Hole’s Essentials of Human Anatomy & Physiology

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Chapter 11
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Endocrine System
Introduction

A. The body has two kinds of glands:
   1. *Endocrine* - secrete products into body fluids
   2. *Exocrine* - secretes products into ducts

B. The function of the endocrine system is to communicate with cells using *hormones*

C. The cells, tissues, and organs of the *endocrine system* secrete hormones into body fluids

D. Hormones diffuse into the bloodstream to act on specific *target cells* elsewhere in the body
A. Endocrine glands and their hormones regulate a number of metabolic processes within cells, tissues, and organs

B. Their actions are precise, they only affect specific target cells

C. Endocrine glands include the:
   1. Pituitary gland
   2. Thyroid gland
   3. Parathyroid glands
   4. Adrenal glands
   5. Pancreas
   6. and other hormone-secreting glands and tissues
Hormone Action

A. Hormones are:
   1. Steroids
   2. Amines
   3. Peptides
   4. Proteins
   5. Glycoproteins

B. They can influence target cells even if they are present only in minute concentrations
A. Steroid Hormones

1. Steroid hormones are lipid-soluble and so can pass through cell membranes
2. Receptors for steroid hormones are located in the targeted cell’s nucleus
3. The hormone-receptor complex:
   1. Binds with target cell DNA
   2. Activates specific genes
   3. Genes direct the synthesis of specific proteins
A. Nonsteroid Hormones

1. Nonsteroid hormones combine with receptors in target cell membranes

2. Receptors have a binding site and an activity site

3. The hormone-receptor complex (as first messenger) triggers a cascade of biological activity

4. The hormone-receptor complex generally activates a $G$ protein

5. $G$ protein then activates the enzyme adenylate cyclase that is bound to the inner cell membrane
1. This enzyme removes two phosphates from ATP to produce cyclic AMP (the *second messenger*)
2. cAMP in turn activates protein enzymes that activate proteins
3. These activated proteins induce changes in the cell
4. Not all nonsteroid hormones use cAMP
5. Others use diacylglycerol (DAG) or inositol triphosphate
A. **Prostaglandins**

1. Locally-produced lipids
2. Affect the organ in which they are produced
3. Produce a variety of effects:
   a) Relax smooth muscle
   b) Contract smooth muscle
   c) Stimulate secretion of other hormones
   d) Influence blood pressure and inflammation
Control of Hormonal Secretions

A. Hormone levels are very precisely regulated.

B. Control Mechanisms:

1. Release of tropic hormones from the hypothalamus controls secretions of the anterior pituitary

2. The nervous system influences certain endocrine glands directly

3. Other glands respond directly to changes in the internal fluid composition
A. Negative Feedback Systems

1. Commonly, *negative feedback mechanisms* control hormonal releases

2. In a negative feedback system, a gland is sensitive to the concentration of the substance it regulates or which regulates it

3. When the concentration of the regulated substance reaches a certain level (high or low), it inhibits the gland from secreting more hormone until the concentration returns to normal
Pituitary Gland

A. The **pituitary gland** is attached to the base of the brain

B. Has an **anterior lobe** (anterior pituitary) and a **posterior lobe** (posterior pituitary).
A. The brain controls the activity of the pituitary gland

1. **Releasing hormones** from the hypothalamus control the secretions of the anterior pituitary

2. The releasing hormones are carried in the bloodstream directly to the anterior pituitary by **hypophyseal portal veins**

3. The posterior pituitary releases hormones into the bloodstream in response to nerve impulses from the hypothalamus
A. Anterior Pituitary Hormones

1. The anterior pituitary consists mostly of:
   a) epithelial tissue arranged around blood vessels
   b) enclosed in a capsule of collagenous connective tissue
1. **Growth hormone** (GH)
   a) Stimulates body cells to grow and reproduce
   b) Speeds the rate at which cells use carbohydrates and fats
   c) *Growth hormone-releasing hormone* from the hypothalamus increases the amount of GH released
   d) *GH release-inhibiting hormone* inhibits its release
   e) Nutritional status affects the release of GH; more is released when nutrients are insufficient.
1. **Prolactin** (PRL)

   a) Promotes milk production following the birth of an infant

   b) The effect of PRL in males is less-well understood, although it may cause a deficiency of male sex hormones
1. **Thyroid-stimulating hormone** (TSH)
   1. Controls the secretion of hormones from the thyroid gland
   2. *Thyrotropin-releasing hormone* (TRH) from the hypothalamus regulates the release of TSH
   3. As blood concentrations of thyroid hormones increases, secretions of TRH and TSH decrease
Hypothalamus

