CHAPTER 42 HORMONES AND THE ENDOCRINE SYSTEM

Chapter Outline

42.1 Chemical Signals

A. Categories of Signals

1. Chemical signals are used between individuals, between body parts, and between cells.
2. **Pheromones** are environmental signals that act at a distance between individual organisms.
   a. Ants lay down a pheromone trail for other members to find food.
   b. The female silkworm moth releases a pheromone to lure a male moth from miles away.
3. Endocrine secretions or hormones are environmental signals that act at a distance between body parts.
4. A **hormone** is an organic chemical produced by one set of cells that affects a different set.
5. A hormone travels through the complete circulatory system until it reaches its target organ.
6. Cells respond to a hormone depending on their receptors.
7. This also includes the secretions of neurosecretory cells into the hypothalamus.
8. Some signals act locally between adjacent cells without entering the bloodstream.
   a. Neurotransmitters released by neurons belong to this category.
   b. Prostaglandins and growth factors are also called local hormones; they affect neighboring cells and do not flow by the bloodstream.
   c. Growth factors are local hormones that promote cell division and mitosis.
9. Axillary secretions of men and women may have some effect on other people; women may synchronize their menstrual cycles with co-workers and some women may prefer the axillary odor of men with a different plasma membrane protein.

B. The Action of Hormones

1. **Steroid hormones** have the same complex of four carbon rings but have different side chains.
   a. Steroid hormones are lipids and cross cell membranes freely.
   b. Inside the cytoplasm or a nucleus, hormones such as estrogen and progesterone bind to a specific receptor.
   c. The hormone-receptor complex binds to DNA resulting in activation of genes that produce enzymes.
2. A hormone does not seek out a target organ; the organ is awaiting the arrival of the hormone.
3. Cells that can react with a hormone have receptor proteins that combine with the hormone in a lock-and-key manner.
4. **Peptide hormones**
   a. Peptide hormones cannot enter a cell so they bind to a receptor protein in plasma membrane.
   b. Epinephrine is an example that binds to a receptor protein; a relay system leads to conversion of ATP to cyclic AMP.
   c. **Cyclic AMP** (cAMP) is made from ATP; it has one phosphate group attached to adenosine at two locations.
   d. Peptide hormones are the **first messenger**; cAMP and calcium are the **second messenger**.
   e. The second messenger sets an *enzyme cascade* in motion.
   f. Activated enzymes can be used repeatedly, resulting in a thousand-fold response.

42.2 Human Endocrine System

A. Endocrine Glands

1. **Endocrine glands** are ductless glands in contrast to exocrine glands with ducts.
2. **Endocrine system** consists of **endocrine glands** that coordinate body activities through hormones.
3. Their hormones are secreted directly into bloodstream.

4. The principal human endocrine glands include:
    a. the hypothalamus, pineal, and pituitary glands located in the brain,
    b. the thyroid and parathyroid glands located in the neck,
    c. the ovaries located in the abdomen, and the testes in the scrotum, and
    d. the thymus located in the thorax.
5. The endocrine system is especially involved with homeostasis.
6. Protein hormones must be injected because they would be digested if taken orally.
7. The effect of hormones is controlled by negative feedback and by antagonistic hormone action.
    a. Endocrine glands can be sensitive to the condition monitored or to the level of hormone produced.
        1) Several hormones affect the blood glucose, calcium, and sodium levels.
        2) Others are involved in the maturation and function of organs (i.e., gonads, etc.)
    b. **Negative feedback** control is one mechanism.
        1) The pancreas produces insulin when blood glucose rises; this causes the liver to store glucose.
        2) When glucose is stored, the glucose level goes down and the pancreas stops insulin production.
    c. **Antagonistic actions** of hormones can control hormonal regulation.
        1) The effect of insulin is offset by the production of glucagon by the pancreas.
        2) Thyroid lowers blood calcium level but the parathyroids raise blood calcium level.

