Chapter 18

The Endocrine System

An Introduction to the Endocrine System

- The Endocrine System
  - Regulates long-term processes
    - Growth
    - Development
    - Reproduction
  - Uses chemical messengers to relay information and instructions between cells

18-1 Homeostasis and Intercellular Communication

- **Direct Communication**
  - Exchange of ions and molecules between adjacent cells across gap junctions
  - Occurs between two cells of same type
  - Highly specialized and relatively rare
- **Paracrine Communication**
  - Uses chemical signals to transfer information from cell to cell within single tissue
  - Most common form of intercellular communication

18-1 Homeostasis and Intercellular Communication

- **Endocrine Communication**
  - Endocrine cells release chemicals (hormones) into bloodstream
  - Alters metabolic activities of many tissues and organs simultaneously

18-1 Homeostasis and Intercellular Communication

- **Target Cells**
  - Are specific cells that possess receptors needed to bind and “read” hormonal messages
- **Hormones**
  - Stimulate synthesis of enzymes or structural proteins
  - Increase or decrease rate of synthesis
  - Turn existing enzyme or membrane channel “on” or “off”

18-1 Homeostasis and Intercellular Communication

- **Synaptic Communication**

- Ideal for crisis management
- Occurs across synaptic clefts
- Chemical message is “neurotransmitter”
- Limited to a very specific area

18-2 Hormones

- Classes of Hormones
  - Hormones can be divided into three groups
    1. **Amino acid derivatives**
    2. **Peptide hormones**
    3. **Lipid derivatives**
- Secretion and Distribution of Hormones
  - Hormones circulate freely or travel bound to special carrier proteins

18-2 Hormones

- Amino Acid Derivatives
  - Are small molecules structurally related to amino acids
    - Derivatives of tyrosine
      - Thyroid hormones
      - Catecholamines
        - Epinephrine, norepinephrine
    - Derivatives of tryptophan
      - Dopamine, serotonin, melatonin

18-2 Hormones

- Peptide Hormones
  - Are chains of amino acids
  - Most are synthesized as prohormones
    - Inactive molecules converted to active hormones before or after they are secreted
  - Glycoproteins
    - Proteins are more than 200 amino acids long and have carbohydrate side chains
      - *Thyroid-stimulating hormone* (*TSH*)
      - *Luteinizing hormone* (*LH*)
      - *Follicle-stimulating hormone* (*FSH*)

18-2 Hormones

- Peptide Hormones
  - **Short polypeptides/small proteins**
    - Short chain polypeptides
      - *Antidiuretic hormone* (*ADH*) and *oxytocin* (*OXT*) (each 9 amino acids long)

        - **Small proteins**
            - *Growth hormone* (*GH*; 191 amino acids) and *prolactin* (*PRL*; 198 amino acids)
        - Includes all hormones secreted by:
            - Hypothalamus, heart, thymus, digestive tract, pancreas, and posterior lobe of the pituitary gland, as well as several hormones produced in other organs

18-2 Hormones

- Lipid Derivatives
    - **Eicosanoids** – derived from arachidonic acid, a 20-carbon fatty acid
        - Paracrine factors that coordinate cellular activities and affect enzymatic processes (such as blood clotting) in extracellular fluids
        - Some eicosanoids (such as **leukotrienes**) have secondary roles as hormones
        - A second group of eicosanoids – **prostaglandins** – involved primarily in coordinating local cellular activities
        - In some tissues, prostaglandins are converted to **thromboxanes** and **prostacyclins**, which also have strong paracrine effects

18-2 Hormones

- Lipid Derivatives
    - **Steroid hormones** – derived from cholesterol
        - Released by:
            - The reproductive organs (androgens by the testes in males, estrogens and progestins by the ovaries in females)
            - The cortex of the adrenal glands (corticosteroids)
            - The kidneys (calcitriol)
        - Because circulating steroid hormones are bound to specific transport proteins in the plasma:
            - They remain in circulation longer than secreted peptide hormones

