ENDOCRINE PHYSIOLOGY

- Uses chemical signals for cell to cell communication
- Coordinates the function of cells
- Response to an endocrine signal occurs within minutes to hours

Chemical Regulating Systems: Overview

- Pheromones: organism to organism communication
- Hormones: cell to cell communication molecules
  - Made in gland(s) or cells
  - Transported by blood
  - Distant or local target tissue receptors
  - Activates physiological response

Types of hormones

- **Functional**
  - Endocrine Hormones – Travel through the blood to act at a site distant from the secreting cell or gland
  - Paracrine Hormones – Act on cells near the secreting cell
  - Autocrine Hormones – Act on the secreting cell
  - Neurocrine Hormones – Secreted by neural cells
    - neurotransmitters
    - neurohormones
- **Chemical**
  - Protein & Polypeptide
  - Amine (amino acid derived)
  - Steroid

Long Distance Communication: Endocrine Hormones

- Signal Chemicals
- Made in endocrine cells
- Transported via blood
- Receptors on target cells

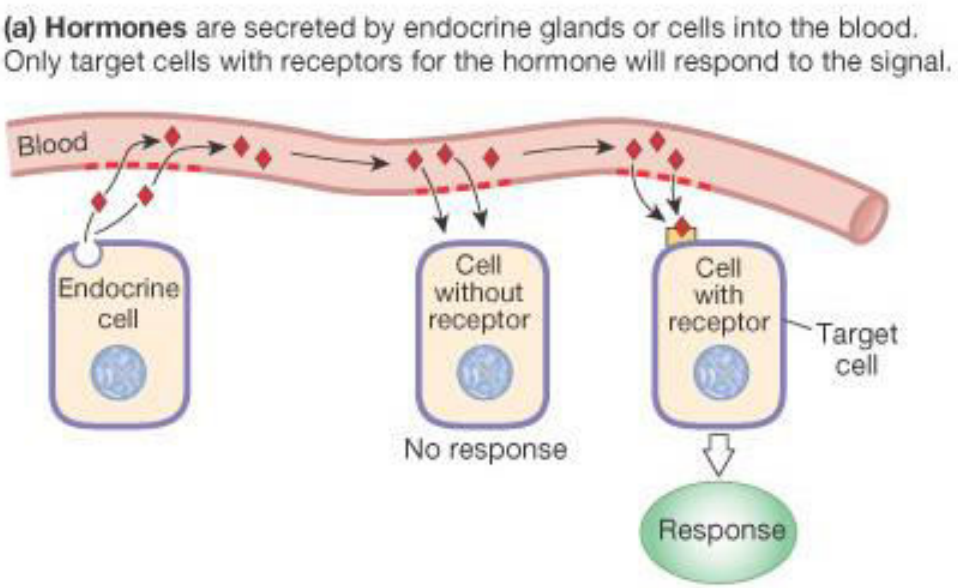
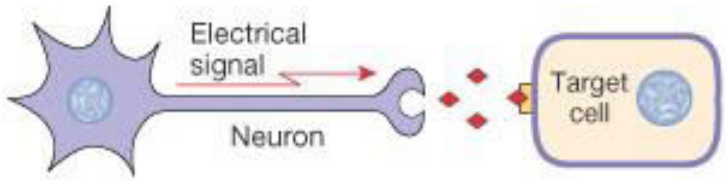


Figure 6-2a: Long distance cell-to-cell communication

(b) Neurotransmitters are chemicals secreted by neurons that diffuse across a small gap to the target cell. Neurons use electrical signals as well.



(c) Neurohormones are chemicals released by neurons into the blood for action at distant targets.

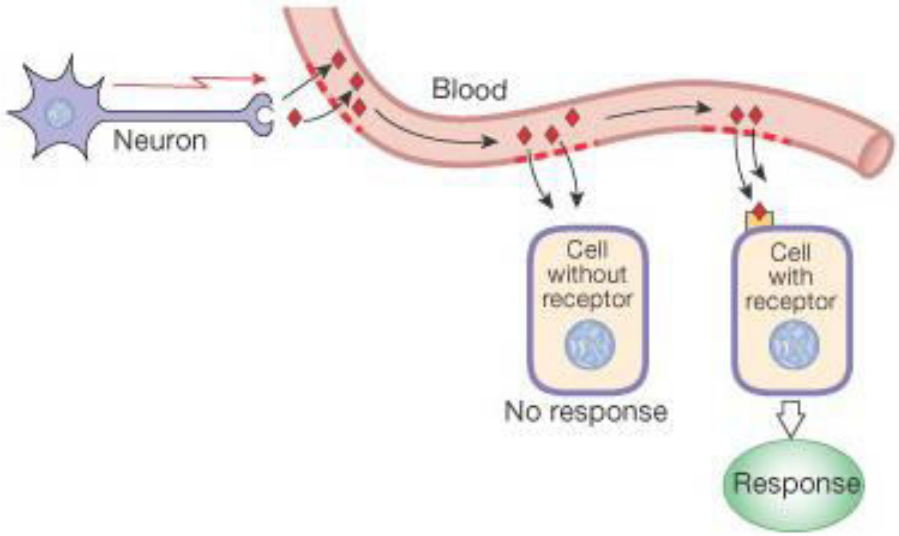


Figure 6-2b, c: Long distance cell-to-cell communication

Paracrine and Autocrine Hormones

- Local communication
- Signal chemicals diffuse to target
- Example: Cytokines
  - Autocrine–receptor on same cell
  - Paracrine–neighboring cells

