The Endocrine System

Biology 105
Lecture 13
Chapter 10

Outline

I. Function of endocrine system
II. Hormones and neurotransmitters
III. Types of hormones and their actions
IV. Endocrine glands/organs and hormones

Function of the Endocrine System

- The function of the endocrine system is to work with the nervous system to regulate and control other systems and maintain homeostasis.
- The endocrine system functions by releasing hormones, which travel through the body (usually through the bloodstream) to reach target cells.
Glands are secretory cells or structures derived from:

1. Muscle
2. Connective tissue
3. Epithelial tissue
4. Nervous

These glands do not have tubes or ducts, and they secrete hormones directly into the bloodstream:

1. Exocrine glands
2. Endocrine glands

Endocrine System Communication

The hormone diffuses into the bloodstream.

The hormone travels throughout the body.

Capillary

Hormone
What is a hormone?

- **Hormones** are chemical messengers that are secreted by one cell and travel to another cell:
  - They affect only target cells that have the correct receptor.
- Target cells have receptors that bind to the hormone.
- Non-target cells do not have these receptor and are unaffected by the hormone.

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Hormones versus Neurotransmitters

- Similarity: the endocrine system and the nervous system are both controlled by negative feedback.
- Endocrine and nervous systems work together to maintain homeostasis, but there are differences…
Hormones versus Neurotransmitters – Differences

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<tr>
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<th>Neurotransmitters</th>
<th>Hormones</th>
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<tbody>
<tr>
<td>Where is it located?</td>
<td>Localized to nerve synapse</td>
<td>Distributed throughout body in bloodstream</td>
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<tr>
<td>How long does it take to act?</td>
<td>Quick-acting</td>
<td>Slow to act</td>
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<tr>
<td>How long does it last?</td>
<td>Taken away quickly</td>
<td>Remain longer in body</td>
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Types of Hormones

- There are two general types of hormones:
  1. Water Soluble (Hydrophilic)
  2. Lipid Soluble (Hydrophobic)

Amino Acid Hormones

- A single amino acid
  - Example: epinephrine
- Polypeptides (a chain of amino acids)
  - Example: human growth hormone
Are amino acids hydrophilic or hydrophobic?

1. Hydrophilic
2. Hydrophobic

Can an amino acid freely cross the plasma membrane?

1. Yes
2. No

Water Soluble Hormones

- Amino acids and polypeptides are examples of water soluble hormones.
- Example: Epinephrine
- Adrenal glands release epinephrine into the bloodstream, and it travels throughout the body.
Water Soluble Hormones

- Water soluble hormones bind to a receptor on the surface of the target cells (ex: muscle cells).
  - The receptor is on the plasma membrane.
- The binding of the hormone epinephrine to the receptor triggers the formation of a secondary messenger (ex: cAMP).
- The secondary messenger triggers a cascade of events ending in cellular activity (ex: the breakdown of glycogen to glucose).
- Note: this type of hormone does not cross the plasma membrane and enter the cell!

Steroid Hormones

- Steroid hormones have a structure similar to cholesterol.
  - Examples: estrogen, testosterone

(a) Four-ring steroid structure
Steroids are...

1. Sugars
2. Proteins
3. Lipids
4. Complex carbohydrates

Are steroids hydrophilic or hydrophobic?

1. Hydrophilic
2. Hydrophobic

Can steroids freely cross the plasma membrane?

1. Yes
2. No
When DNA is copied to make mRNA this is:

1. Translation  50%
2. Transcription 50%

What is the product of translation?

1. DNA 25%
2. RNA 25%
3. Protein/polypeptide 25%
4. Nucleotides 25%

Lipid Soluble Hormones – Steroids

- Lipid soluble hormones enter the target cells, because they can freely pass through the plasma membrane.
- Inside the cell, the hormone binds with a receptor.
- The hormone-receptor complex binds to DNA in the nucleus and activates the transcription of DNA to make mRNA.
- The mRNA leaves the nucleus, binds to a ribosome and is translated to make proteins.
**Lipid Soluble Hormones**

Step 1: The steroid hormone diffuses through the plasma membrane of the target cell.

Step 2: The steroid hormone binds to a receptor in the cytoplasm.

Step 3: The hormone-receptor complex enters the nucleus.

Step 4: The hormone-receptor complex binds to DNA.

Step 5: Certain genes are activated.

Step 6: Proteins, including enzymes, are synthesized.

Step 7: Enzymes alter the activity of the cell.