18-2 Hormones

- Secretion and Distribution of Hormones
    - Free Hormones
        - Remain functional for less than 1 hour
            1. Diffuse out of bloodstream and bind to receptors on target cells
            2. Are broken down and absorbed by cells of liver or kidneys
            3. Are broken down by enzymes in plasma or interstitial fluids

18-2 Hormones

- Secretion and Distribution of Hormones
    - Thyroid and Steroid Hormones

        - Remain in circulation much longer because most are “bound”
        - Enter bloodstream
            - More than 99 percent become attached to special transport proteins
            - Bloodstream contains substantial reserve of bound hormones

18-2 Hormones

- Mechanisms of Hormone Action
    - Hormone Receptor
        - Is a protein molecule to which a particular molecule binds strongly
        - Responds to several different hormones
        - Different tissues have different combinations of receptors
        - Presence or absence of specific receptor determines hormonal sensitivity

18-2 Hormones

- Hormones and Plasma Membrane Receptors
    - Catecholamines and Peptide Hormones
        - Are not lipid soluble
        - Unable to penetrate plasma membrane
        - Bind to receptor proteins at *outer* surface of plasma membrane (extracellular receptors)
    - Eicosanoids
        - Are lipid soluble
        - Diffuse across plasma membrane to reach receptor proteins on *inner* surface of plasma membrane (intracellular receptors)

18-2 Hormones

- Hormones and Plasma Membrane Receptors
    - **First** and **Second Messengers**
        - Bind to receptors in plasma membrane
        - Cannot have direct effect on activities inside target cell
        - Use intracellular intermediary to exert effects

18-2 Hormones

- **First Messenger**
    - Leads to **second messenger**
    - May act as enzyme activator, inhibitor, or cofactor
    - Results in change in rates of metabolic reactions

18-2 Hormones

- Important **Second Messengers**

1. *Cyclic-AMP* (cAMP)
   - Derivative of ATP
2. *Cyclic-GMP* (cGMP)
   - Derivative of GTP
3. Calcium ions

18-2 Hormones

- The Process of *Amplification*
  - Is the binding of a small number of hormone molecules to membrane receptors
  - Leads to thousands of second messengers in cell
  - Magnifies effect of hormone on target cell

18-2 Hormones

- **Down-regulation**
  - Presence of a hormone triggers decrease in number of hormone receptors
  - When levels of particular hormone are high, cells become *less* sensitive to it
- **Up-regulation**
  - Absence of a hormone triggers increase in number of hormone receptors
  - When levels of particular hormone are low, cells become *more* sensitive to it

18-2 Hormones

- G **Protein**
  - Enzyme complex coupled to membrane receptor
  - Involved in link between first messenger and second messenger
- G Proteins and cAMP
  - **Adenylate cyclase** is activated when hormone binds to receptor at membrane surface and changes concentration of second messenger cyclic-AMP (cAMP) within cell
    - Increased cAMP level accelerates metabolic activity within cell

18-2 Hormones

- G Proteins and Calcium Ions
  - Activated G proteins trigger:
    - Opening of calcium ion channels in membrane
    - Release of calcium ions from intracellular stores
    - G protein activates enzyme *phospholipase C* (*PLC*)
    - Enzyme triggers receptor cascade
      - Production of **diacylglycerol** (**DAG**) and **inositol triphosphate** (**IP_3**) from membrane phospholipids

- May further activate more calcium ion channels through **protein kinase C** (**PKC**)
- Calcium ions may activate **calmodulin**, which causes further cellular changes

18-2 Hormones

- Hormones and Intracellular Receptors
  - Alter rate of DNA transcription in nucleus
    - Change patterns of protein synthesis
  - Directly affect metabolic activity and structure of target cell
  - Include steroids and thyroid hormones

