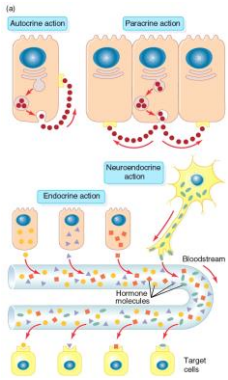
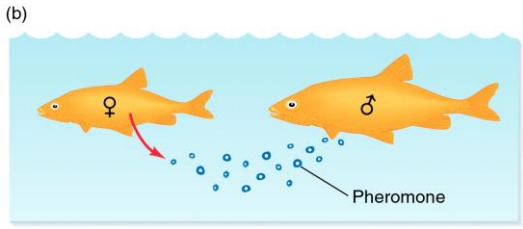
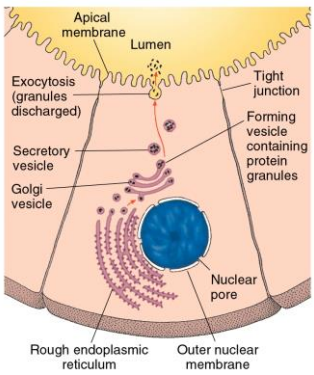
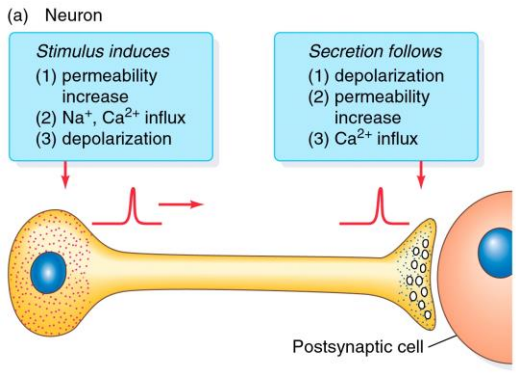
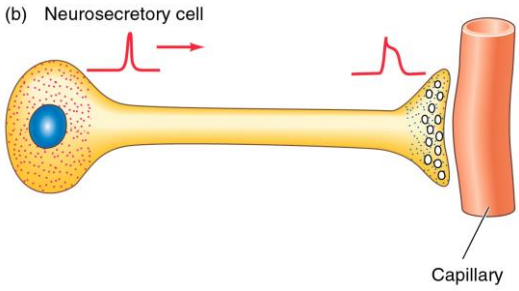
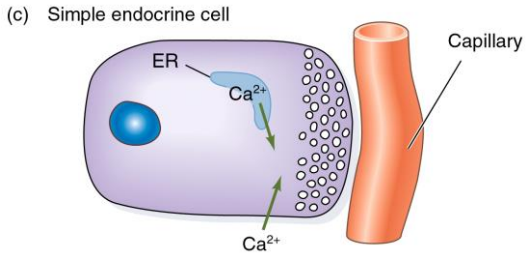

(a)
Autocrine action
Paracrine action
Neuroendocrine action
Endocrine action
Bloodstream
Hormone molecules
Target cells

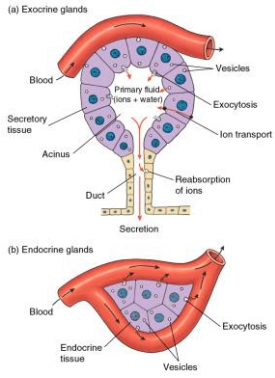

(b)
♀
♂
Pheromone

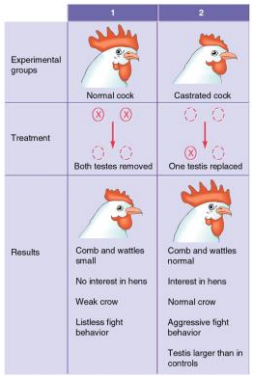

Apical membrane
Lumen
Exocytosis (granules discharged)
Tight junction
Forming vesicle containing protein granules
Secretory vesicle
Golgi vesicle
Nuclear pore
Rough endoplasmic reticulum
Outer nuclear membrane

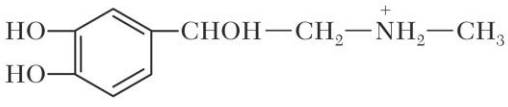

(a) Neuron
Stimulus induces
(1) permeability increase
(2) Na+, Ca2+ influx
(3) depolarization
Secretion follows
(1) depolarization
(2) permeability increase
(3) Ca2+ influx
Postsynaptic cell