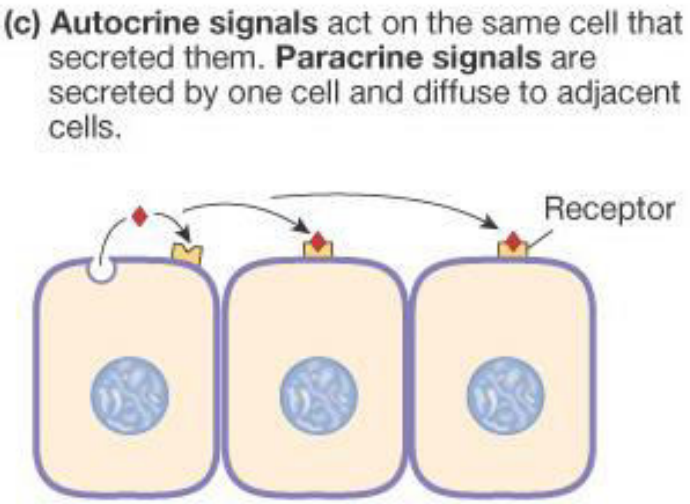
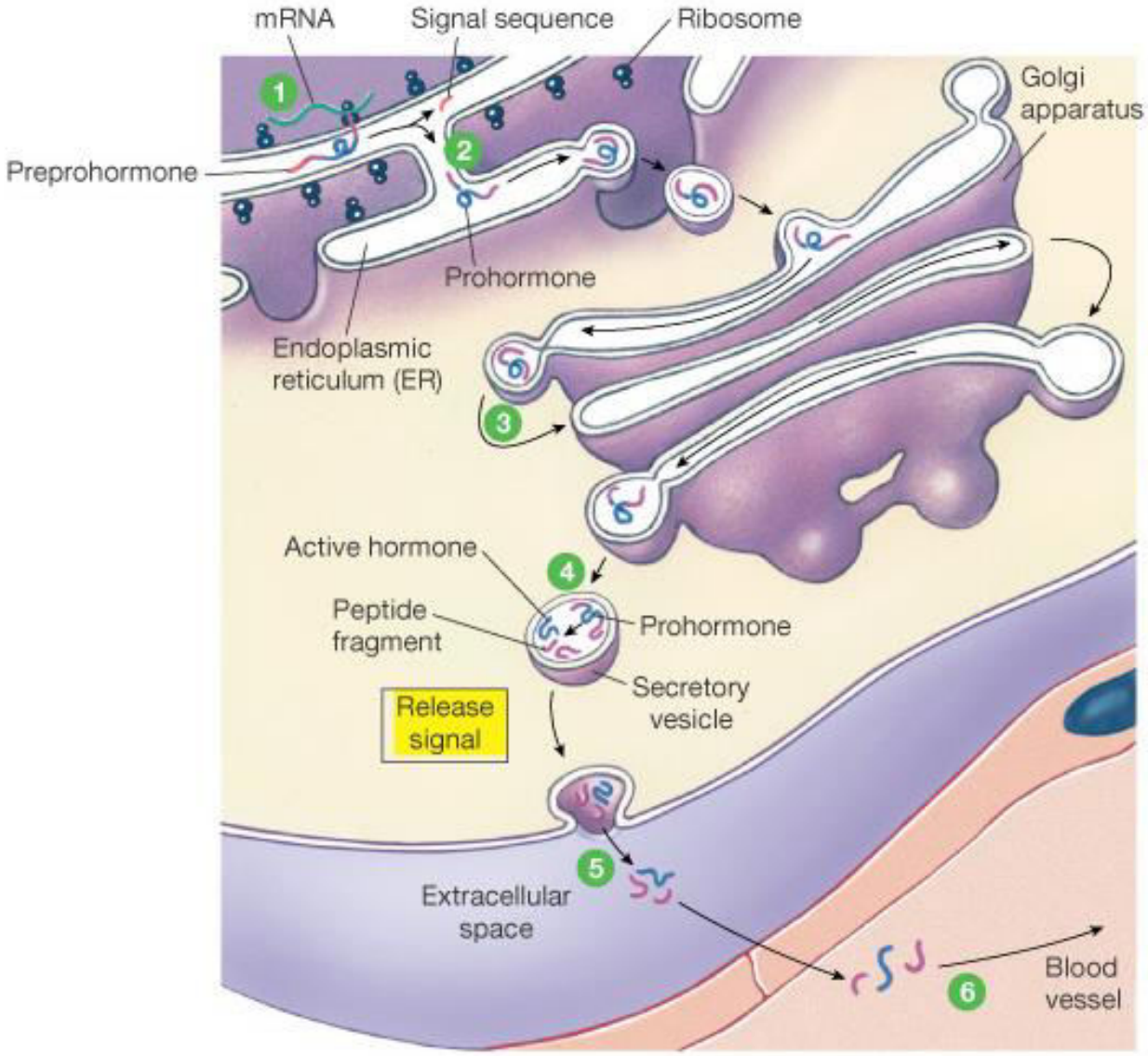


Figure 6-1c: Direct and local cell-to-cell communication

Protein and Polypeptide Hormones: Synthesis and Release



1. Messenger RNA on the ribosomes of the ER binds amino acids into a peptide chain called a **preprohormone**. The chain is directed into the ER lumen by a **signal sequence** of amino acids.
2. Enzymes in the ER chop off the signal sequence, creating an inactive **prohormone**.
3. The prohormone passes from the ER through the Golgi apparatus.
4. Secretory vesicles containing enzymes and prohormone bud off the Golgi. The enzymes chop the prohormone into one or more active peptides plus additional peptide fragments.
5. The secretory vesicle releases its contents by exocytosis into the extracellular space.
6. The hormone moves into the circulation for transport to its target.

Figure 7-3: Peptide hormone synthesis, packaging, and release

Protein and Polypeptide Hormone Receptors

- Binds to surface receptor
- Transduction
- System activation
  - Open ion channel
  - Enzyme activation
    - Second messenger systems
    - Protein synthesis

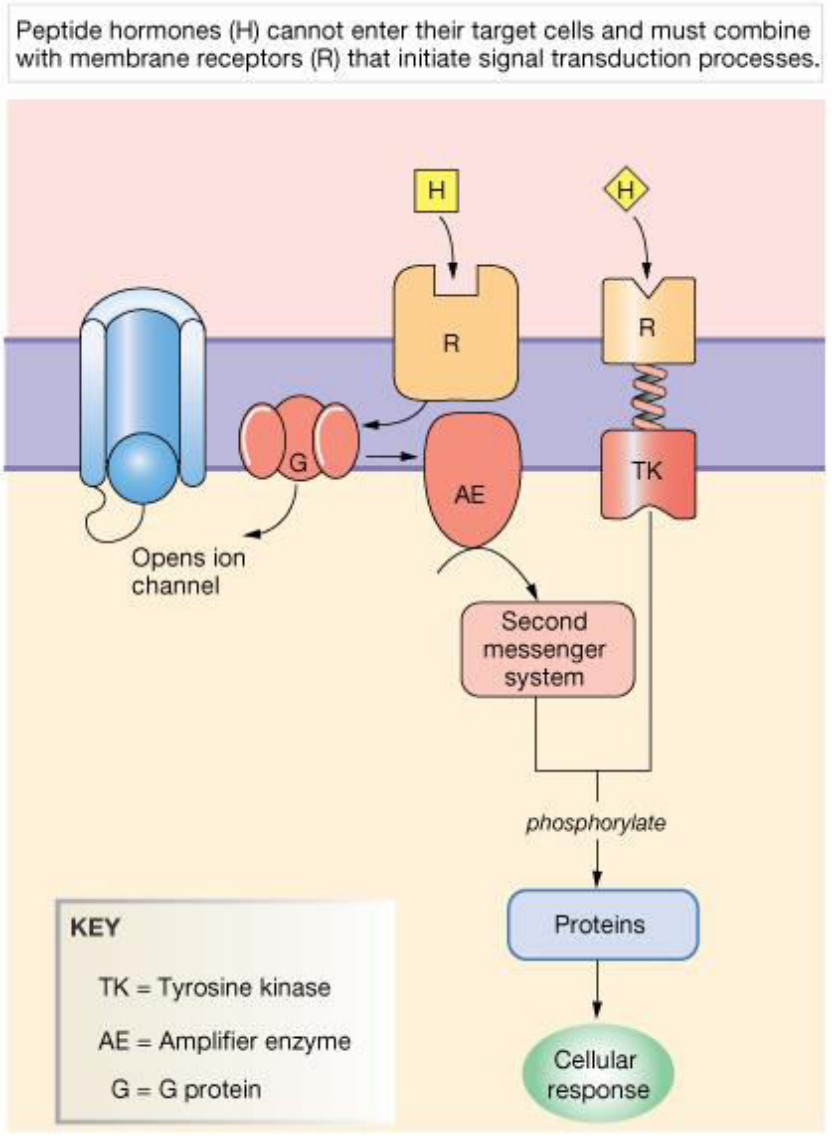


Figure 7-5: Membrane receptors for peptide hormones

Amine Hormones

- Derived from the amino acid tyrosine
- Includes thyroid hormones and catecholamines
- Stored until secreted
- Receptor locations
  - Surface
  - Intracellular