B. Hypothalamus and Pituitary Gland
1. The **hypothalamus** regulates the internal environment through the autonomic system.
2. It controls heartbeat, temperature, water balance, as well as glandular secretions of the pituitary gland.
3. Pituitary Gland
    a. Pituitary gland is connected to the hypothalamus by a stalklike structure.
    b. It is about 1 cm in diameter and lies just below the hypothalamus.
    c. It is comprised of two portions: the **posterior pituitary** and the **anterior pituitary**.
4. **Posterior Pituitary**
    a. This portion contains **neurosecretory cells** that originated in the hypothalamus and respond to neurotransmitters and produce hormones.
    b. The hypothalamus produces **antidiuretic hormone** (**ADH** or **vasopressin**) and **oxytocin**, which pass through axon endings in the posterior pituitary and are stored until released.
    c. **Antidiuretic hormone** (**ADH**) promotes reabsorption of water from the collecting ducts in the kidneys.
        1) Nerve cells in the hypothalamus determine when the blood is too concentrated; ADH is released and the kidneys respond by reabsorbing water.
        2) As the blood becomes dilute, ADH is no longer released; this is a case of negative feedback.
    d. **Oxytocin** is also made in hypothalamus and stored in the posterior pituitary.
        1) Oxytocin stimulates uterine muscle contraction in response to uterine wall nerve impulses.
        2) It also stimulates the release of milk from mammary glands.
        3) This positive feedback increases intensity; such positive feedback does not maintain homeostasis.
5. **Anterior Pituitary**
    a. Stimulation by the hypothalamus controls the release of anterior pituitary hormones through a portal system consisting of two capillary systems connected by a vein.
    b. The hypothalamus produces **hypothalamic-releasing** and **hypothalamic-inhibiting hormones** which pass to the anterior pituitary by this **portal system**.
        1) **Thyroid-releasing hormones** released from the hypothalamus act on cells in the anterior pituitary to stimulate the production and secretion of a specific hormone.
        2) **Thyroid-inhibiting hormones** produced in and released from the hypothalamus act on cells in the anterior pituitary to inhibit the production and secretion of a specific hormone.
    c. The anterior pituitary produces six different hormones, each by a distinct cell type.
    d. Three of these anterior pituitary hormones affect other glands.
        1) The **thyroid-stimulating hormone (TSH)** stimulates thyroid to produce and secrete thyroxin.
        2) **Adrenocorticotropic hormone (ACTH)** stimulates the adrenal cortex to release cortisol.
        3) **Gonadotropic hormones (follicle-stimulating hormone [FSH]** and **luteinizing hormone [LH])** act on the gonads (ovaries and testes) to secrete sex hormones.
    e. The other three hormones have direct effects on the body.

f. **Prolactin** (**PRL**) is produced in quantity only after childbirth.
    1) Prolactin causes the mammary glands to produce milk.
    2) It also plays a role in carbohydrate and fat metabolism.
g. **Melanocyte-stimulating hormone** (**MSH**) causes skin color changes in fishes, amphibians, and reptiles with melanophores, special skin cells.
h. **Growth hormone** (**GH** or somatotropic hormone)
    1) GH promotes skeletal and muscular growth.
    2) GH acts to stimulate the transport of amino acids into cells and to increase the activity of ribosomes.
    3) GH promotes fat metabolism rather than glucose metabolism.
    4) Too little GH during childhood makes an individual a pituitary dwarf.
    5) Too much forms a giant; life expectancy is less because GH affects blood glucose levels and promotes diabetes mellitus.
    6) The overproduction of GH in adults results in **acromegaly**; since long bone growth is no longer possible, only the feet, hands, and face grow.

C. Thyroid Gland
1. The **thyroid gland** is in the neck and attached to the trachea just below the larynx.
2. The two hormones produced by the many follicles of the thyroid both contain iodine.
    a. **Thyroxine** (**T_4**) contains four iodine atoms.
    b. **Triiodothyronine** (**T_3**) contains three iodine atoms.
3. Iodine, actively transported into thyroid, may reach concentrations 25 times greater than in the bloodstream.
4. Lack of iodine causes enlargement of the thyroid (goiter).
    a. The anterior pituitary stimulates the thyroid to secrete thyroxine.
    b. An increase in size (goiter) is ineffective since the thyroxine level is low due to iodine shortage.
    c. Goiter is easily prevented by supplementing iodine intake in salt.
5. Thyroid hormones increase the metabolic rate; there is no one target organ, all organs respond.
6. **Cretinism** occurs in individuals who have suffered from low thyroid function since birth.
    a. They are short and stocky and have had hypothyroidism since infancy.
    b. Thyroid treatment helps but unless it is begun in the first two months, mental retardation can occur.
7. **Myxedema** is hypothyroidism in adults; thyroid hormones can restore normal function.
8. **Hyperthyroidism** (**Graves disease**) occurs when thyroid gland is enlarged or overactive.
    a. The eyes protrude because of edema in the eye socket tissue; this is called exophthalmic goiter.
    b. Removal or destruction of some thyroid tissue by surgery or radiation often cures it.
9. The thyroid gland also produces **calcitonin**.
    a. **Calcitonin** lowers calcium level in the blood and increases deposits in the bone by reducing osteoclasts.
    b. Calcitonin is also necessary for blood clotting.
    c. If blood calcium is lowered to normal, the release of calcitonin is inhibited.
    d. Too low calcium levels stimulate the release of **parathyroid hormone** (**PTH**).

