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. Female silkworm moth releases pheromone to lure a male moth from miles away.
   c. Dog urine serves as a territorial marker.
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 circulatory system to its target organ.
6. Cells respond to a hormone depending on their receptors; they combine in a lock-and-key manner.
7. This also includes the secretions of neurosecretory cells into the hypothalamus.
8. Environmental signals can act locally between adjacent cells.
   a. Neurotransmitters released by neurons belong to this category.
   b. Prostaglandins and growth factors are also called local hormones.

B. Types of Glands

1. There are two types of glands found in the human body.
   a. Exocrine glands – glands that have ducts leading to the target. Sweat glands and salivary glands are examples.
   b. Endocrine glands – glands that do not have ducts leading to the target. The secretion from the gland is carried by way of the circulatory system to the target. This is the group to be studied.

C. Action of Hormones

1. A hormone does not seek out a target organ; the organ is awaiting the arrival of the hormone. The top picture demonstrates peptide hormone action and the second illustrates steroid hormone action.
2. Steroid hormones (single messenger system) are smaller and have the ability to cross cell membranes.
   a. Steroid hormones are lipids.
   b. Inside a nucleus, hormones such as estrogen and progesterone bind to a specific receptor.
   c. Hormone-receptor complex binds to DNA resulting in activation of genes that produce enzymes.
3. Peptide hormones (double messenger system) never enter a cell so they bind to a receptor protein in plasma membrane
   a. Epinephrine binds to receptor protein; relay system leads to conversion of ATP to cyclic AMP.
   b. Cyclic AMP (cAMP) is made from ATP; it has one phosphate group attached to adenosine at two locations.
   c. Peptide hormones are the first messenger; cAMP and calcium are often the second messenger.
   d. cAMP sets an enzyme cascade in motion.
   e. Activated enzymes can be used repeatedly, resulting in a thousand-fold response.

D. Endocrine Glands

Endocrine glands are ductless glands in contrast to exocrine glands with ducts.

1. Endocrine system consists of endocrine glands that coordinate body activities through hormones.
2. Their hormones that are secreted directly into bloodstream.
3. A hormone may have a different function in different species.
   a. Prolactin stimulates breasts to secrete milk but stimulates the gut in pigeons.
   b. Thyroxine in human stimulates metabolism but induces metamorphosis of tadpoles to frogs.

4. Principal human endocrine glands include:
   a. Hypothalamus, pineal, and pituitary glands located in brain
   b. Thyroid and parathyroid glands located in neck.
   c. Ovaries located in abdomen, and testes in scrotum.
   d. Thymus located in thorax.
5. Endocrine system is especially involved with homeostasis.
6. Effect of hormones is controlled by negative feedback and contrary hormone action. (See Class Notes for Negative Feedback diagram and info)
   a. Endocrine glands can be sensitive to the condition monitored or to level of hormone produced.
      1. Several hormones affect blood glucose, calcium, and sodium levels.
      2. Others are involved in maturation and function of organs (i.e. gonads, etc.)
   b. **Negative feedback** control is one mechanism.
      1. Pancreas produces insulin when blood glucose rises; this causes liver to store glucose.
      2. When glucose is stored, level goes down and pancreas stops insulin production.
   c. **Contrary actions** of hormones can control hormonal regulation.
      1. Effect of insulin is offset by production of glucagon by pancreas.
      2. Thyroid lowers blood calcium level but the parathyroids raise blood calcium level.

C. Hypothalamus and Pituitary Gland

1. **Hypothalamus** regulates the internal environment through the autonomic system.
2. It controls heart beat, temperature, water balance, as well as glandular secretions of pituitary gland.
3. Pituitary Gland
   a. Pituitary gland is connected to hypothalamus by a stalk-like structure.
   b. It is about 1 cm in diameter and lies just below the hypothalamus.
   c. It is comprised of two portions: posterior pituitary and anterior pituitary.
4. **Posterior Pituitary**
   a. This portion of pituitary gland is connected to hypothalamus by a stalk-like structure.
   b. It contains portions of neurosecretory cells that originate in hypothalamus and respond to neurotransmitters and produce hormones.
   c. Hypothalamus produces **antidiuretic hormone (ADH or vasopressin)** and **oxytocin**, which pass through axon endings in posterior pituitary and are stored until released.
   d. **Antidiuretic hormone (ADH)** promotes reabsorption of water from collecting ducts in kidneys.
      1. Nerve cells in the hypothalamus determine when blood is too concentrated; ADH is released and kidneys respond by reabsorbing water.
      2. As blood becomes dilute, ADH is no longer released; this is a case of negative feedback.
   e. **Oxytocin** is also made in hypothalamus and stored in posterior pituitary.
      1. Oxytocin stimulates uterine muscle contraction in response to uterine wall nerve impulses.
      2. It also stimulates release of milk from mammary glands.
      3. This positive feedback increases intensity; positive feedback does not maintain homeostasis.
5. **Anterior Pituitary**
   a. Stimulation by hypothalamus controls release of anterior pituitary hormones; direct stimulation of pituitary does not.
   b. Hypothalamus produces **hypothalamic-releasing** and **hypothalamic-release-inhibiting hormones** which pass to anterior pituitary by portal system of two capillary beds and one vein.
1. **Thyroid-releasing hormones** released from hypothalamus act on cells in anterior pituitary to stimulate production and secretion of a specific hormone.