Amine Hormone Structure

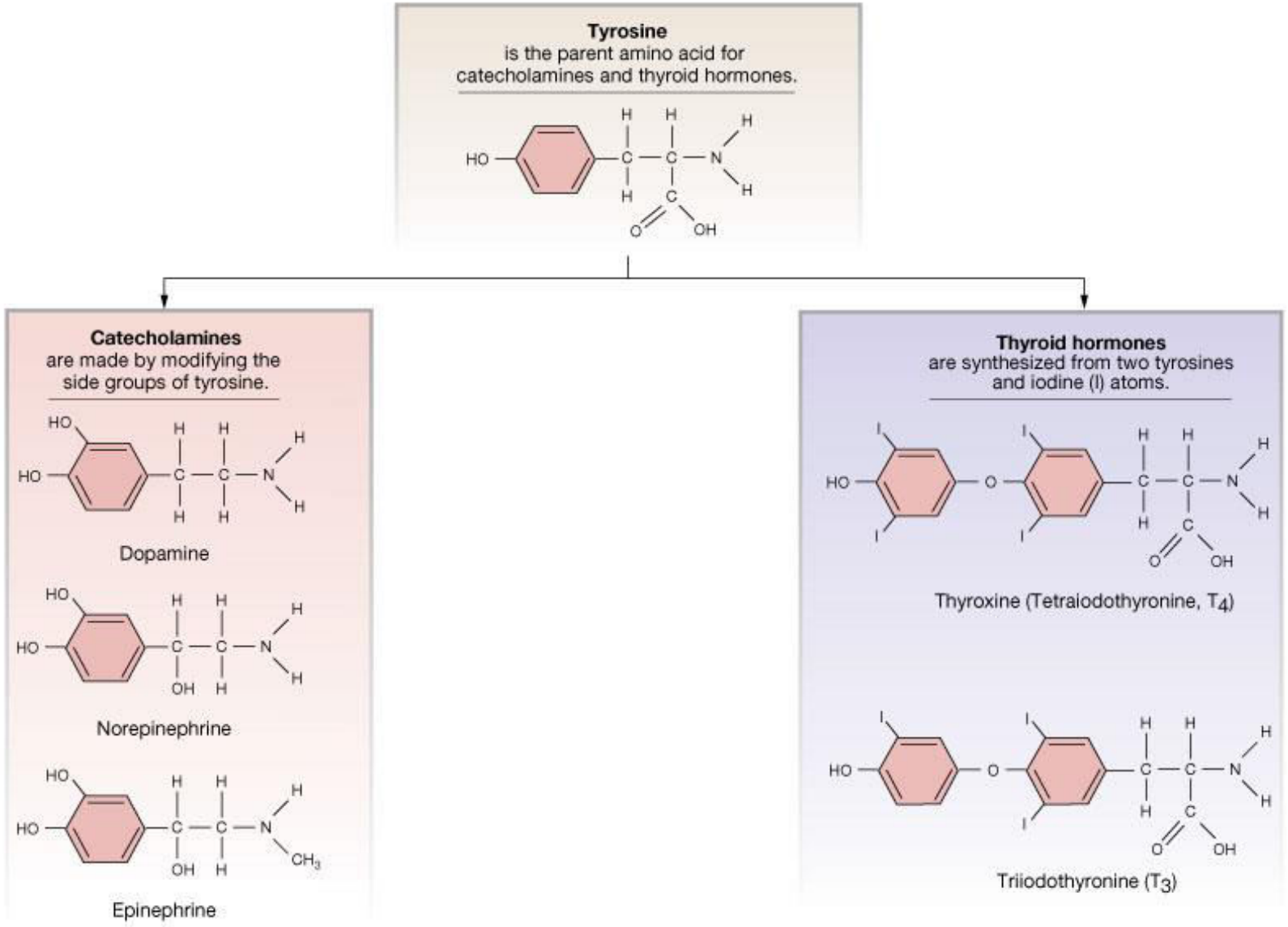


Figure 7-8: Tyrosine-derived amine hormones

Membrane Receptor Classes

- Ligand- gated channel
- Receptor enzymes
- G-protein-coupled
- Integrin

- Membrane associated receptors
  - External reactions
  - Internal reactions
- Receptors bind specific ligand
  - Hormones
  - Cell recognition molecules

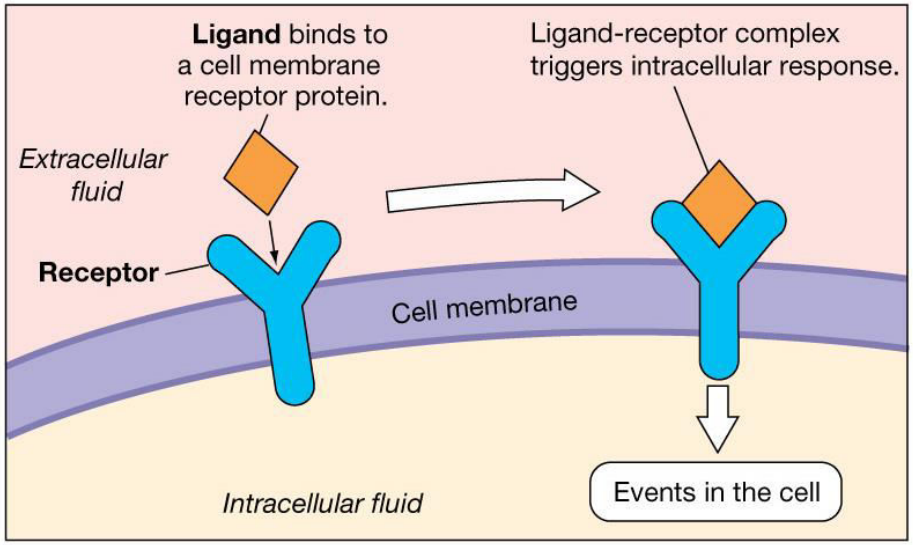


Figure 5-6: Cell membrane receptor

Membrane Receptor Signal Pathways

- Signal molecule (ligand)
- Receptor
- Intracellular signal
- Target protein
- Response

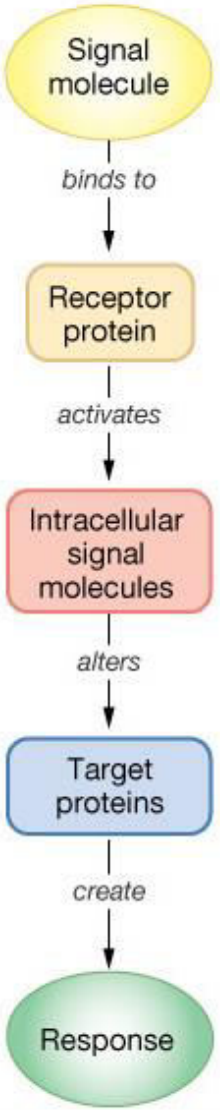


Figure 6-3: Signal pathways

Steroid Hormones: Characteristics

- Are made from cholesterol, are lipophilic & can enter target cell
- Are immediately released from cell after synthesis
- Interact with cytoplasmic or nuclear receptors
- Activate DNA for protein synthesis
- Are slower acting and have longer half-life than peptide hormones
- Examples: cortisol, estrogen & testosterone