D. Parathyroid Glands
1. Four **parathyroid glands** are embedded in posterior surface of the thyroid gland.
2. Parathyroid glands produce **parathyroid hormone** (**PTH**).
3. Under the influence of PTH, the calcium level in blood increases and the phosphate level decreases.
4. **PTH** stimulates the **absorption** of Ca^{2+} by activating vitamin D, the **retention** of Ca^{2+} (and excretion of phosphate) by the kidneys, and **demineralization** of bone by promoting the activity of osteoclasts.
5. When the blood calcium level reaches the right level, the parathyroid glands no longer produce PTH.
6. If PTH is not produced in response to low blood Ca^{2+}, **tetany** results because the Ca^{2+} plays an important role in both nerve conduction and muscle contraction.
7. In tetany, the body shakes from continuous muscle contraction due to the increased excitability of nerves that fire spontaneously and without rest.

E. Adrenal Glands
1. Each of two **adrenal glands** sit atop each kidney.
2. Each gland consists of two parts: an outer adrenal cortex and an inner adrenal medulla.
3. The cortex and medulla have no physiological connection between them.

4. The hypothalamus exerts control over both portions.
    a. Nerve impulses travel via the brain stem to the spinal cord to sympathetic nerve fibers to the medulla.
    b. The hypothalamus uses ACTH-releasing hormone to control the anterior pituitary's secretion of ACTH.
5. Adrenal hormones increase during times of physical and emotional stress.

F. Adrenal Medulla
1. Both **epinephrine** and **norepinephrine** are produced by the adrenal medulla.
2. Both hormones bring about body changes corresponding to an emergency.
    a. The blood glucose level rises and metabolic rate increases.
    b. The bronchioles dilate and breathing rate increases.
    c. Blood vessels to the digestive tract and skin constrict; those to the skeletal muscles dilate.
    d. The cardiac muscle contracts more forcefully and the heart rate increases.

G. Adrenal cortex hormones provide a sustained response to stress.
1. The **adrenal cortex** secretes two types of hormones: **glucocorticoids** and **mineralocorticoids**.
    a. Glucocorticoids help to regulate blood glucose levels.
    b. Mineralocorticoids regulate the levels of minerals in the blood.
    c. It also secretes a small amount of both male and female sex hormones in both sexes.
2. **Cortisol** is a biologically significant glucocorticoid.
    a. Cortisol promotes the breakdown of muscle protein into amino acids taken up by the liver from the blood.
    b. Cortisol breaks down fatty acids rather than carbohydrates; cortisol therefore raises blood glucose levels.
    c. Cortisol counteracts the inflammatory response; it helps medicate arthritis and bursitis.
3. **Aldosterone** is the most important of the **mineralocorticoids.**
    a. The primary target organ is the kidney where it promotes the reabsorption of Na^+ and the excretion of K^+.
    b. Mineralocorticoid secretion is controlled by the **renin-angiotensin-aldosterone system**
        1) Under low blood volume and sodium levels, the kidneys secrete renin.
        2) The enzyme renin converts the plasma protein angiotensinogen to angiotensin I; this becomes angiotensin II by a converting enzyme in lungs.
        3) Angiotensin II stimulates the adrenal cortex to release aldosterone.
        4) Angiotensin I constricts the arterioles directly; aldosterone causes the kidneys to absorb calcium.
        5) When the blood sodium rises, water is reabsorbed as the hypothalamus secretes ADH; blood pressure then increases to normal.
    c. **Atrial natriuretic hormone** (**ANH**) causes the excretion of sodium.
        1) When the atria of the heart are stretched due to increased blood volume, cardiac cells release ANH.
        2) ANH inhibits the secretion of renin by the kidneys and the secretion of aldosterone from the adrenal cortex.
        3) When sodium is excreted, so is water; the blood volume and pressure then return to normal.

H. Malfunction of the Adrenal Cortex
1. Low levels of adrenal cortex hormones (hyposecretion) result in **Addison disease**.
    a. When ACTH is in excess, like MSH, it can lead to the buildup of melanin and a bronzing of the skin.
    b. The lack of cortisol results in low glucose levels; a stressed person has insufficient energy.
    c. The lack of aldosterone drops blood sodium levels; a person then has low blood pressure and dehydration.
    d. Left untreated, Addison disease can be fatal.
2. High levels of adrenal cortex hormones from hypersecretion result in **Cushing syndrome**.
    a. Excess cortisol causes a tendency toward diabetes mellitus.
    b. Muscular protein then decreases and subcutaneous fat forms an obese trunk but normal arms and legs.

c. Other symptoms include high blood sodium level, a basic blood pH, hypertension, and edema of the face.
d. Women may have masculinization from oversecretion of adrenal male sex hormone.