18-2 Hormones

- Control of Endocrine Activity by Endocrine Reflexes
  - **Endocrine Reflexes**
    - Functional counterparts of neural reflexes
    - In most cases, controlled by negative feedback mechanisms
      - Stimulus triggers production of hormone; the direct or indirect effects of the hormone reduce intensity of the stimulus

18-2 Hormones

- Endocrine Reflexes
  - Can be triggered by:
    1. *Humoral stimuli*
       - Changes in composition of extracellular fluid
    2. *Hormonal stimuli*
       - Arrival or removal of specific hormone
    3. *Neural stimuli*
       - Arrival of neurotransmitters at neuroglandular junctions

18-2 Hormones

- Endocrine Reflexes
  - Simple Endocrine Reflex
    - Involves only one hormone
    - Controls hormone secretion by the heart, pancreas, parathyroid gland, and digestive tract
  - Complex Endocrine Reflex
    - One or more intermediary steps
    - Two or more hormones
  - The hypothalamus provides highest level of endocrine control

18-2 Hormones

- Neuroendocrine Reflexes
  - Pathways include both neural and endocrine components
- Complex Commands
  - Issued by changing:
    - Amount of hormone secreted
    - Pattern of hormone release
      - Hypothalamic and pituitary hormones released in sudden bursts
      - Frequency changes response of target cells

18-3 The Pituitary Gland

- The **Pituitary Gland**
  - Also called **hypophysis**
  - Lies within *sella turcica*
    - *Sellar diaphragm*
      - A dural sheet that locks pituitary in position
      - Isolates it from cranial cavity
  - Hangs inferior to hypothalamus
    - Connected by **infundibulum**

18-3 The Pituitary Gland

- The Pituitary Gland
  - Releases nine important peptide hormones
  - Hormones bind to membrane receptors
    - Use cAMP as second messenger

18-3 The Pituitary Gland

- The **Anterior Lobe** of the Pituitary Gland
  - Also called **adenohypophysis**
    - Hormones "turn on" endocrine glands or support other organs
    - Has three regions
      1. **Pars distalis**
      2. **Pars tuberalis**
      3. **Pars intermedia**

18-3 The Pituitary Gland

- The Hypophyseal Portal System
  - *Median eminence*
    - Swelling near attachment of infundibulum
    - Where hypothalamic neurons release regulatory factors
      - Into interstitial fluids
      - Through **fenestrated capillaries**

18-3 The Pituitary Gland

- **Portal Vessels**
  - Blood vessels link two capillary networks
  - Entire complex is **portal system**
    - Ensures that regulatory factors reach intended target cells before entering general circulation

18-3 The Pituitary Gland

- Hypothalamic Control of the Anterior Lobe
  - Two classes of hypothalamic regulatory hormones
    1. **Releasing hormones** (**RH**)
       - Stimulate synthesis and secretion of one or more hormones at anterior lobe
    2. **Inhibiting hormones** (**IH**)
       - Prevent synthesis and secretion of hormones from the anterior lobe
  - Rate of secretion is controlled by negative feedback

18-3 The Pituitary Gland

- The **Posterior Lobe** of the Pituitary Gland
  - Also called **neurohypophysis**
    - Contains unmyelinated axons of hypothalamic neurons
    - **Supraoptic** and **paraventricular nuclei** manufacture:
      - **Antidiuretic hormone** (ADH)
      - **Oxytocin** (OXT)

18-4 The Thyroid Gland

- The Thyroid Gland
  - Lies inferior to thyroid cartilage of larynx
  - Consists of two **lobes** connected by narrow **isthmus**
    - **Thyroid follicles**
      - Hollow spheres lined by cuboidal epithelium
      - Cells surround **follicle cavity** that contains viscous colloid
      - Surrounded by network of capillaries that:
        - Deliver nutrients and regulatory hormones
        - Accept secretory products and metabolic wastes

