To run the animations you must be in **Slideshow View**. Use the buttons on the animation to play, pause, and turn audio/text on or off.

*Please Note:* Once you have used any of the animation functions (such as Play or Pause), you must first click on the slide’s background before you can advance to the next slide.

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes and animations.
Functions

1. Controls homeostasis
2. Maintains water balance
3. Controls uterine contractions
4. Controls milk production
5. Regulates ions (calcium, sodium, potassium)
6. Regulates metabolism and growth
7. Regulates heart rate and blood pressure
8. Monitors blood glucose levels
9. Aids the immune system
10. Reproductive functions
Components of Endocrine System

- **Endocrine glands:**
  secrete their product directly into blood stream

- **Chemical signal:**
  molecules that are released from one location, move to another location, and produce a response
Types of Chemical Signals

- **Intracellular:**
  produce in one of part a cell and move to another part of same cell

- **Intercellular:**
  released from one cell and bind to receptors on another cell
Types of Intercellular Signals

• Autocrine:
  - released by cells and have a local effect on the same cell type
  - Ex. Eicosanoids (released in response to inflammation)

• Paracrine:
  - released by cells that affect other cell types in close proximity
  - Ex. Somatostatin (inhibits insulin secretion)
• **Neurotransmitter and neuromodulators:**
  - secreted by nerve cells
  - Ex. Nervous system function

• **Pheromones:**
  - secreted into env’t and modify behavior and physiology of other individual in same species
  - Ex. Women and menstrual cycles

• **Hormones and neurohormones:**
  - secreted into blood and bind to receptor sites
  - Ex. Epinephrine and insulin
<table>
<thead>
<tr>
<th>Chemical Messengers</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autocrine</td>
<td>Secreted by cells in a local area; influences the activity of the same cell from which it was secreted</td>
<td>Eicosanoids (prostaglandins, thromboxanes, prostacyclins, leukotrienes)</td>
</tr>
<tr>
<td>Paracrine</td>
<td>Produced by a wide variety of tissues and secreted into extracellular fluid; has a localized effect on other tissues</td>
<td>Somatostatin, histamine, eicosanoids</td>
</tr>
<tr>
<td>Neurotransmitter</td>
<td>Produced by neurons; secreted into a synaptic cleft by presynaptic nerve terminals; travels short distances; influences postsynaptic cells</td>
<td>Acetylcholine, epinephrine</td>
</tr>
<tr>
<td>Endocrine</td>
<td>Secreted into the blood by specialized cells; travels some distance to target tissues; results in coordinated regulation of cell function</td>
<td>Thyroid hormones, growth hormone, insulin, epinephrine, estrogen, progesterone, testosterone, prostaglandins</td>
</tr>
</tbody>
</table>
Components of Hormones

- **Receptor site:**
  location on a cell where hormone binds (lock)

- **Target tissues:**
  group of cells that respond to specific hormones

- **Specificity:**
  specific hormones bind to specific receptor sites
Hormone 1 bound to its receptor

Capillary

Circulating blood

Hormone 1 receptor

Target cell for hormone 1

Hormone 2 cannot bind to this receptor

Hormone 1

Hormone 2
How does this work?

1. Hormones are secreted by endocrine glands directly into bloodstream

2. Hormones travel to all parts of body

3. Hormones (key) bind to receptor site (lock) on target tissue

4. Response occurs
How do hormones cause change?

• Alter cell activity of target tissues by increasing or decreasing cell’s normal processes

• Change permeability of cell membrane by opening or closing ion channels

• Synthesis of proteins
Types of Hormones

• **Water soluble:**
  - includes proteins, peptides, amino acids
  - most common
  - Ex. Growth hormone, antidiuretic, prolactin, etc.

