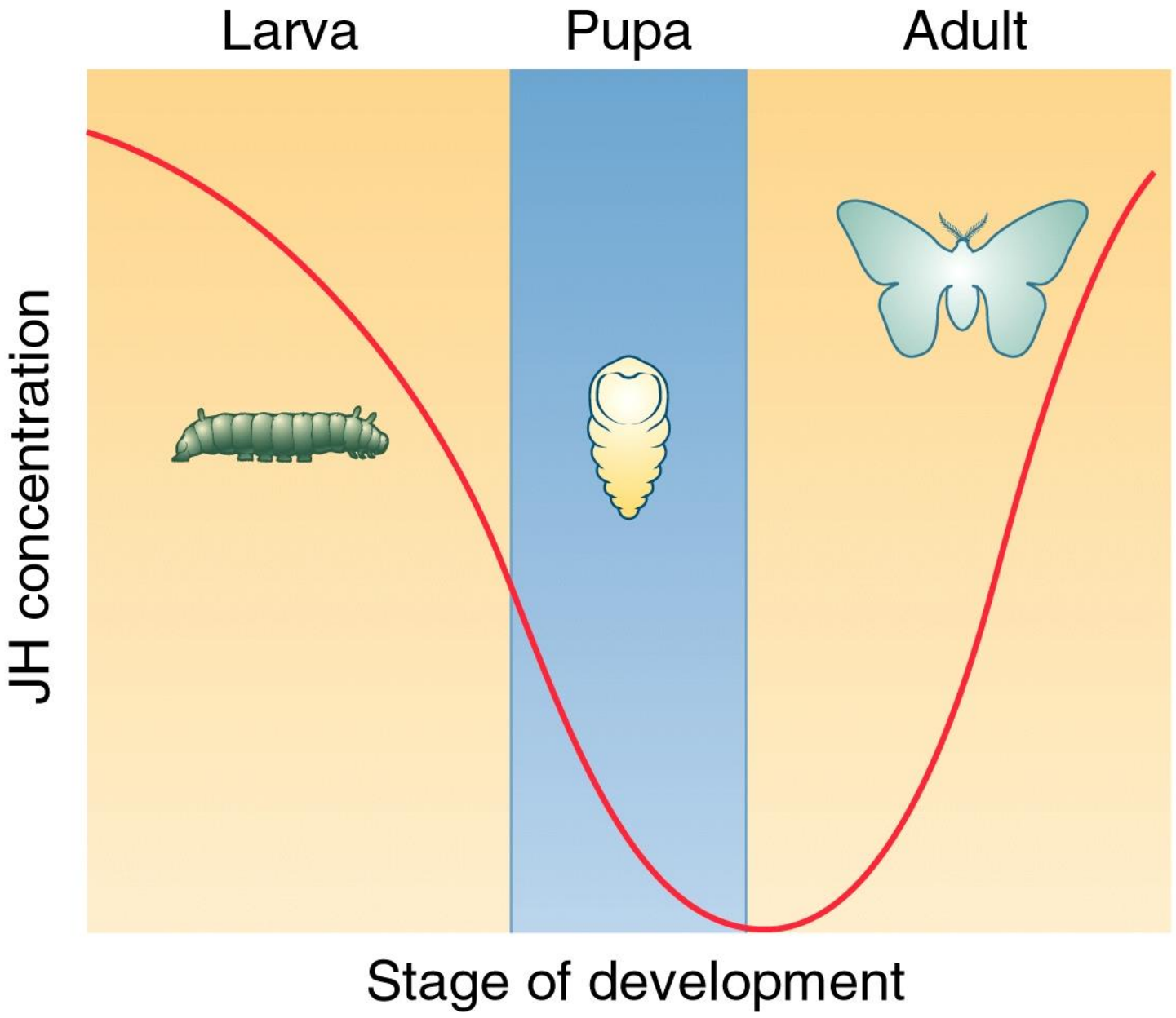


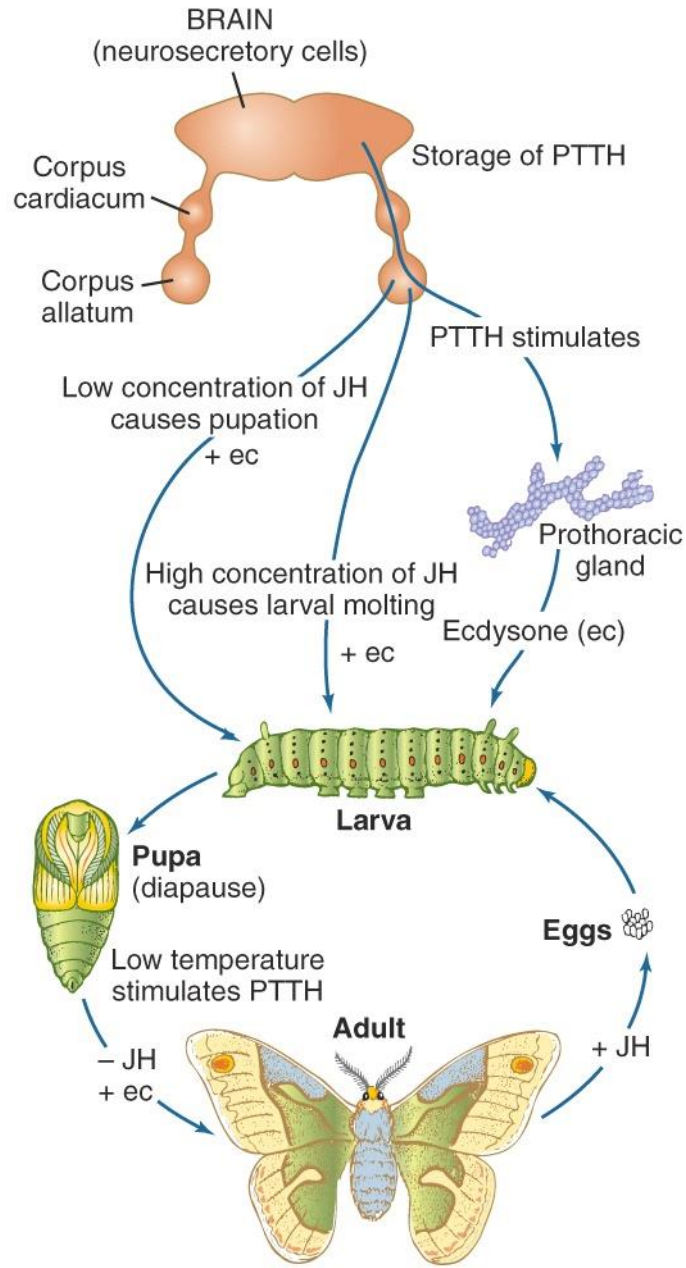












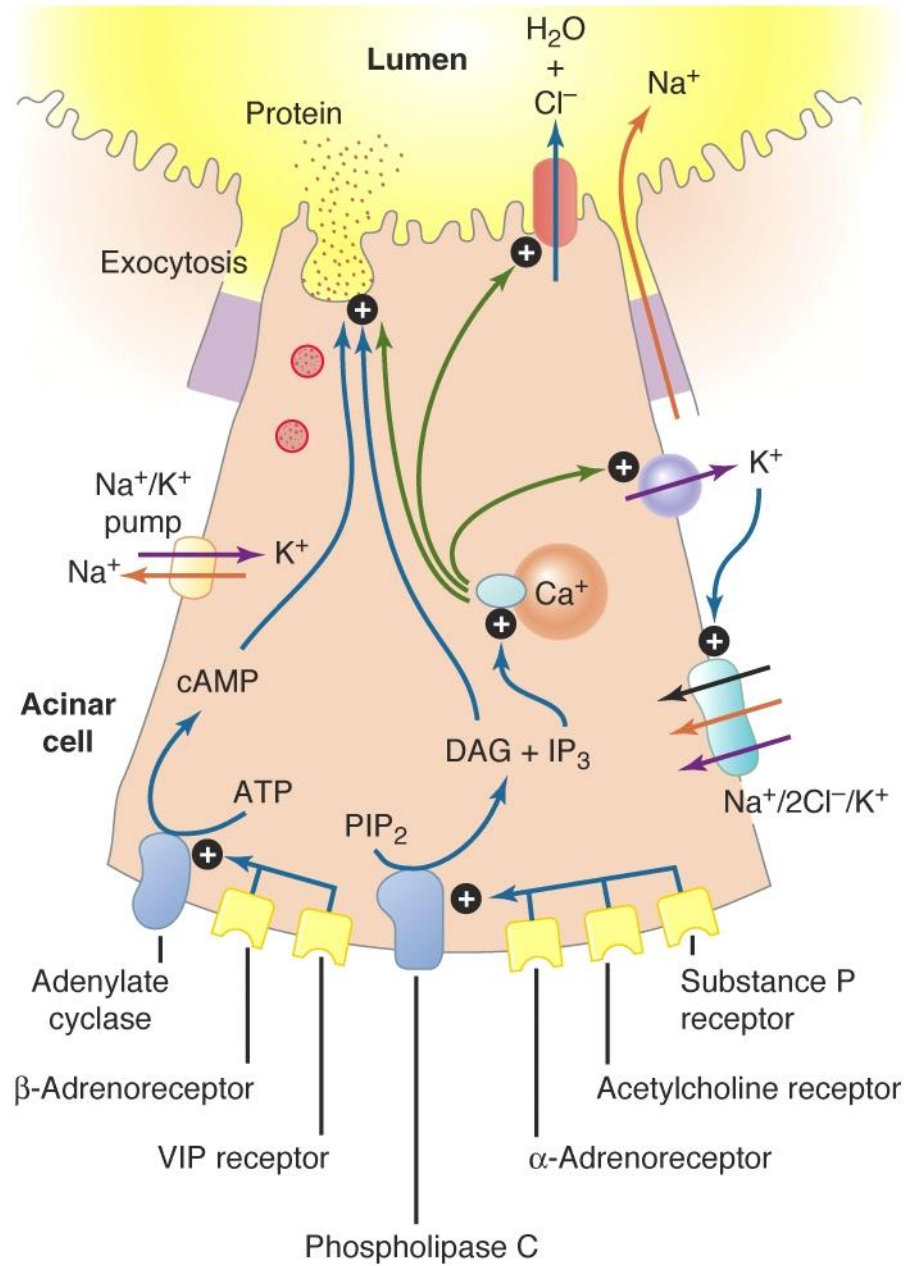


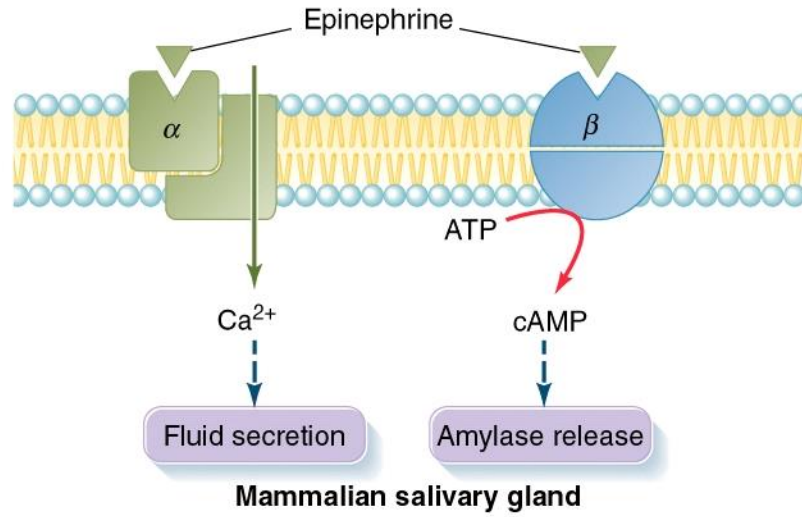
Table 9-10 Selected prostaglandins

Tissue of origin	Target tissue	Primary action	Regulation
Seminal vesicles, uterus, ovaries	Uterus, ovaries, fallopian tubes	Potentiates smooth muscle contraction and possibly