Steroid Hormones: Structure

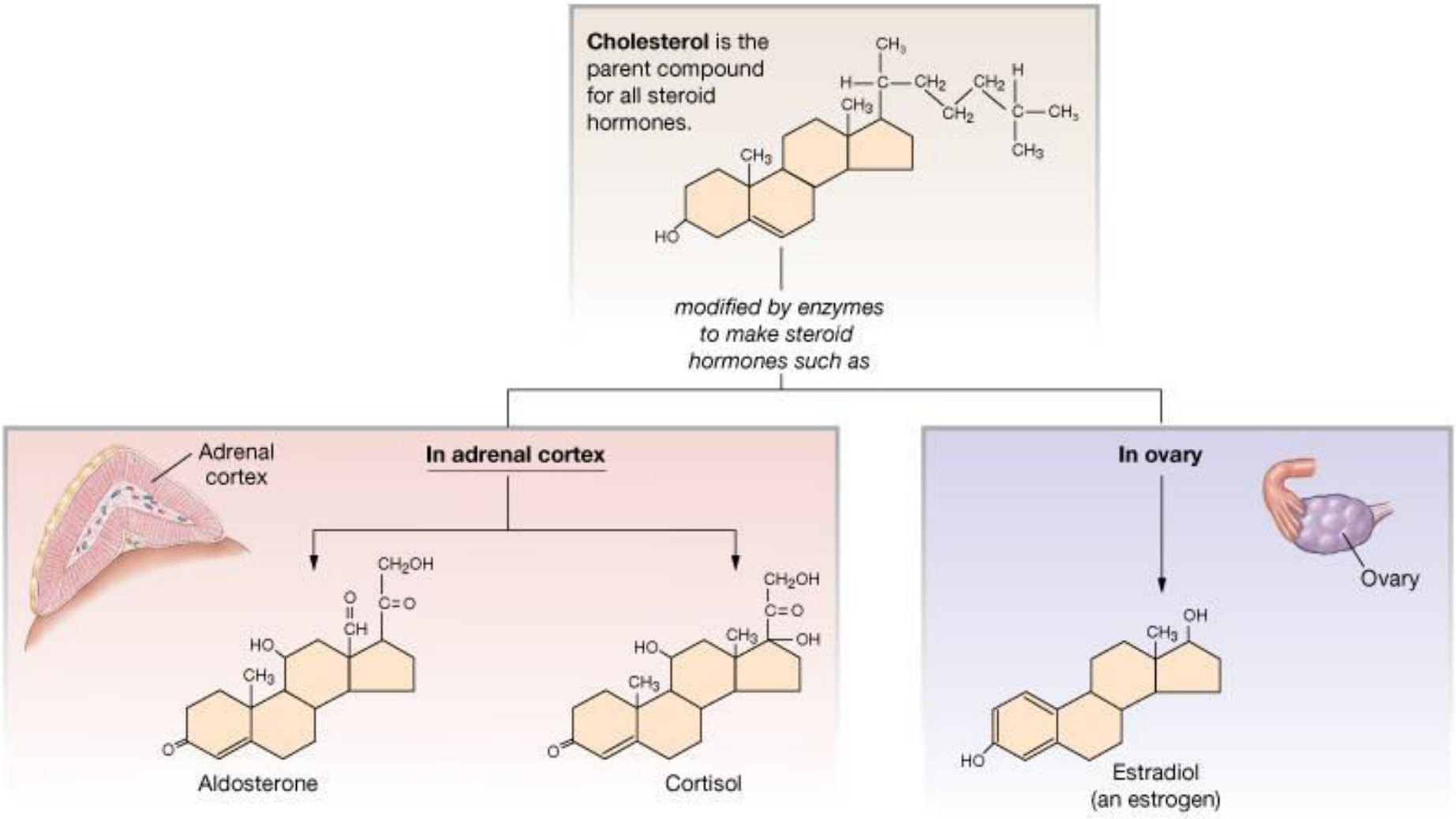
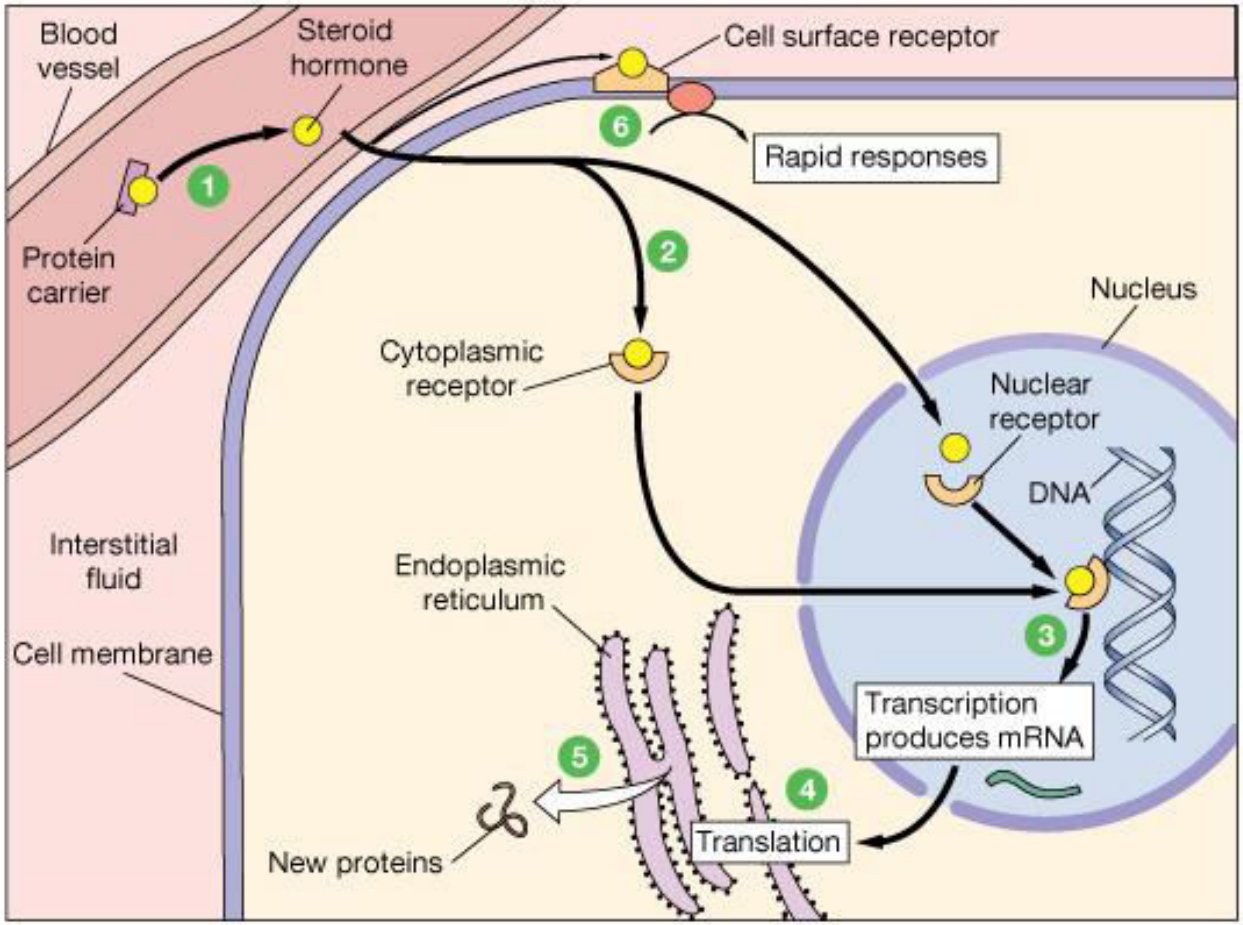


Figure 7-6: Steroid hormones are derived from cholesterol

Steroid Hormones: Action



1. Most hydrophobic steroids are bound to plasma protein carriers. Only unbound hormones can diffuse into the target cell.
2. Steroid hormone receptors are in the cytoplasm or nucleus.
3. The receptor-hormone complex binds to DNA and activates or represses one or more genes.
4. Activated genes create new mRNA that moves back to the cytoplasm.
5. Translation produces new proteins for cell processes.
6. Some steroid hormones also bind to membrane receptors that use second messenger systems to create rapid cellular responses.