• **Lipid hormones:**
  - includes steroids and eicosanoids
  - Ex. LH, FSH, androgens
Cellular responses

Nuclear receptor

Hormone

DNA

Lipid-soluble hormone (thyroid or steroid)

(a)

Water-soluble hormone (glucagon, prolactin)

Membrane-bound receptor

G protein complex

ATP

Protein kinase

Adenylate cyclase

cAMP

Cellular responses

(b)
1 Lipid-soluble hormones diffuse through the plasma membrane.

2 Lipid-soluble hormones bind to cytoplasmic receptors and travel to the nucleus or bind to nuclear receptors. Some lipid-soluble hormones bind receptors in the cytoplasm and then move into the nucleus.

3 The hormone–receptor complex binds to a hormone response element on the DNA, acting as a transcription factor.

4 The binding of the hormone–receptor complex to DNA stimulates the synthesis of messenger RNA (mRNA), which codes for specific proteins.

5 The mRNA leaves the nucleus, passes into the cytoplasm of the cell, and binds to ribosomes, where it directs the synthesis of specific proteins.

6 The newly synthesized proteins produce the cell's response to the lipid-soluble hormones—for example, the secretion of a new protein.
Regulation of Hormones

• Blood levels of chemicals:
  Ex. Blood glucose levels (insulin)

• Other hormones:
  Ex. TSH signals thyroid gland to release thyroid hormone

• Nervous system:
  Ex. Epinephrine and fight or flight response

• Negative Feedback:
  tells body when homeostasis is reached
The target endocrine cell secretes its hormone into the blood, where it travels to its target and produces a response.

1 Neurons in the hypothalamus release stimulatory hormones, called releasing hormones. Releasing hormones travel in the blood to the anterior pituitary gland.

2 Releasing hormones stimulate the release of hormones from the anterior pituitary, which travel in the blood to their target endocrine cell.

3 The target endocrine cell secretes its hormone into the blood, where it travels to its target and produces a response.
The anterior pituitary gland secretes a tropic hormone, which travels in the blood to the target endocrine cell.

The hormone from the target endocrine cell travels to its target.

The hormone from the target endocrine cell also has a negative-feedback effect on the anterior pituitary and hypothalamus and decreases secretion of the tropic hormone.

The anterior pituitary gland secretes a tropic hormone, which travels in the blood to the target endocrine cell.

The hormone from the target endocrine cell travels to its target.

The hormone from the target endocrine cell also has a positive-feedback effect on the anterior pituitary and increases secretion of the tropic hormone.
During the menstrual cycle, before ovulation, small amounts of estrogen are secreted from the ovary.
Hormone Receptors and Mechanisms of Action

1. Lipid Soluble Hormones bind to Nuclear Receptors

2. Water Soluble Hormones bind to Membrane-Bound Receptors

3. Intracellular Receptor Hormones
Cellular responses

Nuclear receptor

Hormone

DNA

Lipid-soluble hormone (thyroid or steroid)

Water-soluble hormone (glucagon, prolactin)

Membrane-bound receptor

Adenylate cyclase

G protein complex

ATP

cAMP

Protein kinase

Cellular responses
When a ligand binds to the receptor site on the outside of the cell membrane, the G protein changes conformation and guanosine triphosphate replaces the guanosine diphosphate on the alpha subunit of the G protein.
Aldosterone is a lipid-soluble hormone that can easily diffuse through the plasma membrane.
Pituitary Gland

- Small gland in brain
- Controlled by hypothalamus
- Divided into 2 regions: anterior and posterior
- Secretes at least 6 hormones
Anterior Pituitary Gland

• Growth Hormone:
  - **Target tissues**: most
  - **Functions**: stimulates growth of bones, muscles, and organs
  - **Abnormalities**:  
    Too much GH causes giantism
    Too little GH causes pituitary dwarfism
1. Stimuli within the nervous system cause releasing and inhibiting hormones (blue circles) to be secreted from nerve cells of the hypothalamus.

2. Releasing and inhibiting hormones pass through the hypothalamic-pituitary portal system to the anterior pituitary.

3. Releasing and inhibiting hormones leave capillaries, bind to membrane-bound receptors, and influence the secretion of hormones from anterior pituitary cells.