luteolysis; may mediate LH stimulation of estrogen and progesterone synthesis	Introduced during coitus with semen
Kidney	Blood vessels, especially in kidneys	Regulates vasodilation or vasoconstriction	Increased angiotensin II and epinephrine stimulate secretion; inactivated in lungs and liver
Neuronal tissue	Adrenergic terminals	Blocks norepinephrine- sensitive adenylate cyclase	Neuronal activity increases release

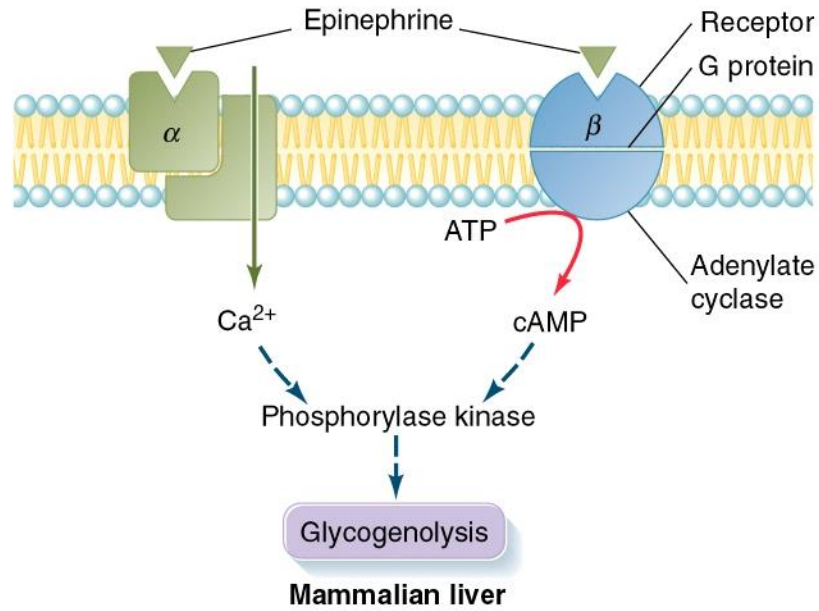
Table 9-11 Insect developmental hormones

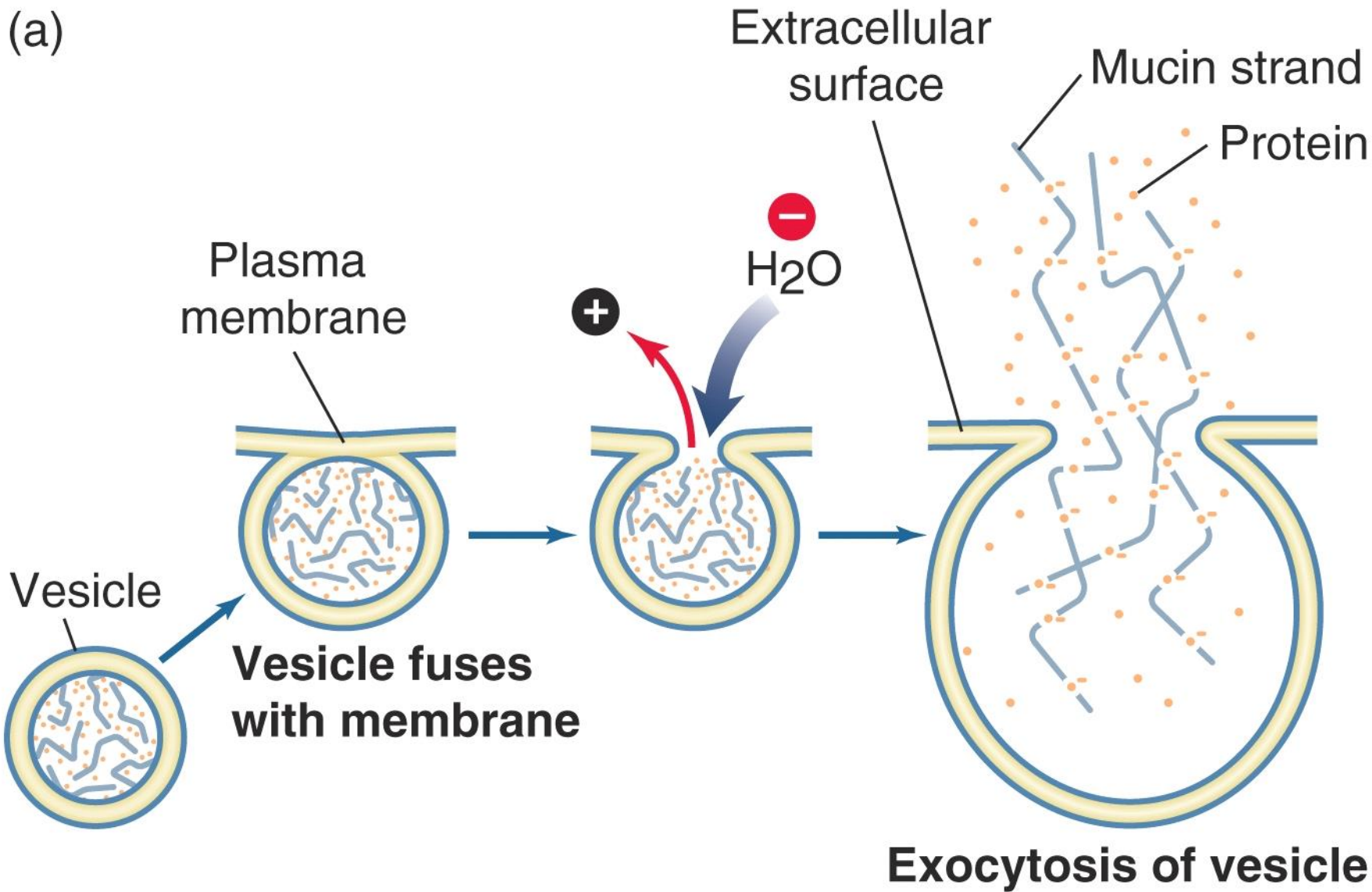
Hormone	Tissue of origin	Structure	Target tissue	Primary action	Regulation
Bursicon	Neurosecretory cells in brain and nerve cord	Protein (MW ~ 40,000)	Epidermis	Promotes cuticle development; induces tanning of cuticle of newly molted adults	Stimuli associated with molting stimulate secretion