(b) Neurosecretory cell
Capillary

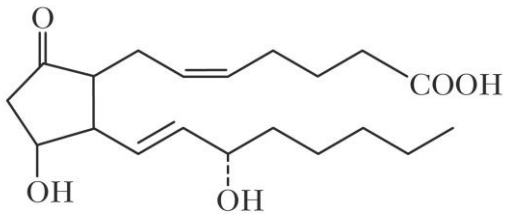

(c) Simple endocrine cell
ER
Ca2+
Ca2+
Capillary



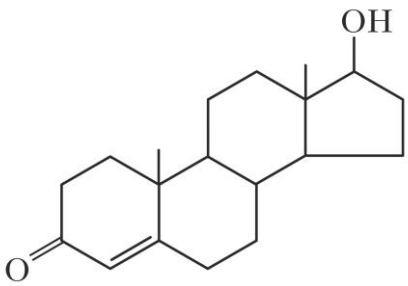




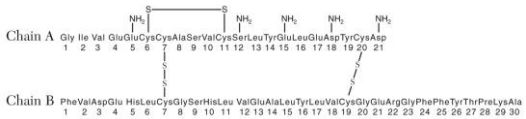
Epinephrine
(an amine)



Prostaglandin PGE_2
(an eicosanoid)



Testosterone
(a steroid)



Insulin (bovine)
(a peptide)

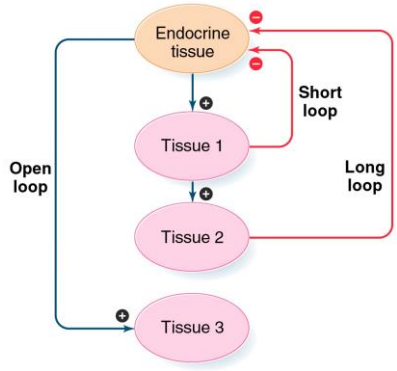


Table 9-1a **Vertebrate endocrine glands and tissues**

Gland/source	Hormone	Major physiological role*
Adrenal gland		
Steroidogenic tissue (cortex)	Aldosterone	↑ Sodium retention
	Cortisol and corticosterone	↑ 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; ↑ gallbladder 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)

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**

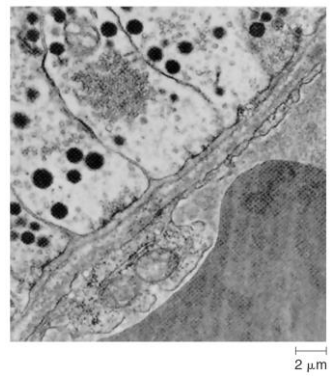
Gland/source	Hormone	Major physiological role*
Pancreas (islets of Langerhans)	Glucagon	↑ Blood glucose, gluconeogenesis, and glycogenolysis
	Insulin	↓ Blood glucose; ↑ protein, glycogen, and fat synthesis
	Pancreatic polypeptide	↑ ↓ Secretion of other pancreatic islet hormones
	Somatostatin	↓ Secretion 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)

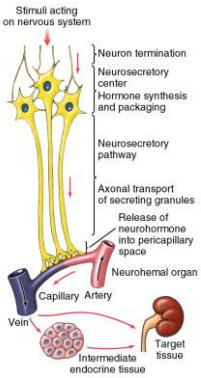
(continued on the next page)

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 D_3 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.





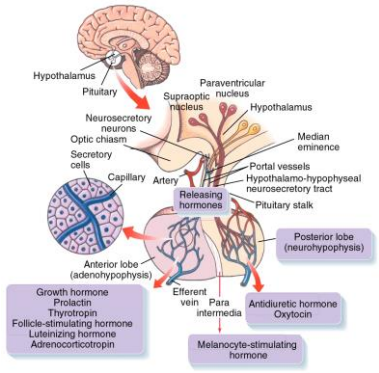


Table 9-2 Hypothalamic neurohormones that stimulate or inhibit release of adenohypophyseal hormones