4. Anterior pituitary hormones (yellow squares) are carried in the blood to their target tissues (green arrow), which in some cases are other endocrine glands.
- **Thyroid-Stimulating Hormone (TSH):**
  - **Target tissues:** thyroid gland
  - **Functions:** regulates thyroid gland secretions
  - **Abnormalities:**
    - Too much TSH, thyroid gland enlarges
    - Too little TSH, thyroid gland shrinks
1. Neurons within the hypothalamus release TSH-releasing hormone into the blood. It passes through the hypothalamic-pituitary portal system to the anterior pituitary.

2. TSH-releasing hormone causes cells of the anterior pituitary to secrete TSH, which passes through the general circulation to the thyroid gland.

3. TSH causes increased release of thyroid hormones ($T_3$ and $T_4$) into the general circulation.

4. $T_3$ and $T_4$ act on target tissues to produce a response.

5. $T_3$ and $T_4$ also have an inhibitory effect on the secretion of TSH-releasing hormone from the hypothalamus and TSH from the anterior pituitary.

Target tissue:
- Increases metabolism
- Increases body temperature
- Increases normal growth and development
GONADOTROPINS

- **LH (Luteinizing) for females:**
  - **Target tissue:** ovaries
  - **Function:** promotes ovulation and progesterone production

- **LH for males:**
  - **Target tissue:** testes
  - **Function:** sperm production and testosterone
- **FSH (Follicle-Stimulating) for females:**
  - **Target tissue:** follicles in ovaries
  - **Function:** follicle maturation and estrogen secretion

- **FSH for males:**
  - **Target tissue:** seminiferous tubules (testes)
  - **Function:** sperm production
- **Prolactin:**
  - **Target tissues:** mammary glands and ovaries
  - **Functions:** milk production
Posterior Pituitary Gland

• Antidiuretic Hormone (ADH):
  - **Target tissues**: kidneys
  - **Functions**: conserve water
  - **Abnormalities**:
    
    **Diabetes insipidus**:
    
    - low ADH
    - kidneys to produce large amounts of dilute (watery) urine
    - can lead to dehydration and thirst
• **Oxytocin:**
  - **Target tissues:** uterus
  - **Functions:** increases uterine contractions during labor
Stimuli within the nervous system stimulate hypothalamic nerve cells to produce action potentials.

Action potentials are carried by axons of nerve cells to the posterior pituitary. The axons of nerve cells store hormones in the posterior pituitary.

In the posterior pituitary gland, action potentials cause the release of hormones (red circles) from the axons into the circulatory system.

The hormones pass through the circulatory system and influence the activity of their target tissues (green arrow).
Figure 10.11 Thyroid and Parathyroid Glands
(a) Anterior view of the thyroid gland. (b) The four small parathyroid glands are embedded in the posterior surface of the thyroid gland. (c) Three-dimensional interpretive drawing of thyroid follicles and parafollicular cells. (d) Light micrograph of thyroid and parathyroid tissue.
Thyroid Gland

• One of largest glands
• Requires iodine to function
• Thyroid hormones:
  - **Target tissues**: most
  - **Functions**: regulates metabolic rates and is needed for growth
Abnormalities of Thyroid Gland

• Hypothyroidism:
  – Decreased metabolism
  – Weight gain, reduced appetite, fatigue
  – Low temp. and pulse
  – Dry, cold skin
  – Myxedema in adults
  – Cretinism in infants

• Hyperthyroidism:
  – Increased metabolism
  – Weight loss, increased appetite, nervousness
  – Higher temp. and pulse
  – Warm, flushed skin
  – Graves’ disease (leads to goiter)
1. Neurons within the hypothalamus release TSH-releasing hormone into the blood. It passes through the hypothalamic-pituitary portal system to the anterior pituitary.

2. TSH-releasing hormone causes cells of the anterior pituitary to secrete TSH, which passes through the general circulation to the thyroid gland.