Note that the lipid soluble hormones will take longer to act than the water soluble hormones, since they cause DNA transcription and translation to make a protein.

Also remember that water soluble hormones do not enter the target cell – they work through secondary messengers, whereas lipid soluble hormones enter the cell.

**Endocrine Glands and Organs that Secrete Hormones**

- Pituitary
- Thyroid
- Parathyroid
- Adrenals
- Pineal
- Hypothalamus
- Thymus
- Pancreas
- Ovaries
- Testes
- Heart
- Placenta
- Stomach
- Intestines
- Kidneys

**Water Soluble versus Lipid Soluble Hormones**

- Note that the lipid soluble hormones will take longer to act than the water soluble hormones, since they cause DNA transcription and translation to make a protein.

- Also remember that water soluble hormones do not enter the target cell – they work through secondary messengers, whereas lipid soluble hormones enter the cell.
Endocrine System

Figure 10.2 (1 of 2)

ENDOCRINE SYSTEM

Parathyroid glands (two of four)

Pineal gland

Thymus gland

Adrenal gland (one on each kidney)

Adrenal cortex

Adrenal medulla

Heart

Kidney

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Endocrine System

Figure 10.2 (2 of 2)

Uterus

Thyroid gland

Pancreas

Testis (one of a pair)

Ovary (one of a pair)

Stomach

Small intestine

Gastric

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Hypothalamus

- Hypothalamus: regulates the internal environment through the autonomic nervous system.
  - Helps control heart rate.
  - Helps control body temperature.
  - Helps control water balance.
Hypothalamus

- Hypothalamus: controls glandular secretions of the pituitary gland.

- Produces:
  1. Antidiuretic hormone (ADH)
  2. Oxytocin
  3. Hypothalamic-releasing hormones
  4. Hypothalamic-inhibiting hormones
ADH and oxytocin travel to the ends of the cells in the posterior pituitary, where they are released into the bloodstream to influence target tissues.

Nerve cells in the hypothalamus produce antidiuretic hormone (ADH) and oxytocin.

ADH and oxytocin are stored in the posterior lobe of the pituitary gland.

Posterior pituitary gland releases these hormones when needed.

Function: regulates water reabsorption in the kidneys (H₂O is returned to the bloodstream).

Target: kidneys
ADH-Related Disorder

- Diabetes insipidus – caused by a deficiency of ADH.
- Results in excessive urine production, leading to dehydration.
- Treatment: administer synthetic ADH.

Oxytocin

- Function: stimulates uterine contraction during childbirth and milk release (ejecting milk from the glands).
- Target: uterus and mammary glands
- Pitocin: synthetic form of oxytocin that is administered to induce labor.

Anterior Pituitary Gland

- There are two sections of the pituitary gland: posterior and anterior.
- The anterior pituitary gland produces:
  1. Thyroid-stimulating hormone (TSH)
  2. Adrenocorticotropic hormone (ACTH)
  3. Gonadotropic hormones – (FSH and LH)
  4. Prolactin (PRL)
  5. Growth hormone (GH)
ANTERIOR PITUITARY GLAND...

...releases the hormones it has produced after receiving hypothalamic-releasing hormones from the hypothalamus.

Hypothalamic-Releasing and Hypothalamic-Inhibiting Hormones

- The hypothalamus produces hypothalamic-releasing and hypothalamic-inhibiting hormones.
- These hormones travel a short distance in the bloodstream to the anterior pituitary gland.
  - Hypothalamic-releasing hormones: stimulate the anterior pituitary gland to release (secrete) its hormones.
  - Hypothalamic-inhibiting hormones: inhibit the anterior pituitary gland from secreting its hormones.

Anterior Pituitary Hormones:
Thyroid-Stimulating Hormone (TSH)

- Function: stimulates the thyroid gland to produce thyroxine (one of the thyroid hormones).
- Target: thyroid gland
Anterior Pituitary Hormones: Adrenocorticotropic Hormone (ACTH)

- **Function:** stimulates the adrenal cortex to produce cortisol.
- **Target:** adrenal cortex

Anterior Pituitary Hormones: Gonadotropic Hormones

- **Function:** stimulate the gonads to produce gametes and hormones.
- The two gonadotropic hormones are:
  - **Follicle Stimulating Hormone (FSH)** – stimulates gamete development in males and females.
  - **Luteinizing Hormone (LH)** – stimulates ovaries to produce estrogen and progesterone in females, and testosterone in males.