Figure 7-7: Steroid hormone action

Receptor locations

- Cytosolic or Nuclear
  - Lipophilic ligand enters cell
  - Often activates gene
  - Slower response
- Cell membrane
  - Lipophobic ligand can't enter cell
  - Outer surface receptor
  - Fast response

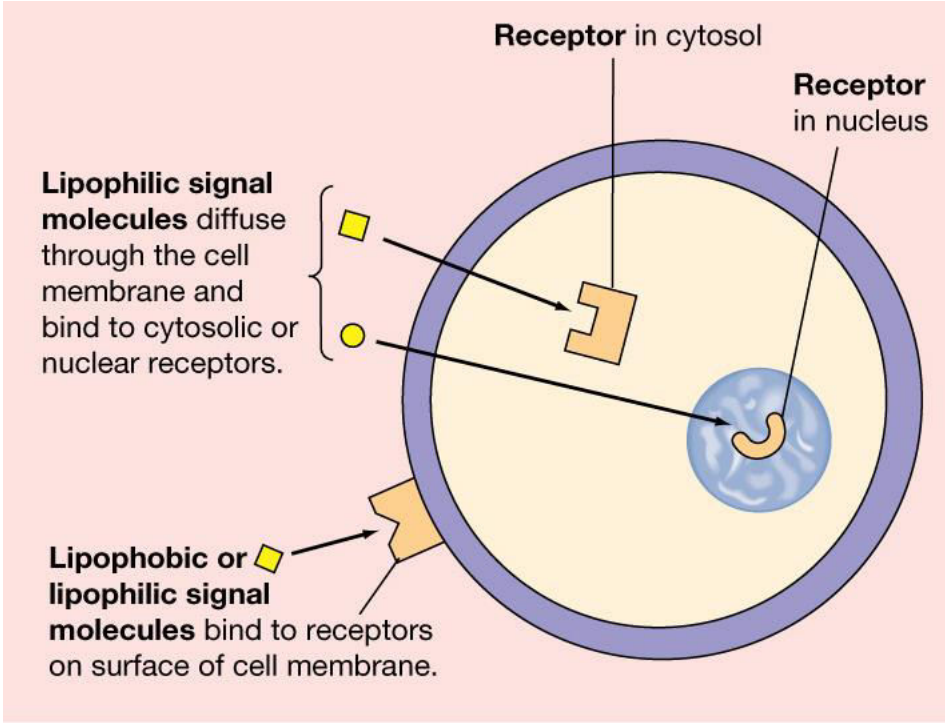


Figure 6-4: Target cell receptors

Feedback Loops

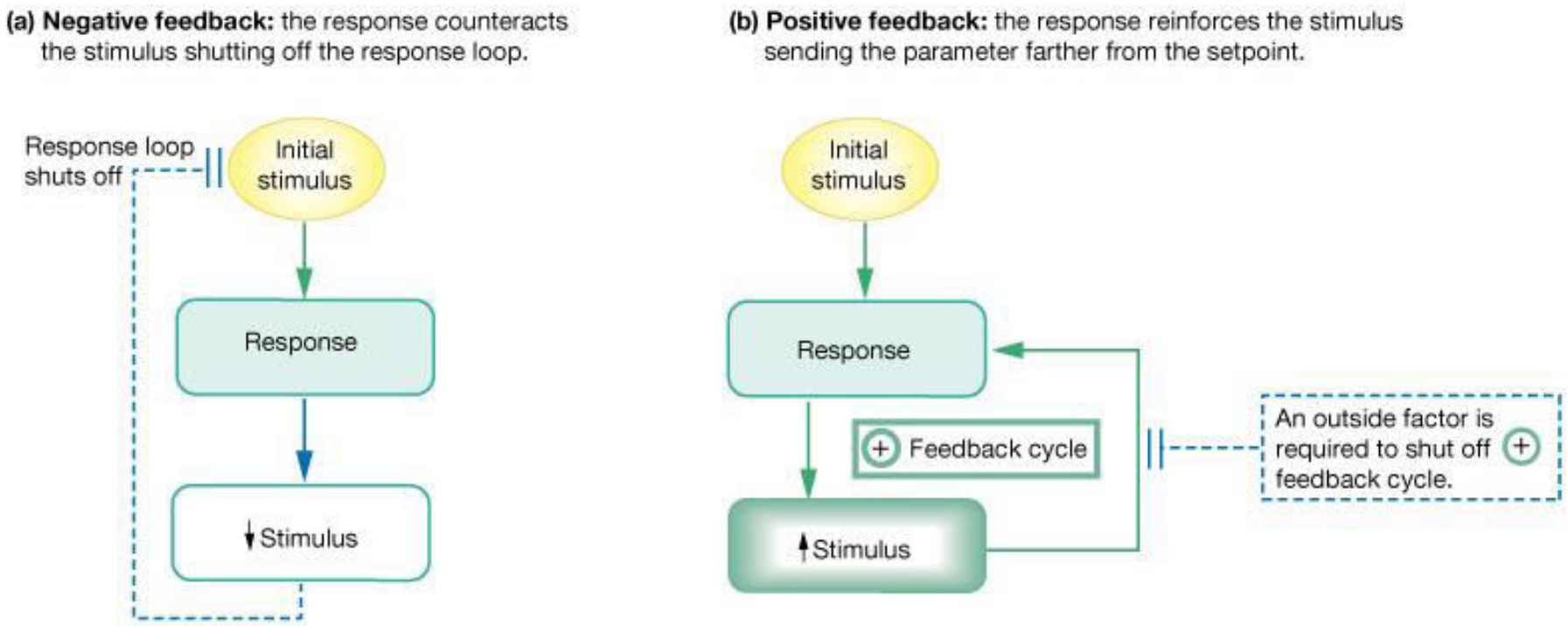


Figure 6-26: Negative and positive feedback

Negative Feedback Controls: Long & Short Loop Reflexes

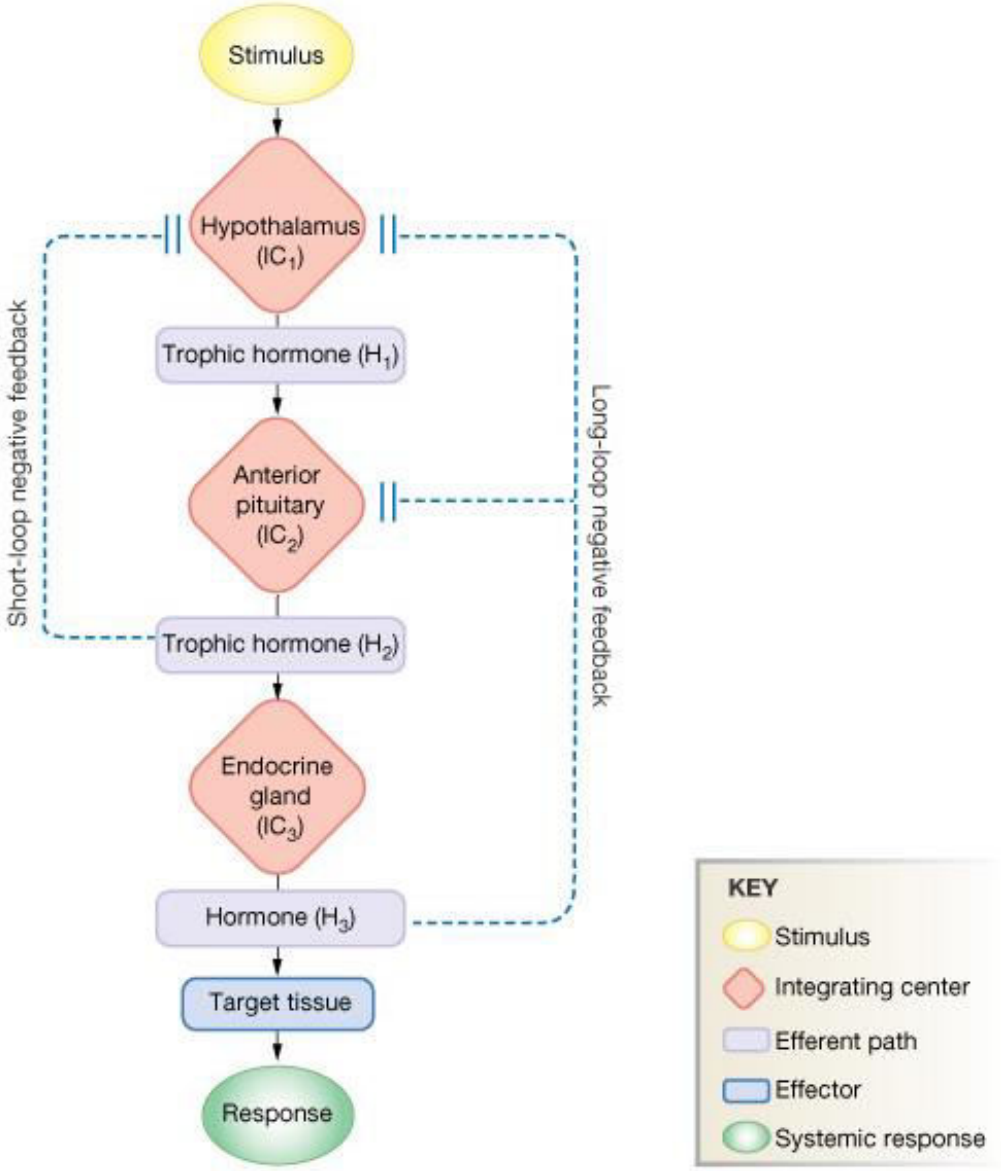


Figure 7-14: Negative feedback loops in the hypothalamicanterior pituitary pathway

Endocrine Reflex Pathways: Overview

- Stimulus
- Afferent signal
- Integration
- Efferent signal (the hormone)
- Physiological action
- Negative feedback