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

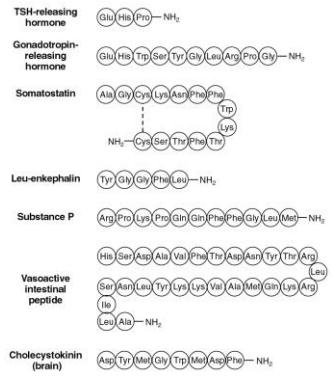
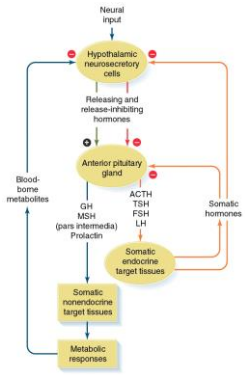
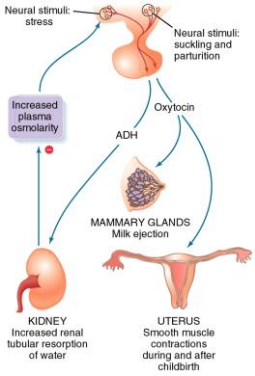


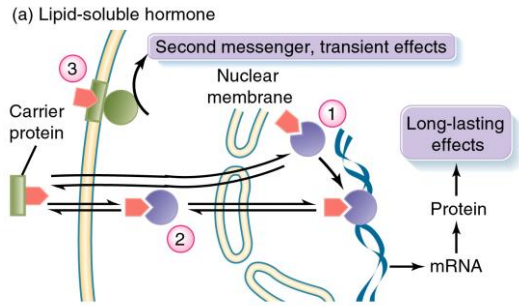
Table 9-3 Tropic hormones of the anterior pituitary gland

Hormone	Structure	Target tissue	Primary action in mammals	Regulation*
Adrenocorticotropic 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.







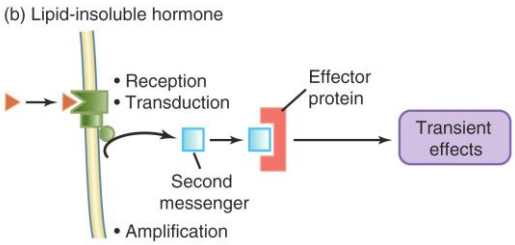
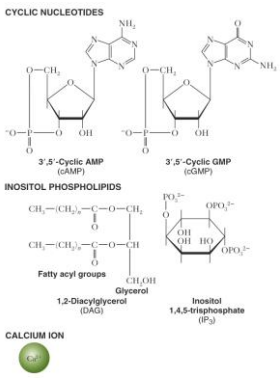
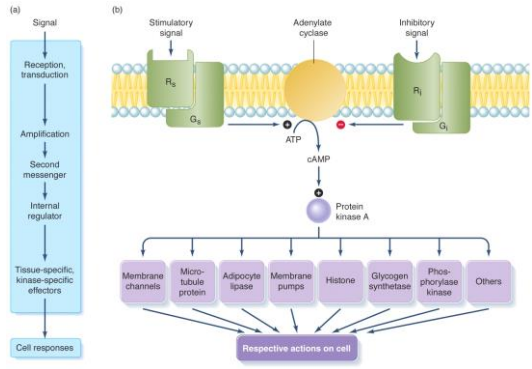


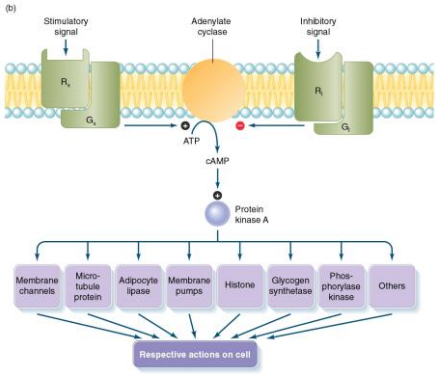
Table 9-5 Comparison of lipid-soluble and lipid-insoluble hormones

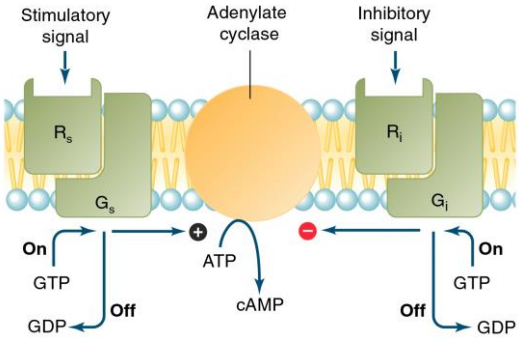
	Lipid-soluble		Lipid-insoluble	
Property	Steroids	Thyroid hormones	Peptides and proteins	Catecholamines
Feedback regulation of synthesis	Yes	Yes	Yes	Yes
Binding to carrier proteins	Yes	Yes	Rarely	No
Lifetime in blood plasma	Hours	Days	Minutes	Seconds
Time course of action	Hours to days	Days	Minutes to 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.