Anterior Pituitary Hormones: Prolactin (PRL)

- **Function:** causes mammary glands to develop and produce milk.
- **Target:** mammary glands
Anterior Pituitary Hormones:
Growth Hormone (GH)

- **Function:** promotes skeletal and muscular growth.
- **Target:** bones, muscles, and cartilage

Disorders:
Gigantism

- **Gigantism:** too much GH during childhood can result in rapid growth, where an individual attains heights of 8-9 feet.
- **Treatment:** if caused by a pituitary tumor, then treatment is to remove or reduce the tumor using surgery, radiation or chemotherapy.

Gigantism
Disorders: Pituitary Dwarfism

- Pituitary dwarfism: insufficient GH production results in sterility, and affected individuals attain a maximum height of about 4 feet.

- Treatment: administer GH during childhood.

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Which of the following hormones stimulates water reabsorption by the kidneys?

1. Insulin
2. Thyroxin
3. ADH
4. Calcitonin

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Which hormone stimulates the adrenal cortex to produce cortisol?

1. Insulin
2. Thyroxin
3. ADH
4. ACTH

Which gland produces oxytocin?

1. Anterior Pituitary
2. Posterior Pituitary
3. Hypothalamus
4. Adrenal Cortex

Which gland produces prolactin?

1. Anterior Pituitary
2. Posterior Pituitary
3. Hypothalamus
4. Adrenal Cortex
Thyroid Gland

- Thyroid gland: large gland located below the larynx.
- Requires iodine to make hormones.

- Produces:
  1. Thyroid Hormones (TH):
     - Thyroxine (T4) – stimulated by TSH from anterior pituitary gland
     - Triiodothyronine (T3)
  2. Calcitonin

Thyroid Gland: Thyroid Hormones (TH)

- **Function**: regulates metabolism by stimulating protein synthesis, the breakdown of lipids, and the use of glucose for the production of ATP.

- **Target**: most cells in the body!
Simple Goiter

- Simple goiter:
  - Results in an enlarged thyroid gland
  - May be caused by a diet deficient in iodine, which is needed for the production of TH.
  - Can be treated by iodine supplements or administration of TH.

Graves’ Disease

- Caused by an oversecretion of TH.
- Results in an autoimmune disorder due to the production of antibodies that mimic the action of TSH.

Graves’ Disease

- Symptoms include:
  - Increased metabolic rate and heart rate, accompanied by sweating, nervousness, and weight loss.
  - Many also have exophthalmos (= bulging or protruding eyeballs).
- Treatment: administer drug that blocks the synthesis of TH, and thyroid gland may be reduced by surgery or radioactive iodine.
Exophthalmos

(c) Exophthalmos

Thyroid Gland: Calcitonin

- **Function:** lowers blood calcium levels.
- **Target:**
  - Bones – stimulates osteoblasts (type of bone cells) to deposit calcium.
  - Kidneys – stimulates kidneys to excrete more calcium in the urine.

Parathyroid Glands

- Parathyroid glands – embedded in the lobes of the thyroid gland.
- Secrete: parathyroid hormone (PTH)
  - PTH functions to increase blood calcium levels.
- **Targets:**
  - Bone – stimulates the osteoclasts (type of bone cell) to release calcium.
  - Kidneys – stimulates the kidneys to reabsorb calcium.
  - Intestines – stimulates the intestines to increase absorption of calcium.
Regulation of Calcium Levels in Blood

- If calcium levels in blood are too low:
  - PTH is released from parathyroid gland.

- Effects: PTH causes the...
  - bones to release calcium,
  - kidneys to reabsorb calcium, and
  - intestines to absorb more calcium.

Calcium Regulation

Regulation of Calcium Levels in Blood

- If calcium levels in blood are too high:
  - CT is released from thyroid gland.

- Effects: CT causes the...
  - bones to deposit calcium, and
  - kidneys to excrete more calcium.
Calcium Regulation

When levels of calcium are high, the thyroid gland releases CT, and calcium is taken up by the bones.

Calcitonin lowers or raises the blood’s calcium level?

1. Lowers
2. Raises

Calcitonin is produced by the:

1. Hypothalamus
2. Thyroid
3. Parathyroid
Adrenal Glands

(a) Each adrenal gland sits on top of a kidney.

(b) A section through the adrenal gland reveals two regions, the outer adrenal cortex and the inner adrenal medulla. These regions secrete different hormones.