18-4 The Thyroid Gland

- **Thyroglobulin** (Globular Protein)
  - Synthesized by follicle cells
  - Secreted into colloid of thyroid follicles
  - Molecules contain the amino acid *tyrosine*
- **Thyroxine** (**T_4**)

- Also called *tetraiodothyronine*
- Contains four iodide ions

- **Triiodothyronine** (**T_3**)
  - Contains three iodide ions

18-4 The Thyroid Gland

- **Thyroid-binding Globulins** (**TBGs**)
  - Plasma proteins that bind about 75 percent of T_4 and 70 percent of T_3 entering the bloodstream
- **Transthyretin** (*thyroid-binding prealbumin – TBPA*) and *albumin*
  - Bind most of the remaining thyroid hormones
- About 0.3 percent of T_3 and 0.03 percent of T_4 are unbound

18-4 The Thyroid Gland

- Thyroid-Stimulating Hormone (TSH)
  - Absence causes thyroid follicles to become inactive
    - Neither synthesis nor secretion occurs
  - Binds to membrane receptors
  - Activates key enzymes in thyroid hormone production

18-4 The Thyroid Gland

- Functions of Thyroid Hormones
  - Thyroid Hormones
    - Enter target cells by transport system
    - Affect most cells in body
    - Bind to receptors in:
      1. Cytoplasm
      2. Surfaces of mitochondria
      3. Nucleus
    - In children, essential to normal development of:
      - Skeletal, muscular, and nervous systems

18-4 The Thyroid Gland

- **Calorigenic Effect**
  - Cell consumes more energy resulting in increased heat generation
  - Is responsible for strong, immediate, and short-lived increase in rate of cellular metabolism

18-4 The Thyroid Gland

- Effects of Thyroid Hormones on Peripheral Tissues
  1. Elevates rates of oxygen consumption and energy consumption; in

children, may cause a rise in body temperature
2. Increases heart rate and force of contraction; generally results in a rise in blood pressure
3. Increases sensitivity to sympathetic stimulation
4. Maintains normal sensitivity of respiratory centers to changes in oxygen and carbon dioxide concentrations
5. Stimulates red blood cell formation and thus enhances oxygen delivery
6. Stimulates activity in other endocrine tissues
7. Accelerates turnover of minerals in bone

18-4 The Thyroid Gland

- The C Cells of the Thyroid Gland and Calcitonin
  - **C** (**clear**) **cells** also called *parafollicular cells*
  - Produce **calcitonin** (**CT**)
    - Helps regulate concentrations of Ca^{2+} in body fluids
      1. Inhibits osteoclasts, which slows the rate of Ca^{2+} release from bone
      2. Stimulates Ca^{2+} excretion by the kidneys

18-5 Parathyroid Glands

- Four Parathyroid Glands
  - Embedded in the posterior surface of the thyroid gland
  - Altogether, the four glands weigh 1.6 g
- **Parathyroid Hormone** (PTH) or *parathormone*
  - Produced by **parathyroid** (**chief**) **cells** in response to low concentrations of Ca^{2+}
  - Antagonist for calcitonin

18-5 Parathyroid Glands

- Three Effects of PTH
  1. It stimulates osteoclasts and inhibits osteoblasts
     - Accelerates mineral turnover and releases Ca^{2+} from bone
     - Reduces rate of calcium deposition in bone
  2. It enhances reabsorption of Ca^{2+} at kidneys, reducing urinary losses
  3. It stimulates formation and secretion of *calcitriol* by the kidneys
     - Effects complement or enhance PTH
     - Also enhances Ca^{2+}, PO_4^{3-} absorption by digestive tract

18-6 Adrenal Glands

- The **Adrenal Glands**
  - Lie along superior border of each kidney
  - Subdivided into:
    - Superficial **adrenal cortex**
      - Stores lipids, especially cholesterol and fatty acids