Ecdysone (molting hormone)	Prothoracic glands, ovarian follicle	Steroid	Epidermis, fat body, imaginal disks	Increases synthesis of RNA, protein, mitochondria, and endoplasmic reticulum; promotes secretion of new cuticle	PTTH stimulates secretion
Eclosion hormone	Neurosecretory cells in brain	Peptide	Nervous system	Induces emergence of adult from puparium	Endogenous "clock"
Juvenile hormone (JH)	Corpus allatum	Fatty acid derivative	Epidermis, ovarian follicles, sex accessory glands, fat body	In larva, promotes synthesis of larval structures and inhibits metamorphosis; in adult, stimulates synthesis of yolk protein; activates ovarian follicles and sex accessory glands	Inhibitory and stimulatory factors from the brain control secretion
Prothoracicotropic (PTTH)	Neurosecretory cells in brain	Small protein (MW ~ 5000)	Prothoracic gland	Stimulates ecdysone release	Various environmental and internal cues (e.g., photoperiod, temperature, crowding, abdominal stretch) stimulate release; JH inhibits release in some species

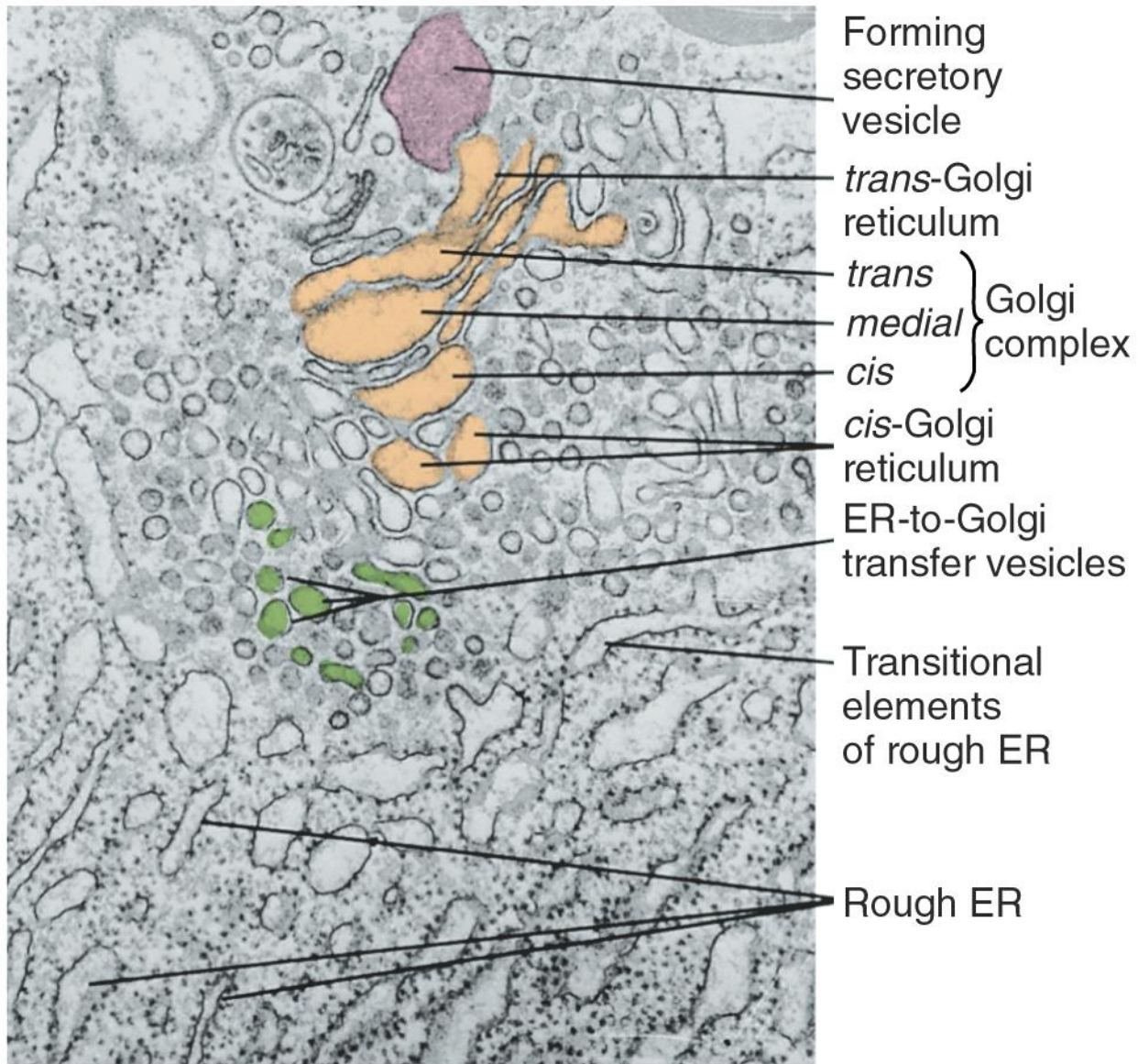
(a) Divergent pathway



(b) Convergent pathway







(a)

0.5 μm