Endocrine Reflex Pathways: Overview

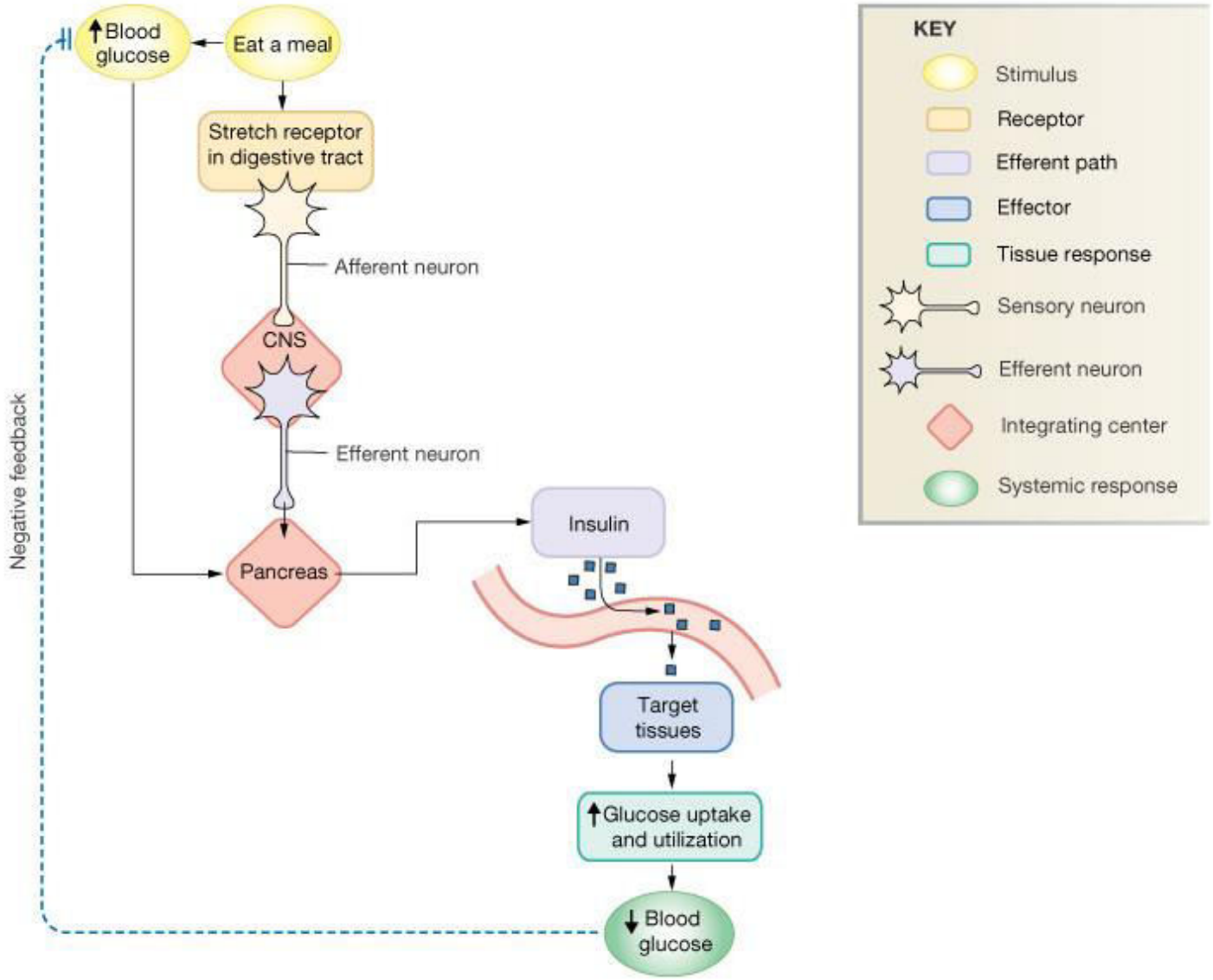


Figure 7-9: Hormones may have multiple stimuli for their release

Pathologies: Over or Under Production

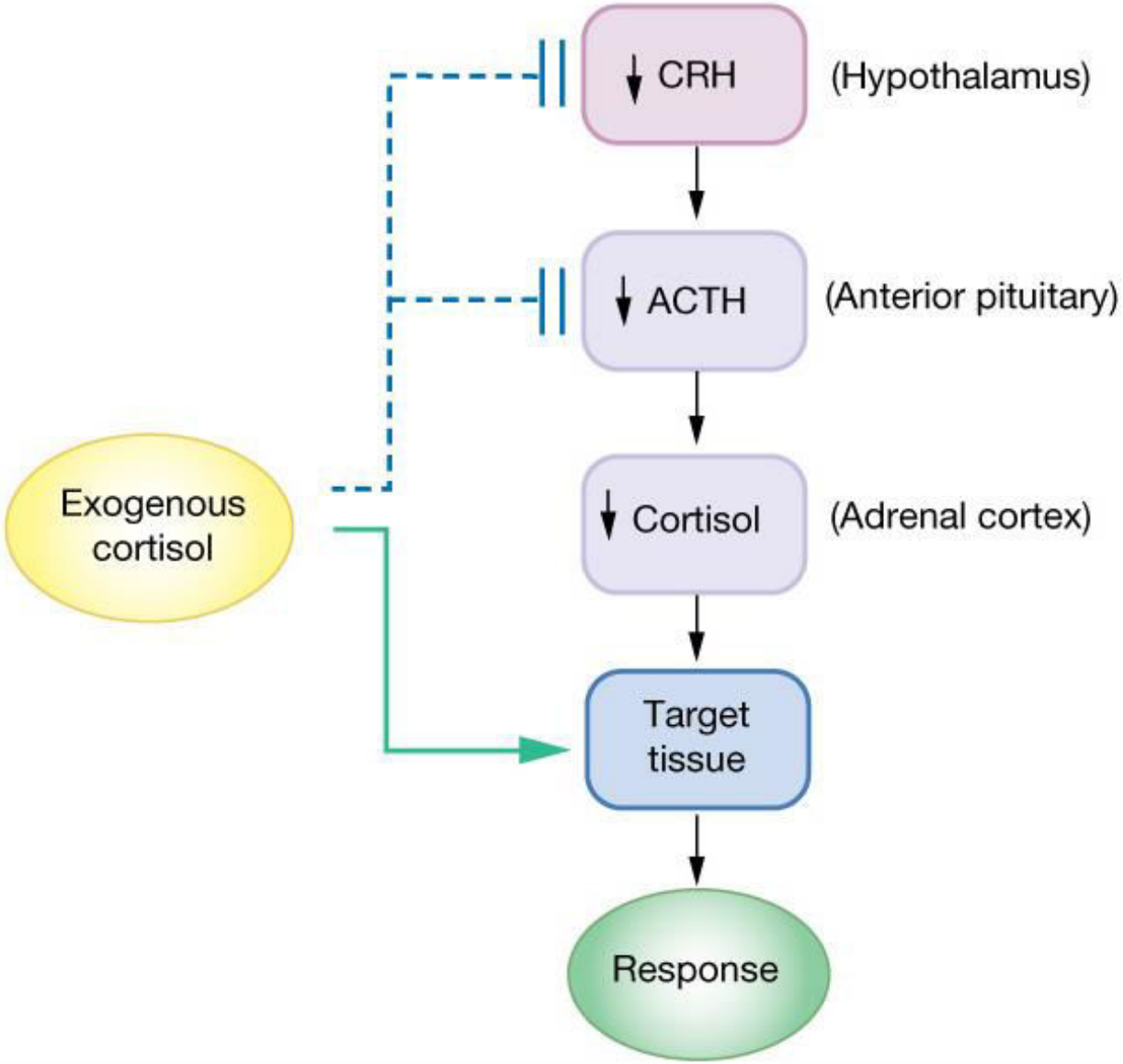


Figure 7-19: Negative feedback by exogenous cortisol