    - Manufactures steroid hormones (**corticosteroids**)
  - Inner **adrenal medulla**
    - Secretory activities controlled by sympathetic division of ANS
    - Produces epinephrine (adrenaline) and norepinephrine
    - Metabolic changes persist for several minutes

18-6 Adrenal Glands

- Adrenal Cortex
  - Subdivided into three regions
    1. **Zona glomerulosa**
    2. **Zona fasciculata**
    3. **Zona reticularis**

18-6 Adrenal Glands

- **Zona Glomerulosa**
  - Outer region of adrenal cortex
  - Produces **mineralocorticoids**
    - For example, **aldosterone**

18-6 Adrenal Glands

- **Aldosterone**
  - Stimulates conservation of sodium ions and elimination of potassium ions
  - Increases sensitivity of salt receptors in taste buds
  - Secretion responds to:
    - Drop in blood Na^+, blood volume, or blood pressure
    - Rise in blood K^+ concentration

18-6 Adrenal Glands

- **Zona Fasciculata**
  - Produces **glucocorticoids**
  - For example, **cortisol** (hydrocortisone) with **corticosterone**
    - Liver converts cortisol to **cortisone**
  - Secretion regulated by negative feedback
  - Has inhibitory effect on production of:
    - Corticotropin-releasing hormone (CRH) in hypothalamus
    - ACTH in adenohypophysis

18-6 Adrenal Glands

- **Glucocorticoids**
  - Accelerate glucose synthesis and glycogen formation
  - Show **anti-inflammatory** effects
    - Inhibit activities of white blood cells and other components of immune

system

18-6 Adrenal Glands

- **Zona Reticularis**
  - Network of endocrine cells
  - Forms narrow band bordering each adrenal medulla
  - Produces androgens under stimulation by ACTH

18-6 Adrenal Glands

- The Adrenal Medulla
  - Contains two types of secretory cells
    - One produces **epinephrine** (adrenaline)
      - 75 to 80 percent of medullary secretions
    - The other produces **norepinephrine** (noradrenaline)
      - 20 to 25 percent of medullary secretions

18-6 Adrenal Glands

- Epinephrine and Norepinephrine
  - Activation of the adrenal medullae has the following effects:
    - In skeletal muscles, epinephrine and norepinephrine trigger mobilization of glycogen reserves
    - And accelerate the breakdown of glucose to provide ATP
      - This combination increases both muscular strength and endurance
    - In adipose tissue, stored fats are broken down into fatty acids
      - Which are released into the bloodstream for other tissues to use for ATP production

18-6 Adrenal Glands

- Epinephrine and Norepinephrine
  - Activation of the adrenal medullae has the following effects:
    - In the liver, glycogen molecules are broken down
    - The resulting glucose molecules are released into the bloodstream
      - Primarily for use by neural tissue, which cannot shift to fatty acid metabolism
    - In the heart, the stimulation of beta 1 receptors triggers an increase in the rate and force of cardiac muscle contraction

18-7 Pineal Gland

- The **Pineal Gland**
  - Lies in posterior portion of roof of third ventricle
  - Contains **pinealocytes**
    - Synthesize hormone **melatonin**

18-7 Pineal Gland

- Functions of Melatonin:
  - *Inhibits reproductive functions*
  - *Protects against damage by free radicals*
  - *Influences circadian rhythms*

18-8 Pancreas

- The **Pancreas**
  - Lies between:
    - Inferior border of stomach
    - And proximal portion of small intestine
  - Contains exocrine and endocrine cells

18-8 Pancreas

- **Exocrine Pancreas**
  - Consists of clusters of gland cells called *pancreatic acini* and their attached ducts
  - Takes up roughly 99 percent of pancreatic volume
  - Gland and duct cells secrete alkaline, enzyme-rich fluid
    - That reaches the lumen of the digestive tract through a network of secretory ducts