Adrenal cortex
- Mineralocorticoids
- Gonadocorticoids
- Glucocorticoids

Adrenal medulla
- Epinephrine
- Norepinephrine

Control of the Adrenal Glands

- The adrenal glands are controlled by both nerves and hormones.

- **Adrenal medulla**: controlled by nerves from the hypothalamus.

- **Adrenal cortex**: controlled by ACTH (a hormone) secreted by the anterior pituitary gland.
Adrenal Medulla – Epinephrine

- Hormone secreted by adrenal medulla:
  - **Epinephrine** – prepares the body for quick action.
    - “Fight or flight” situations and short-term response to stress.
  - Effects: increases blood pressure, increases heart rate, increases blood glucose levels.

Adrenal Cortex

- Two types of hormone secreted by adrenal cortex:
  1. **Mineralocorticoids**
  2. **Glucocorticoids**

Adrenal Cortex – Mineralocorticoids

- An example of a mineralocorticoid is **aldosterone**:
  - Promotes renal absorption of Na⁺ and renal excretion of K⁺.
  - Increases blood pressure.
  - **Target:** kidneys
- **Effects:** mineral homeostasis and water balance.
Adrenal Cortex – Glucocorticoids

- An example of a glucocorticoid is cortisol:
  - Affects glucose homeostasis.
  - Acts on the liver to promote the conversion of fat and protein into intermediate substances available to the body’s cells.
  - Inhibits the inflammatory response (suppresses the immune system).

What effect does the presence of epinephrine have on blood pressure?

1. Increases
2. Decreases
3. Has no effect

Which of the following effects the adrenal cortex?

1. ACTH
2. TSH
3. FSH
4. Nerves
The complex carbohydrate stored in humans is:

1. Cellulose
2. Starch
3. Glycogen
4. Triglycerides

Where is glycogen stored in the body?

1. Adipose tissue
2. Muscle
3. Liver
4. 2 and 3

Which of the following glands secretes cortisol?

1. Pituitary
2. Pancreas
3. Adrenal medulla
4. Adrenal cortex
Cortisol: A Stress Hormone

- The pituitary gland produces and releases ACTH (adrenocorticotropic hormone).
- ACTH travels to the adrenal gland, where it stimulates the adrenal cortex to release glucocorticoids like cortisol.
- Cortisol plays a role in regulating how much free glucose there is in the body.

Cortisol

- Cortisol prompts the muscles to break down glycogen and release glucose.
- It also prompts the adipose tissue to break down fat.
- So basically it tells the body to take biomolecules out of storage so they can be used for energy!

Disorders of the Adrenal Glands: Addison Disease

- *Addison disease*: hyposecretion from the adrenal cortex results in too few hormones being secreted.
  - Cannot recover from stressful situations.
  - Can lead to low blood pressure and dehydration.
  - Can be fatal if not treated.
- Treatment: supplement with glucocorticoids and mineralocorticoids.
Disorders of the Adrenal Glands: Cushing’s Syndrome

- **Cushing’s syndrome**: hypersecretion from the adrenal cortex results in too many hormones being secreted.
  - Can result in diabetes.
  - Can result in redistribution of fat and reduced muscle mass.

- Treatments: if caused by a tumor, surgical removal of the tumor (if possible).
  - Can treat with radiation and chemotherapy.
  - Can be treated with drugs to reduce the activity of the adrenal cortex.

Pancreas

- Hormones of the pancreas:
  - Secreted from the pancreatic islets (Islets of Langerhans).
  - Regulate blood glucose levels through two hormones:
    1. Glucagon
    2. Insulin
Pancreas: Glucagon

- **Glucagon**: raises blood glucose levels.

- **Target and effects:**
  - Liver – stimulates the breakdown of glycogen to glucose, and the formation of glucose from lactic acid.
Pancreas:
Insulin

- Insulin: lowers blood glucose levels.
- **Target and effects:**
  - Stimulates transport of glucose into muscle cells, white blood cells, and connective tissue cells.
  - Liver: inhibits the breakdown of glycogen to glucose.
  - Prevents conversion of amino acids and fatty acids into glucose.
  - Adipose tissue: stimulates formation of triglycerides from glucose.

Glucose Regulation

- Diabetes mellitus: caused by the lack of insulin or by the inability of cells to respond to insulin as they should.
- Type 1 diabetes – autoimmune disorder that causes the pancreas to not produce enough insulin.
- Type 2 diabetes – inability of cells to respond to insulin. (Cells do not have enough insulin receptors.)
What type of diabetes mellitus is caused by the lack of insulin?