Pathologies: Due to Receptors

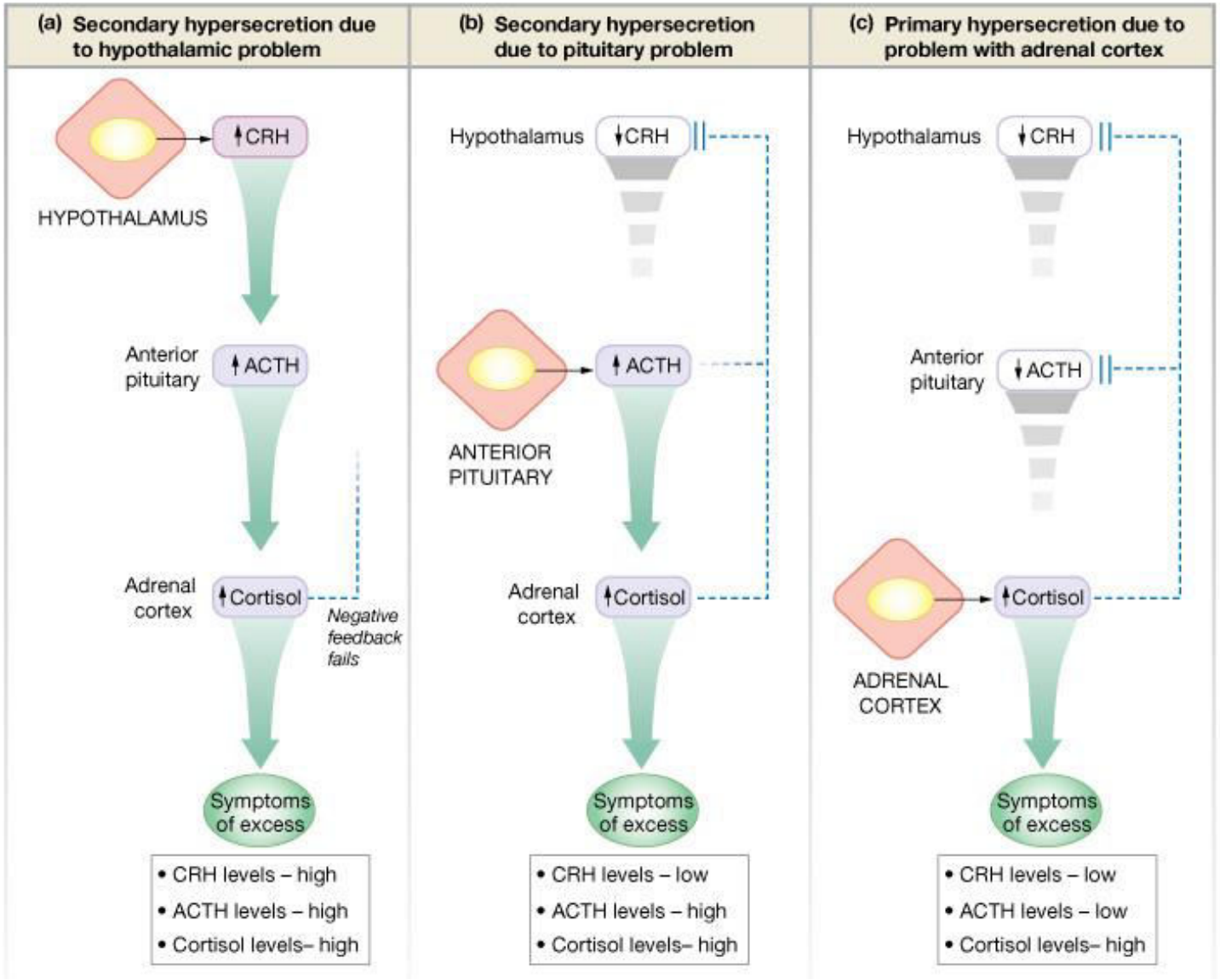


Figure 7-20: Primary and secondary hypersecretion of cortisol

Homeostasis & Controls

- Successful compensation
  - Homeostasis reestablished
- Failure to compensate
  - Pathophysiology
    - Illness
    - Death