18-8 Pancreas

- **Endocrine Pancreas**
  - Consists of cells that form clusters known as **pancreatic islets**, or *islets of Langerhans*
    1. **Alpha cells** produce glucagon
    2. **Beta cells** produce insulin
    3. **Delta cells** produce peptide hormone identical to GH–IH
    4. **F cells secrete pancreatic polypeptide** (**PP**)

18-8 Pancreas

- Blood Glucose Levels
  - When levels rise:
    - Beta cells secrete insulin, stimulating transport of glucose across plasma membranes
  - When levels decline:
    - Alpha cells release glucagon, stimulating glucose release by liver

18-8 Pancreas

- **Insulin**

- Is a peptide hormone released by beta cells
- Affects target cells
  - *Accelerates glucose uptake*
  - *Accelerates glucose utilization and enhances ATP production*
  - *Stimulates glycogen formation*
  - *Stimulates amino acid absorption and protein synthesis*
  - *Stimulates triglyceride formation in adipose tissue*

18-8 Pancreas

- Glucagon
  - Released by alpha cells
  - Mobilizes energy reserves
  - Affects target cells
    - *Stimulates breakdown of glycogen in skeletal muscle and liver cells*
    - *Stimulates breakdown of triglycerides in adipose tissue*
    - *Stimulates production of glucose in liver* (*gluconeogenesis*)

18-8 Pancreas

- **Diabetes Mellitus**
  - Is characterized by glucose concentrations high enough to overwhelm the reabsorption capabilities of the kidneys
    - **Hyperglycemia** = abnormally high glucose levels in the blood in general
    - **Glucose** appears in the urine, and urine volume generally becomes excessive (**polyuria**)

18-8 Pancreas

- Diabetes Mellitus
  - **Type 1** (**insulin dependent**) **diabetes**
    - Is characterized by inadequate insulin production by the pancreatic beta cells
    - Persons with type 1 diabetes require insulin to live and usually require multiple injections daily, or continuous infusion through an insulin pump or other device
    - This form of diabetes accounts for only around 5–10 percent of cases; it often develops in childhood

18-8 Pancreas

- Diabetes Mellitus
  - **Type 2** (**non-insulin dependent**) **diabetes**
    - Is the most common form of diabetes mellitus
    - Most people with this form of diabetes produce normal amounts of insulin, at least initially, but their tissues do not respond properly, a

condition known as **insulin resistance**
    - Type 2 diabetes is associated with obesity
        - Weight loss through diet and exercise can be an effective treatment

18-8 Pancreas

- Diabetes Mellitus
    - Complications of untreated, or poorly managed diabetes mellitus include:
        - Kidney degeneration
        - Retinal damage
        - Early heart attacks
        - Peripheral nerve problems
        - Peripheral tissue damage

18-8 Pancreas

- Kidney Degeneration
    - **Diabetic nephropathy**
        - Degenerative changes in the kidneys can lead to kidney failure
- Retinal Damage
    - **Diabetic retinopathy**
        - The proliferation of capillaries and hemorrhaging at the retina may cause partial or complete blindness

18-8 Pancreas

- Early Heart Attacks
    - Degenerative blockages in cardiac circulation can lead to early heart attacks
        - For a given age group, heart attacks are three to five times more likely in diabetic individuals than in nondiabetic people
- Peripheral Nerve Problems
    - Abnormal blood flow to neural tissues is probably responsible for a variety of neural problems with peripheral nerves, including abnormal autonomic function
        - These disorders are collectively termed **diabetic neuropathy**

18-8 Pancreas

- Peripheral Tissue Damage
    - Blood flow to the distal portions of the limbs is reduced, and peripheral tissues may suffer as a result
        - For example, a reduction in blood flow to the feet can lead to tissue death, ulceration, infection, and loss of toes or a major portion of one or both feet

18-9 Endocrine Tissues of Other Systems

- Many Organs of Other Body Systems Have Secondary Endocrine Functions
  - Intestines (digestive system)
  - Kidneys (urinary system)
  - Heart (cardiovascular system)
  - Thymus (lymphatic system and immunity)
  - Gonads (reproductive system)