TRH

Anterior pituitary gland

TSH

Thyroid hormones inhibit TSH and TRH

Bloodstream

Thyroid hormones stimulate target cells

Target cells

TSH stimulates the secretion of certain thyroid hormones

Thyroid gland

Release into bloodstream

Stimulation

Inhibition
1. **Adrenocorticotropic hormone** (ACTH)
   a) Controls secretion of hormones from the adrenal cortex
   b) Regulated by *corticotropin-releasing hormone* from the hypothalamus
   c) Stress can also increase its release
1. **Follicle-stimulating hormone** (FSH) and luteinizing hormone (LH) are gonadotropins affecting the male and female sex organs.
A. Posterior Pituitary Hormones

1. The posterior lobe consists of nerve fibers and neuroglial cells

2. Supports nerve fibers arising in the hypothalamus

3. Neurons in the hypothalamus produce
   a) *Antidiuretic hormone* (ADH)
      1) Produces its effect by causing the kidneys to conserve water
      2) hypothalamus regulates the secretion of ADH based on the amount of water in body fluids
      3) Stored in the posterior pituitary
a) **Oxytocin**

1) Plays a role in childbirth by contracting muscles in the uterine wall
2) Forces milk into ducts from the milk glands
3) Stretching of the uterus in the latter stages of pregnancy stimulates release of oxytocin
4) Suckling of an infant at the breast stimulates release of oxytocin after childbirth
Thyroid Gland

A. The thyroid gland is located below the larynx and consists of two broad lobes connected by an isthmus

B. The thyroid consists of secretory parts called follicles filled with hormone-storing colloid
C. Thyroid Hormones

1. The hypothalamus and pituitary gland control release of thyroid hormones
1. Follicular cells produce two iodine-containing hormones:
   a) **Thyroxine** \((T_4)\) (tetraiodothyronine)
   b) **Triiodothyronine** \((T_3)\)
   c) Essential for normal growth and development
   d) Together regulate energy metabolism
      1) Increase the rate at which cells release energy from carbohydrates
      2) Enhance protein synthesis
      3) Stimulate the breakdown and mobilization of lipids
1. Extrafollicular cells of the thyroid secrete **calcitonin**
   
a) Lowers blood levels of calcium and phosphate ions when they are too high
b) Increases the rate at which calcium is stored in bones and excreted in the urine
c) Secretion is regulated by negative feedback involving blood concentrations of calcium
Parathyroid Glands

A. The four, tiny parathyroids are located on the posterior of the thyroid

B. Parathyroid glands consist of tightly packed secretory cells covered by a thin capsule of connective tissue
A. **Parathyroid Hormone**

1. Parathyroid hormone (PTH) increases blood calcium ion concentration
2. Decreases phosphate ion concentration
3. PTH stimulates bone resorption by osteoclasts, which releases calcium into the blood
4. PTH also influences the kidneys to conserve calcium and causes increased absorption of calcium in the intestines
5. A negative feedback mechanism involving blood calcium levels regulates release of PTH

B. Calcitonin and PTH exert opposite effects in regulating calcium ion levels in the blood
Adrenal Glands

A. The adrenal glands sit atop the kidneys enclosed in a layer of fat

B. The pyramid-shaped glands consist of
   1. Inner **adrenal medulla**
      a) Made up of modified postganglionic neurons
      b) Connected to the sympathetic nervous system
   2. Outer **adrenal cortex**
      a) Makes up most of the adrenal glands
      b) Consists of epithelial cells in three layers
         1) Outer zone
         2) Middle zone
         3) Inner zone
A. Hormones of the Adrenal Medulla

1. The adrenal medulla secretes epinephrine and norepinephrine into the blood stream

2. The effects of these hormones resemble those of the sympathetic division neurotransmitters of the same name

3. They last up to 10 times longer when they are secreted as hormones

4. Used in times of stress and for “fight or flight”

5. Release of medullary hormones is regulated by nervous impulses from the central nervous system
A. Hormones of the Adrenal Cortex

1. The cells of the adrenal cortex produce over 30 different steroids
2. Some are vital to survival
3. Most important are
   a) *Aldosterone*
      1) A mineralocorticoid
      2) Causes the kidneys to conserve sodium ions and thus water
      3) Causes the kidneys to excrete potassium ions
      4) secreted in response to decreasing blood volume and blood pressure as a result of changes in the kidney
a) **Cortisol**