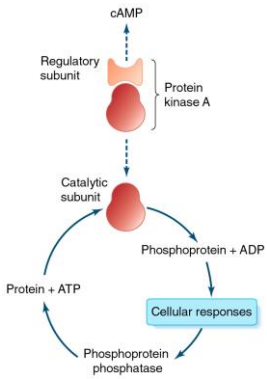
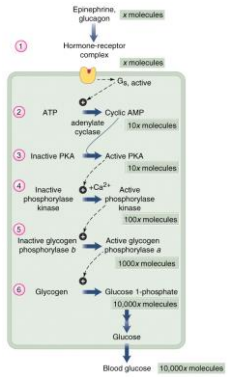
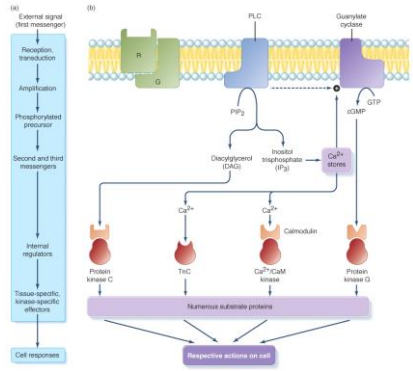


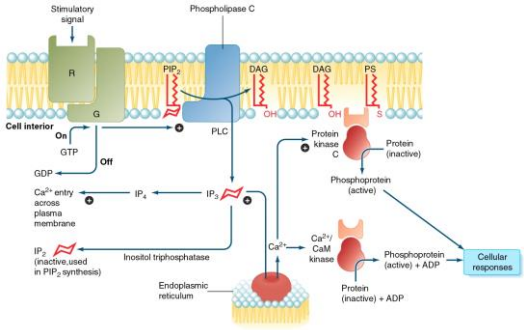
Table 9-6 Some hormone-induced responses mediated by the cAMP pathway

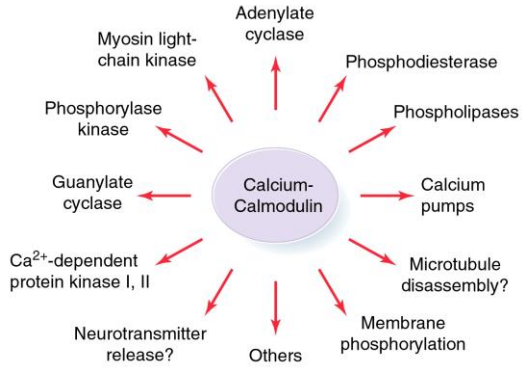
Signal	Tissue	Cellular response
Stimulatory		
Epinephrine (β-adrenoreceptors)	Skeletal muscle	Breakdown of glycogen
	Fat cells	Increased breakdown of lipids
	Heart	Increased heart rate and force of contraction
	Intestine	Fluid secretion
	Smooth muscle	Relaxation
Thyroid-stimulating hormone (TSH)	Thyroid 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

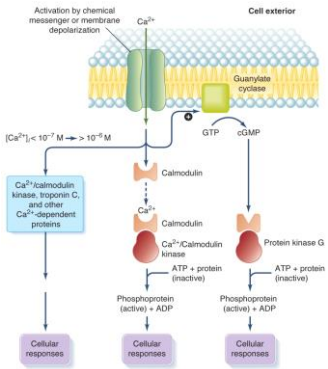
Source: Berridge, 1985.