18-9 Endocrine Tissues of Other Systems

- The Intestines
  - Produce hormones important to coordination of digestive activities
- The Kidneys
  - Produce the hormones **calcitriol** and **erythropoietin** (**EPO**)
  - Produce the enzyme **renin**

18-9 Endocrine Tissues of Other Systems

- The Heart
  - Produces **natriuretic peptides** (*ANP* and *BNP*)
    - When blood volume becomes excessive
    - Action opposes angiotensin II
    - Resulting in reduction in blood volume and blood pressure

18-9 Endocrine Tissues of Other Systems

- The **Thymus**
  - Produces **thymosins** (blend of thymic hormones)
    - That help develop and maintain normal immune defenses

18-9 Endocrine Tissues of Other Systems

- The Gonads
  - Testes
    - Produce androgens in interstitial cells
      - **Testosterone** is the most important male hormone
    - Secrete **inhibin** in **nurse cells**
      - Support differentiation and physical maturation of sperm

18-9 Endocrine Tissues of Other Systems

- The Gonads
  - Ovaries
    - Produce **estrogens**
      - Principal estrogen is **estradiol**
    - After ovulation, follicle cells:

- Reorganize into corpus luteum
- Release estrogens and **progestins**, especially **progesterone**

18-9 Endocrine Tissues of Other Systems

- Adipose Tissue Secretions
  - **Leptin**
    - Feedback control for appetite
    - Controls normal levels of GnRH, gonadotropin synthesis

18-10 Hormone Interactions

- Hormones Interact to Produce Coordinated Physiological Responses
  - When a cell receives instructions from two hormones at the same time, four outcomes are possible
    1. **Antagonistic effects** – opposing
    2. **Synergistic effects** – additive
    3. **Permissive effects** – one hormone is necessary for another to produce effect
    4. **Integrative effects** – hormones produce different and complementary results

18-10 Hormone Interactions

- Hormones Important to Growth
  - *Growth hormone* (*GH*)
  - *Thyroid hormones*
  - *Insulin*
  - *PTH and calcitriol*
  - *Reproductive hormones*

18-10 Hormone Interactions

- Growth Hormone (GH)
  - In children:
    - Supports muscular and skeletal development
  - In adults:
    - Maintains normal blood glucose concentrations
    - Mobilizes lipid reserves

18-10 Hormone Interactions

- Thyroid Hormones
  - If absent during fetal development or for first year:
    - Nervous system fails to develop normally
    - Mental retardation results
  - If T_4 concentrations decline before puberty:

        - Normal skeletal development will not continue

18-10 Hormone Interactions

- Insulin
    - Allows passage of glucose and amino acids across plasma membranes
- Parathyroid Hormone (PTH) and Calcitriol
    - Promote absorption of calcium salts for deposition in bone
    - Inadequate levels cause weak and flexible bones

18-10 Hormone Interactions

- Reproductive Hormones
    - Androgens in males, estrogens in females
    - Stimulate cell growth and differentiation in target tissues
    - Produce gender-related differences in:
        - Skeletal proportions
        - Secondary sex characteristics

18-10 Hormone Interactions

- The Hormonal Responses to Stress
    - **General Adaptation Syndrome** (**GAS**)
        - Also called **stress response**
        - How body responds to stress-causing factors
        - Is divided into three phases
            1. *Alarm phase*
            2. *Resistance phase*
            3. *Exhaustion phase*

18-10 Hormone Interactions

- The Effects of Hormones on Behavior
    - Hormone changes
        - Can alter intellectual capabilities, memory, learning, and emotional states
        - Affect behavior when endocrine glands are oversecreting or undersecreting

18-10 Hormone Interactions

- Aging and Hormone Production
    - Causes few functional changes
    - Decline in concentration of:
        - Growth hormone
        - Reproductive hormones