1) a glucocorticoid
2) influences the metabolism of glucose, protein, and fat
3) response to conditions that stress the body and require a greater supply of energy in the bloodstream
4) A negative feedback mechanism involving CRH from the hypothalamus and ACTH from the anterior pituitary controls the release of cortisol
5) Stress, injury, or disease can also trigger increased release of cortisol
a) **Adrenal Sex Hormones**

1) Produced in the inner zone
2) Mostly of the male type
3) Can be converted to female hormones in the skin, liver, and adipose tissues
4) Supplement hormones released by the gonads
5) May stimulate early development of reproductive organs
Pancreas

A. Elongated organ posterior to the stomach

B. The pancreas secretes digestive juices to the digestive tract as an exocrine gland

C. Secretes hormones as an endocrine gland

D. Islets of Langerhans, its endocrine portions, include two cell types:
   1. Alpha cells that secrete glucagon
   2. Beta cells that secrete insulin
A. Hormones of the Islets of Langerhans

1. **Glucagon**
   
a) Increases the blood levels of glucose by stimulating the breakdown of glycogen and the conversion of noncarbohydrates into glucose.

b) Release is controlled by a negative feedback system involving low blood glucose levels.
1. **Insulin**

   a) Decreases the blood levels of glucose by stimulating the liver to form glycogen

   b) Increasing protein synthesis, and stimulating adipose cells to store fat

   c) The release of insulin is controlled by a negative feedback system involving high blood glucose levels

2. Insulin and glucagon coordinate to maintain a relatively stable blood glucose concentration
Control center
Beta cells secrete insulin

Receptors
Beta cells detect a rise in blood glucose

Stimulus
Rise in blood glucose

Effectors
Insulin
• Promotes movement of glucose into certain cells
• Stimulates formation of glycogen from glucose

Response
Blood glucose drops toward normal (and inhibits insulin secretion)

Normal blood glucose concentration
too high
too low

Stimulus
Drop in blood glucose

Receptors
Alpha cells detect a drop in blood glucose

Effectors
Glucagon
• Stimulates cells to break down glycogen into glucose
• Stimulates cells to convert noncarbohydrates into glucose

Control center
Alpha cells secrete glucagon
Other Endocrine Glands

A. Pineal Gland
   1. Near the upper portion of the thalamus
   2. Secretes **melatonin**, which is involved in the regulation of circadian rhythms of the body

B. Thymus Gland
   1. Lies between the lungs under the sternum
   2. Secretes **thymosins** that affect production and differentiation of T lymphocytes (important in immunity)
A. Reproductive Glands

1. Ovaries produce estrogen and progesterone
2. The placenta produces estrogen, progesterone, and gonadotropin
3. Testes produce testosterone

B. Digestive Glands

1. Secrete hormones associated with digestion

C. Other Hormone Producing Organs

1. Heart secretes atrial natriuretic peptide affecting Na^+
2. Kidneys secrete erythropoietin for blood cell production
Stress and Health

A. Factors that serve as stressors to the body produce stress and threaten homeostasis.

B. Types of Stress

1. Physical
   a) Threatens the survival of tissues
   b) Includes extreme cold, prolonged exercise, or infections

2. Psychological
   a) Results from real or perceived dangers
   b) Includes feelings of anger, depression, fear, and grief
   c) even pleasant stimuli cause stress

3. Combination of the two
A. Response to Stress

1. Responses to stress are designed to maintain homeostasis

2. The hypothalamus controls the *general adaptation syndrome*
   a) Involves increased sympathetic activity
   b) Increased secretion of:
      1) Cortisol
      2) Glucagon
      3) Growth hormone
      4) Antidiuretic hormone
Stress results from changes in the external environment

Signals from sensory receptors

Hypothalamus

CRH released

Anterior pituitary

ACTH released

Adrenal cortex

Cortisol released

Sympathetic impulses

Adrenal medulla

Epinephrine and norepinephrine released

Norepinephrine released

Short term “fight or flight” or alarm stage

- Blood glucose increases.
- Blood glycerol and fatty acids increase.
- Heart rate increases.
- Blood pressure rises.
- Breathing rate increases.
- Air passages dilate.
- Pupils dilate.
- Blood flow redistributes.

Long term adjustment or resistance stage

- Increase in blood concentration of amino acids.
- Increased release of fatty acids.
- Increased glucose formed from non-carbohydrates—amino acids (from proteins) and glycerol (from fats).

Hormonal signals

Neural signals