1. Type 1
2. Type 2

Glucagon _______ the blood glucose levels.

1. Lowers
2. Raises

Gonads: Ovaries and Testes

- They are controlled by the hypothalamus and the pituitary gland by the gonadotrophic hormones.
- Testes produce testosterone.
- Ovaries produce estrogen and progesterone.
**Gonads:**

**Testosterone**

- **Effects:**
  - During development, testosterone stimulates growth of male reproductive organs.
  - Responsible for male secondary sex characteristics.
  - Prompts larynx and vocal cords to enlarge.
  - Responsible for muscular strength of males.

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**Anabolic Steroids**

- Some athletes take testosterone-like compounds to enhance their performance.
  
  - There is a downside to taking steroids:
    - Increase in body odor, baldness, acne, breast enlargement in men, kidney disease, decreased testicular size, low sperm count, impotence, high cholesterol, high blood pressure, heart damage, liver dysfunction, liver cancer, stunted growth if taken during development, personality changes including rage and delusions…

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**Gonads:**

**Estrogen and Progesterone**

- **Effects:**
  - During development, stimulates growth of female reproductive organs.
  - Responsible for secondary sex characteristics.
  - Necessary for egg maturation.
  - Regulates uterine cycle.
Thymus Gland

- Thymus gland: lies behind the sternum.
- Secretes the hormones thymosin and thymopoietin, which stimulate T-cell lymphocyte development.
- Important in immune system function.
- **Target:** bone marrow
- Thymus is largest and most active in children.

Pineal Gland

- Located in the brain.
- Secretes the hormone melatonin:
  - Involved in our daily sleep-wake cycle (Circadian rhythms).
  - Regulates sexual development.
  - May play a role in SAD = seasonal affective disorder.
Kidneys

- The kidneys release the hormones:
  - Erythropoietin – stimulates the bone marrow to produce more red blood cells.
  - Renin – through a series of reactions, stimulates the adrenal cortex to release aldosterone, which increases blood pressure.

Adipose Tissue: Leptin

- Leptin is a hormone produced in adipose tissue and affects the hypothalamus:
  - Tells you that you are full and do not need to eat anymore.

Homeostasis

- The nervous and endocrine systems exert control over the other systems and thereby maintain homeostasis.
- Both systems work closely together to govern the internal organs.
Which endocrine gland is the most involved in the immune response?

1. Adrenal medulla  
2. Pancreas  
3. Thymus  
4. Ovaries

Which hormone tells us when we should stop eating?

1. Renin  
2. Leptin  
3. Melatonin  
4. Thymosin

Which hormone is involved in our daily sleep-wake cycle?

1. Renin  
2. Leptin  
3. Melatonin  
4. Thymosin
Important Concepts

- Read Chapter 10
- What is the function of the endocrine system?
- What are similarities and differences between neurotransmitters and hormones?
- What are the two types of hormones? How do the two types of hormones work, and how do they affect the target cells?
  - Know the differences between the two types of hormones, and examples of each type of hormone.

Important Concepts

- For ALL the hormones in this lecture, you should be able to answer:
  - Where is the hormone produced and released from?
  - What is/are the function(s) of the hormone?
  - What is/are the target(s) of the hormone?
- Know the disorders discussed in the lecture:
  - What are the causes and effects of each disorder?
  - What are the treatments of each disorder?
- Know the location and names of the endocrine glands, and be able to label a drawing with the glands.

Important Concepts

- How does the hypothalamus control the pituitary gland?
- What is the function of the hypothalamus?
- How are the adrenal glands controlled?
- What are the two parts of the adrenal glands, and how is each part controlled? Which hormones are released from which part?
Important Concepts

- How are calcium levels in the blood regulated?
  - Which hormones and glands are responsible for blood calcium regulation?

- How are blood glucose levels regulated?
  - Which hormones and glands are responsible for blood glucose regulation?
  - What are the causes of the two types of diabetes?

Definitions

- Endocrine gland, hormones, receptor, target cell, non-target cell, pancreatic islets (Islets of Langerhans), negative feedback, water soluble, hydrophilic, lipid soluble, hydrophobic, secondary messenger, transcription, translation, produce, release, dilute, concentrated, extremities, deficient, sufficient, synthesis, reabsorption, inhibit, stimulate

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<th>Where Produced</th>
<th>Released From</th>
<th>Target</th>
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<td>ADH</td>
<td>Hypothalamus</td>
<td>Post. Pit.</td>
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<td>Oxytocin</td>
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