3. TSH causes increased release of thyroid hormones (T₃ and T₄) into the general circulation.

4. T₃ and T₄ act on target tissues to produce a response.

5. T₃ and T₄ also have an inhibitory effect on the secretion of TSH-releasing hormone from the hypothalamus and TSH from the anterior pituitary.
- **Calcitonin:**
  - **Target tissues:** bones
  - **Functions:** secreted when blood $\text{Ca}^{2+}$ levels are high
Parathyroid gland

• Parathyroid hormone (PTH):
  - **Target tissues:** bones and kidneys
  
  - **Functions:** regulates blood Ca$^{2+}$ levels
    (more than calcitonin)

If Ca$^{2+}$ is low then osteoclasts break down bone matrix and less Ca$^{2+}$ is lost in urine.

If Ca$^{2+}$ is high then osteoclasts *don’t* break down bone matrix and more Ca$^{2+}$ is lost in urine.
Blood Ca\textsuperscript{2+} levels increase: 
**Homeostasis Disturbed**

Control centers: 
Parafollicular cells increase calcitonin secretion. 
Parathyroid gland decreases PTH secretion.

Blood Ca\textsuperscript{2+} levels decrease: 
**Homeostasis Disturbed**

Control centers: 
Parafollicular cells decrease calcitonin secretion. 
Parathyroid gland increases PTH secretion.

Blood Ca\textsuperscript{2+} levels increase: 
**Homeostasis Restored**

Effector activated: Decreased bone resorption and decreased uptake of Ca\textsuperscript{2+} from intestine and kidney result.

Blood Ca\textsuperscript{2+} levels decrease: 
**Homeostasis Restored**

Effector activated: Increased bone resorption and increased uptake of Ca\textsuperscript{2+} from intestine and kidney result.
Adrenal glands

Cortex

Medulla

Connective tissue capsule
Secretes mineralocorticoids

Secretes glucocorticoids

Secretes androgens

Secretes epinephrine and norepinephrine

Abdominal aorta

Adrenal gland

Fat

Renal artery

Renal vein

Kidney

Ureter

Anterior view

Adrenal gland

Cortex

Medulla

Adrenal glands

Adrenal gland

Abdominal aorta

Adrenal gland

Fat

Renal artery

Renal vein

Kidney

Ureter

Anterior view

Adrenal gland

Cortex

Medulla

Connective tissue capsule
Secretes mineralocorticoids

Secretes glucocorticoids

Secretes androgens

Secretes epinephrine and norepinephrine

LM 100x

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Adrenal Glands

- On kidneys
- 2 regions medulla and cortex

Adrenal Medulla (inner portion):

- Epinephrine/Norepinephrine:
  - **Target tissues**: heart, blood vessels, liver, fat cells
  - **Functions**: released as part of fight or flight response
Adrenal secretion of epinephrine and norepinephrine increases.

Target tissue:
- Increases release of glucose from the liver
- Increases release of fatty acids from fat stores
- Increases heart rate
- Decreases blood flow through blood vessels of internal organs and skin
- Increases blood flow to skeletal muscles and the heart
- Decreases function of visceral organs
- Increases blood pressure
- Increases metabolic rate in skeletal muscles

Hypothalamus stimulated by:
- Stress
- Physical activity
- Low blood glucose levels

Action potentials travel through the sympathetic division of the autonomic nervous system.
Adrenal Cortex (outer portion):

- **Aldosterone:**
  - Type of mineralocorticoids
  - **Target tissues:** kidneys

  - **Functions:** causes Na$^+$ and H$_2$O to be retained and K$^+$ to be secreted, indirectly involved with blood pressure and blood volume
Aldosterone stimulation of the kidneys causes Na\(^+\) retention, K\(^+\) excretion, and decreased water loss.

Angiotensin II causes increased secretion of aldosterone, which primarily affects the kidneys.