I. Pancreas
1. The pancreas lies transverse in the abdomen between the kidneys and near the duodenum.
2. The pancreas is composed of two types of tissue.
   a. Exocrine tissue produces and secretes **digestive juices** into the small intestine by way of ducts.
   b. Endocrine tissues called **pancreatic islets** (**of Langerhans**) produce **insulin** and **glucagon**.
3. All body cells utilize glucose; therefore its level must be closely regulated.
4. **Insulin** is secreted when the blood glucose level is high after eating; insulin has three actions.
   a. Insulin stimulates liver, fat, and muscle cells to take up glucose.
   b. Insulin stimulates liver and muscles to store glucose as glycogen.
   c. Insulin promotes buildup of fats and proteins and inhibits their use as an energy source.
5. **Glucagon** is secreted between meals in response to low blood glucose level.
   a. Liver and adipose tissue are the main targets.
   b. Adipose tissue cells break the fat into glycerol and fatty acids.
   c. The liver uses glycerol and fatty acids as substrates for glucose, raising the blood glucose levels.

J. Diabetes Mellitus
1. **Diabetes mellitus** is a common disease where the body cells do not take up or metabolize sugar.
2. Blood glucose level becomes high enough for the kidneys to excrete glucose; therefore this is detected by a urine test.
3. The liver is not storing glucose as glycogen and cells are not utilizing glucose for energy.
4. Since carbohydrate is not being metabolized, the body breaks down protein and fat for energy.
5. Ketones then build up in blood; the resulting reduced blood volume and acidosis can lead to coma and death.
6. In **type I** (**insulin-dependent**) **diabetes**, the pancreas does not produce insulin.
   a. A viral infection can cause cytotoxic T cells to destroy pancreatic islets.
   b. This is treated with a daily administration of insulin; an overdose or lack of eating results in hypoglycemia.
   c. The brain also has constant sugar requirements; low blood sugar can result in unconsciousness.
   d. An immediate intake of sugar is a simple and effective treatment.
7. Of 16 million diabetics in U.S., most have **type II** (**noninsulin-dependent**) **diabetes**.
   a. This form of diabetes usually occurs in obese and inactive individuals of any age.
   b. The pancreas does produce insulin but live and muscle cells do not respond to it.
   c. Initially, this is a result of cells lacking the receptors for insulin.
   d. Untreated, type II diabetes can have serious symptoms: blindness, kidney disease, circulatory disorders, strokes, etc.
   e. A low fat diet and regular exercise help; oral drugs can make cells more sensitive to insulin or stimulate higher levels of insulin production by pancreas.

K. Testes and Ovaries
1. Male **testes** located in the scrotum function as gonads and produce **androgens** (e.g., testosterone).
   a. **Testosterone** is male sex hormone.
   b. It stimulates the development of male secondary sex characteristics: large vocal cords, pubic hair, etc.
   c. Testosterone is largely responsible for the sex drive.
   d. Anabolic steroids are supplemental testosterone or similar chemicals with serious side effects.
   e. Testosterone also affects sweat glands, expression of baldness genes, and other effects.
2. Female sex hormones include **estrogens** and **progesterone**.
   a. **Estrogens** secreted at puberty stimulate the maturation of ovaries and other sexual organs.
   b. Estrogen is necessary for oocyte development.
   c. It is responsible for the development of female secondary sex characteristics: a layer of fat beneath the skin, a larger pelvic girdle, etc.
   d. Estrogen and progesterone are required for breast development and the regulation of the uterine cycle.

L. Pineal Gland
    1. The **pineal gland** produces **melatonin**, primarily at night.
    2. The pineal gland and melatonin help establish **circadian rhythms**, 24-hour physiological cycles.
    3. Pineal gland may also be involved in human sexual development; children in whom a brain tumor has destroyed the pineal gland experience puberty earlier.

M. Thymus Gland
    1. The **thymus** is a lobular gland that lies just beneath the sternum in the upper thoracic cavity.
    2. It reaches its largest size and is most active during childhood; with age, it shrinks and becomes fatty.
    3. Some lymphocytes that originate in the bone marrow pass through the thymus and change into T lymphocytes.
    4. The thymus produces **thymosins** which aid in the differentiation of T cells and may stimulate immune cells.

N. Prostaglandins
    1. Prostaglandins are potent chemical signals produced within cells from arachidonate, a fatty acid.
    2. They are not distributed in the blood but act locally.
    3. In the uterus, prostaglandins cause the uterus to contract and are implicated in menstrual discomfort.
    4. Aspirin reduces temperature and controls pain because of its effect on prostaglandins.