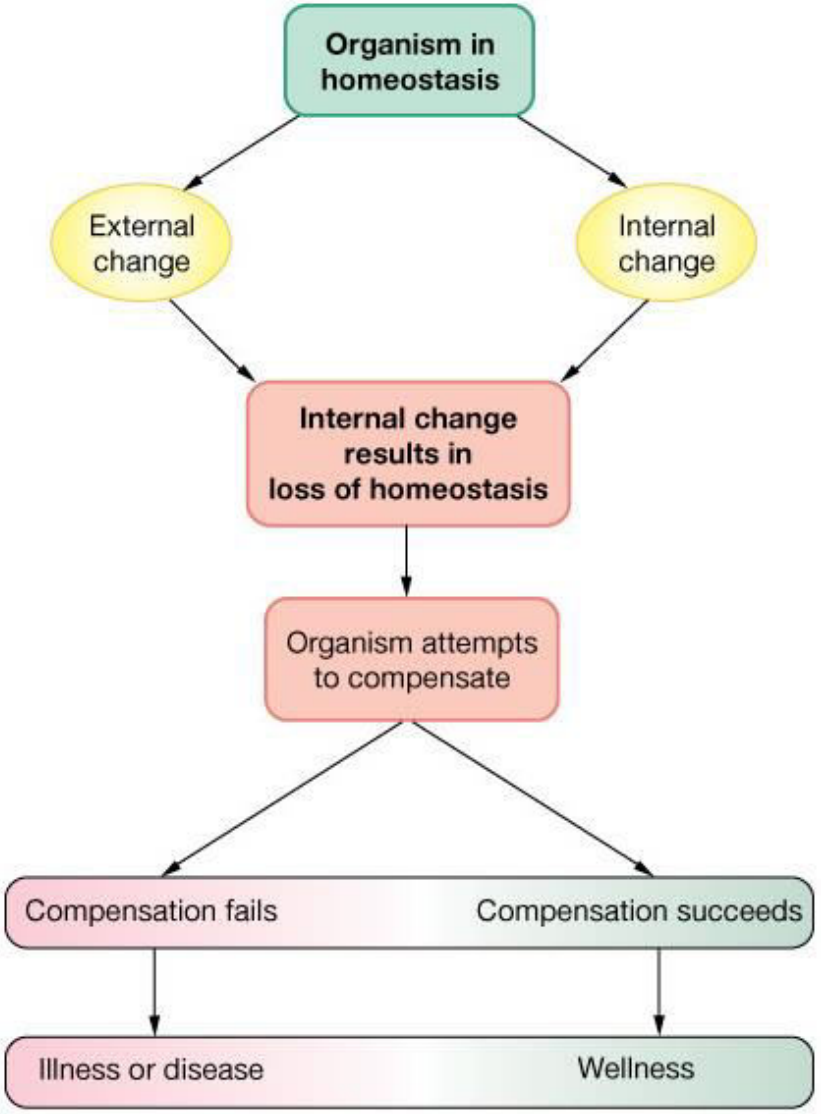


Figure 1-5: Homeostasis

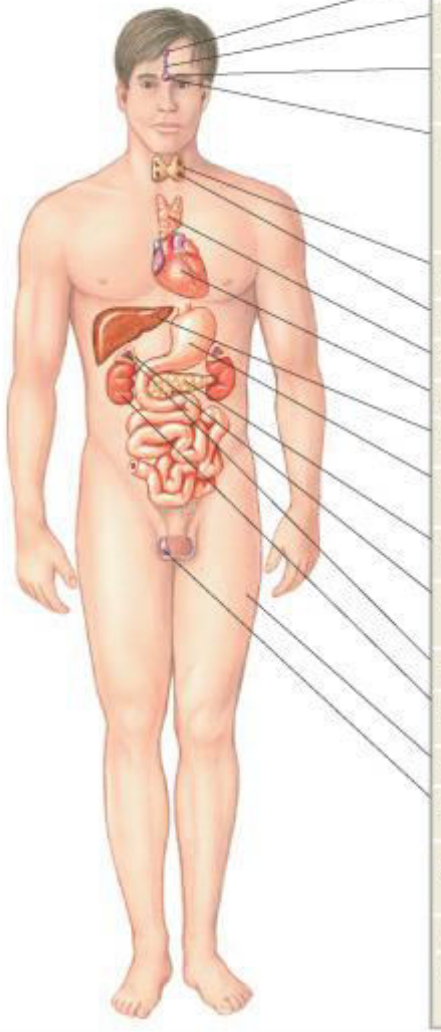
Summary

- Endocrine glands throughout body are key to chemical integration and homeostasis
- Protein, polypeptide, amine and a few steroid hormones are plasma soluble and target membrane
- Surface receptors transduce signals into cell and activate via second messengers

Summary

- Most steroid and some amine hormones are lipophilic, can pass into cell, bind on cytoplasmic or nuclear receptors and activate DNA for protein synthesis
- Hypothalamus, pituitary trophic hormone pathways coordinate endocrine regulation

Summary of the Endocrine System



Location	Gland or cell?	Chemical class
Pineal gland	Gland	Amine
Hypothalamus	Clusters of neurons	Peptides
Posterior pituitary	Extensions of hypothalamic neurons	Peptides
Anterior pituitary	Gland	Peptides
Thyroid	Gland	Iodinated amines Peptide
Parathyroid	Gland	Peptide
Thymus	Gland	Peptides
Heart	Cells	Peptide
Liver	Cells	Peptides
Stomach and small intestine	Cells	Peptides
Pancreas	Gland	Peptide
Adrenal cortex	Gland	Steroids
Adrenal medulla	Gland	Amines
Kidney	Cells	Peptide Steroid
Skin	Cells	Steroid
Testes (male)	Glands	Steroids Peptide
Ovaries (female)	Glands	Steroids Peptide
Adipose tissue	Cells	Peptide
Placenta (pregnant females only)	Gland	Steroids Peptide

Figure 7-2-1: ANATOMY SUMMARY: Hormones

Summary of the Endocrine System

Hormone	*Target*	*Main Effect*
Melatonin	Unclear in humans	Circadian rhythms. Other effects uncertain
Trophic hormones (see Fig. 7-13) See posterior pituitary	Anterior pituitary	Release or inhibit pituitary hormones
Oxytocin (OT)	Breast and uterus	Milk ejection; labor and delivery; behavior
Vasopressin (ADH) Prolactin (PRL) Growth hormone (GH, somatotropin) Corticotropin (ACTH) Thyrotropin (TSH) Follicle stimulating hormone (FSH) Luteinizing hormone (LH)	Kidney Breast Many tissues Adrenal cortex Thyroid gland Gonads Gonads	Water reabsorption Milk production Growth and metabolism Cortisol release Thyroid hormone synthesis and release Egg or sperm production; sex hormone production Sex hormone production; egg or sperm production
Triiodothyronine and thyroxine (T_3, T_4) Calcitonin (CT)	Many tissues Bone	Metabolism, growth and development Plasma calcium levels (minimal effect in humans)
Parathyroid hormone (PTH)	Bone, kidney	Regulate plasma calcium and phosphate levels
Thymosin, thymopoietin	Lymphocytes	Lymphocyte development
Atrial natriuretic peptide (ANP)	Kidneys	Increase sodium excretion
Angiotensinogen Insulin-like growth factors (IGF)	Adrenal cortex, blood vessels, brain Many tissues	Aldosterone secretion, increase blood pressure Growth

Figure 7-2-2: ANATOMY SUMMARY: Hormones

Summary of the Endocrine System

Hormone	*Target*	*Main Effect*
Gastrin, cholecystokinin (CCK), secretin, and others	GI tract and pancreas	Assist digestion and absorption of nutrients
Insulin, glucagon, somatostatin (SS), pancreatic polypeptide	Many tissues	Metabolism of glucose and other nutrients
Aldosterone Cortisol Androgens	Kidney Many tissues Many tissues	Na^+ and K^+ homeostasis Stress response Sex drive in females
Epinephrine, norepinephrine	Many tissues	Fight-or-flight response
Erythropoietin (EPO) 1,25 Dihydroxy-vitamin D_3 (calciferol)	Bone marrow Intestine	Red blood cell production Increase calcium absorption
Vitamin D_3	Intermediate form of hormone	Precursor of 1,25 dihydroxy-vitamin D_3
Androgen Inhibin	Many tissues Anterior pituitary	Sperm production, secondary sex characteristics Inhibit FSH secretion
Estrogens and progesterone Ovarian inhibin Relaxin (pregnancy)	Many tissues Anterior pituitary Uterine muscle	Egg production, secondary sex characteristics Inhibit FSH secretion Relaxes muscle
Leptin	Hypothalamus, other tissues	Food intake, metabolism, reproduction
Estrogens and progesterone (P) Chorionic somatomammotropin (CS) Chorionic gonadotropin (CG)	Many tissues Many tissues Corpus luteum of ovary	Fetal and maternal development Metabolism Hormone secretion

Figure 7-2-3: ANATOMY SUMMARY: Hormones