The kidneys detect a decrease in blood pressure. In response, they increase the secretion of renin into the general circulation. Renin converts angiotensinogen to angiotensin I. A converting enzyme changes angiotensin I to angiotensin II, which causes constriction of blood vessels, resulting in increased blood pressure.

Angiotensin II causes increased secretion of aldosterone, which primarily affects the kidneys.

Increased blood K\(^+\) levels or decreased blood Na\(^+\) levels cause the adrenal cortex to increase the secretion of aldosterone into the general circulation.
• Cortisol:
  - Type of glucocorticoids
  - Target tissues: most
  - Functions: increases breakdown of fat and protein for energy uses, reduces inflammatory and immune responses
Cortisol acts on the hypothalamus and anterior pituitary to decrease ACTH secretion.

Cortisol acts on its target tissues to increase protein breakdown and blood glucose.

ACTH acts on the adrenal cortex and stimulates the secretion of cortisol into the general circulation.

In response to stress or low blood glucose, ACTH-releasing hormone passes from the hypothalamus through the hypothalamic-pituitary portal system to the anterior pituitary. The releasing hormone binds to and stimulates cells that secrete ACTH into the general circulation.

Target tissue:
- Increases fat and protein breakdown
- Increases blood glucose levels
- Has anti-inflammatory effects
• Androgens:
  - **Target tissues**: most

  - **Functions**:
    Males: secondary sexual characteristics
    Females: sex drive
Pancreas

- **Organ in abdomen**
- **Insulin:**
  - **Target tissues:** liver, skeletal muscle, adipose tissue
  - **Functions:**
    - regulates blood glucose levels
    - after a meal glucose levels are high and insulin is secreted
    - extra glucose is stored in form of glycogen
Exocrine portions of pancreas (secrete enzymes that move through the ducts to the small intestine)

Pancreatic duct

Common bile duct from liver

Duodenum (first part of small intestine)

Pancreas

Bile duct from liver

Pancreatic islet

Beta cell (secretes insulin)

To pancreatic duct

To bloodstream

Alpha cell (secretes glucagon)

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- Abnormalities:

**Diabetes mellitus:**

- Causes: too little insulin or faulty insulin receptors
- Symptoms: exaggerated appetite, excess urine, dehydration, thirst, fatigue
- Type I: insulin dependent (daily injections required)
- Type II: insulin independent, often found in obese people, can be treated with diet but can turn into type I
• **Glucagon:**
  - **Target tissues:** liver

  - **Function:**
    - regulates blood glucose levels
    - between meals glucose levels drop and glucagon is secreted
    - glucagon allows glycogen to be broken down into glucose
Blood glucose (normal range)

1. Blood glucose level increases:
   Homeostasis Disturbed

   Control center:
   Pancreatic islets detect an increase in blood glucose and do not secrete insulin.

   Effector activated:
   Insulin stimulates glucose uptake by most tissues and promotes glycogen storage in skeletal muscle and liver. Excess glucose is stored as fat.

2. Blood glucose level decreases:
   Homeostasis Disturbed

   Control center:
   Pancreatic islets detect a decrease in blood glucose and do not secrete insulin.

   Effector activated:
   Decreased insulin results in decreased glucose uptake, increased glycogen breakdown by the liver and skeletal muscle, and increased glucose synthesis.

3. Blood glucose level increases:
   Homeostasis Disturbed

4. Blood glucose level decreases:
   Homeostasis Restored

5. Blood glucose level increases:
   Homeostasis Restored
Testes

• Testosterone:
  - Target tissues: most

  - Functions: aids in sperm and reproductive organ development and function
Ovaries

- **Estrogen/Progesterone:**
  - **Target tissues:** most
  - **Functions:** involved in uterine and mammary gland development and menstrual cycle
Thymus gland

• Thymosin:
  
  - **Target tissues**: immune system tissues
  
  - **Functions**: promotes immune system development and function
Pineal Body (Gland)

- **Melatonin:**
  - **Target tissues:** hypothalamus
  - **Functions:** plays a role in onset of puberty and controls circadian rhythms. Light affects its function.