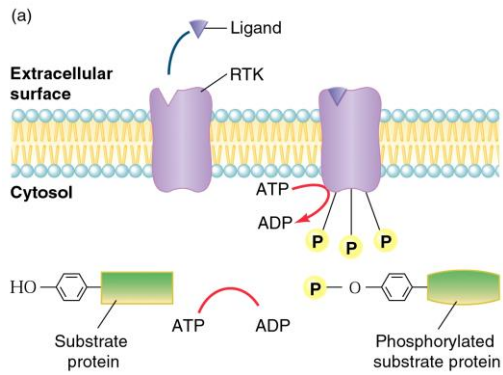


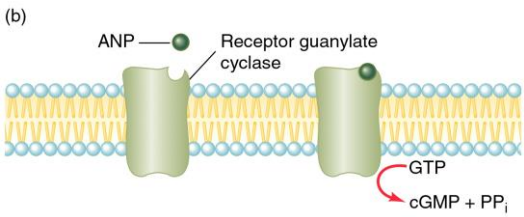


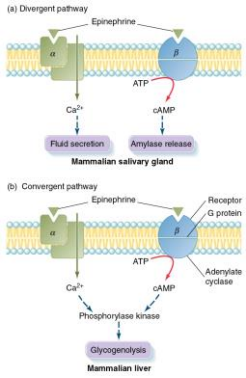

Stimulatory signal
Phospholipase C
R
G
PIP2
DAG
DAG
PS
OH
OH
S
Cell interior
On
GTP
Off
GDP
PLC
Protein kinase C
Protein (inactive)
Phosphoprotein (active)
Ca2+ entry across plasma membrane
IP4
IP3
IP2 (inactive, used in PIP2 synthesis)
Inositol triphosphatase
Ca2+
Ca2+/ CaM kinase
Phosphoprotein (active) + ADP
Cellular responses
Endoplasmic reticulum
Protein (inactive) + ADP

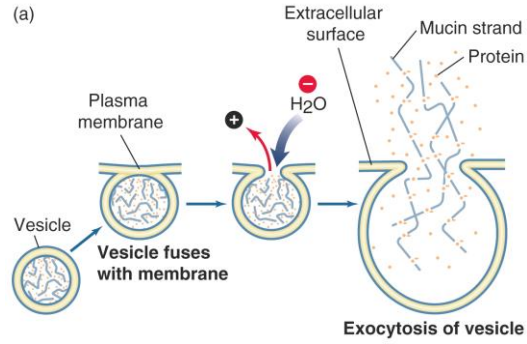

Adenylate cyclase
Myosin light-chain kinase
Phosphodiesterase
Phosphorylase kinase
Phospholipases
Guanylate cyclase
Calcium-Calmodulin
Calcium pumps
Ca2+-dependent protein kinase I, II
Microtubule disassembly?
Neurotransmitter release?
Others
Membrane phosphorylation

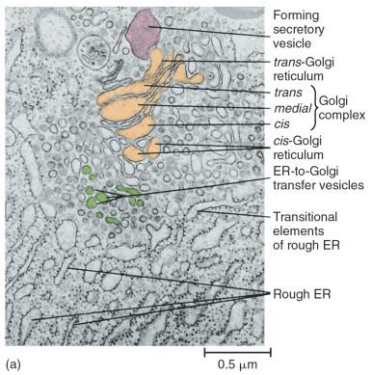

Activation by chemical messenger or membrane depolarization
Ca2+
Cell exterior
Guanylate cyclase
[Ca2+]i < 10−7 M → > 10−5 M
GTP
cGMP
Calmodulin
Ca2+/calmodulin kinase, troponin C, and other Ca2+-dependent proteins
Ca2+
Calmodulin
Ca2+/Calmodulin kinase
Protein kinase G
ATP + protein (inactive)
ATP + protein (inactive)
Phosphoprotein (active) + ADP
Phosphoprotein (active) + ADP
Cellular responses
Cellular responses
Cellular responses

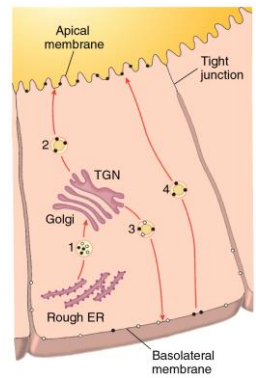

(a)
Ligand
Extracellular surface
RTK
Cytosol
ATP
ADP
P
P
P
HO
Substrate protein
ATP
ADP
P
O
Phosphorylated substrate protein


(b)
ANP
Receptor guanylate cyclase
GTP
cGMP + PPi


(a) Divergent pathway
Epinephrine
α
β
ATP
Ca2+
cAMP
Fluid secretion
Amylase release
Mammalian salivary gland
(b) Convergent pathway
Epinephrine
Receptor
G protein
α
β
ATP
Adenylate cyclase
Ca2+
cAMP
Phosphorylase kinase
Glycogenolysis
Mammalian liver


(a)
Extracellular surface
Mucin strand
Protein
Plasma membrane
H2O
Vesicle
Vesicle fuses with membrane
Exocytosis of vesicle


Forming secretory vesicle
trans-Golgi reticulum
trans
medial
cis
Golgi complex
cis-Golgi reticulum
ER-to-Golgi transfer vesicles
Transitional elements of rough ER
Rough ER
(a)
0.5 μm


Apical membrane
Tight junction
2
TGN
4
Golgi
3
1
Rough ER
Basolateral membrane