2. **Thyroid-inhibiting hormones** produced in and released from hypothalamus act on cells in anterior pituitary to inhibit production and secretion of a specific hormone.

c. Anterior pituitary produces six different hormones, each by a distinct cell type.

d. Three anterior pituitary hormones affect other glands.

   1. **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 gonads (ovaries and testes) to secrete sex hormones.

e. Three hormones have direct effects on the body.

f. **Prolactin (PRL)** is produced in quantity only after childbirth.

   1. Prolactin causes 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 transport of amino acids into cells and to increase 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-GH affects blood glucose levels and promotes diabetes mellitus.
   6. Overproduction of GH in adults results in **acromegaly**; only feet, hands, and face grow.

![Image of the anterior pituitary](image-url)
D. Thyroid Glands

(Make use of Thyroid Reading from class. An excellent source for this topic.)

1. **Thyroid gland** is in neck and attached to trachea just below larynx.
2. The two hormones produced by many follicles of the thyroid both contain iodine.
   a. **Thyroxine** (T₄) contains four iodine atoms.
   b. **Triiodothyronine** (T₃) contains three iodine atoms.
3. Iodine, actively transported into thyroid, may reach concentrations 25 times greater than in blood.
4. Lack of iodine causes enlargement (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 prevented by supplementing iodine in salt.
5. Thyroid hormones increase 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 begun in first two months, mental retardation occurs.
7. **Myxedema** is hypothyroidism in adults; thyroid hormones restore normal function.
8. **Hyperthyroidism (Grave's disease)** occurs when thyroid gland is enlarged or overactive.
   a. The eyes protrude because of swelling in eye socket tissue; called exophthalmic goiter.
   b. Removal or destruction of some thyroid tissue by surgery or radiation often cures it.
9. Thyroid gland also produces **calcitonin**.
   a. **Calcitonin** lowers calcium level in blood and increases deposit in bone. If blood calcium is normal, release of calcitonin is inhibited; low calcium levels stimulate release of **parathyroid hormone (PTH)**.

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**Notes**

**Anatomy and Physiology**
E. Parathyroid Glands

1. Four parathyroid glands are embedded in posterior surface of thyroid gland.
2. Parathyroid glands produce parathyroid hormone (PTH).
4. PTH stimulates the absorption of Ca^{2+}, the retention of Ca^{2+} by the kidneys, and
demineralization of bone by promoting activity of osteoclasts.
5. When blood calcium level reaches the right level, parathyroid glands no longer produce
PTH.
6. If PTH is not produced in response to low blood Ca^{2+}, tetany results because 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 increased
excitability of nerves that fire spontaneously and without rest.

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

Adrenal Medulla

1. Epinephrine and norepinephrine are produced by adrenal medulla.
2. Both hormones bring about body changes corresponding to an emergency.
   a. Blood glucose level rises and metabolic rate increases.
   b. Bronchioles dilate and breathing rate increases.
   c. Blood vessels to digestive tract and skin constrict; those to skeletal muscles
      dilate.
   d. Cardiac muscle contracts more forcefully and heart rate increases.
3. This is known as the fight or flight response to stress.

Adrenal cortex hormones provide a sustained response to stress.
1. **Adrenal cortex** secretes two types of hormones: **glucocorticoids** and **mineralocorticoids**.
   a. Glucocorticoids help regulate blood glucose levels.
   b. Mineralocorticoids regulate levels of minerals in 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 breakdown of muscle protein to amino acids taken up by liver from blood.
   b. Cortisol breaks down of fatty acids rather than carbohydrates; cortisol raises blood glucose levels.
   c. Cortisol counteracts the inflammatory response; it helps mediate arthritis and bursitis. (Cortisone)

3. **Aldosterone** is the most important of the **mineralocorticoids**.
   a. Primary target organ is kidney where it promotes reabsorption of Na⁺ to help control low blood pressure.

### Malfunction of the Adrenal Cortex

1. Low levels of adrenal cortex hormones (hyposcretion) results in **Addison disease**.
   a. ACTH is in excess; like MSH, it can lead to buildup of melanin and bronzing of skin.
   b. Lack of cortisol results in low glucose levels; a stressed person has insufficient energy.
   c. Lack of aldosterone drops blood sodium levels; a person has low blood pressure and dehydration.
   d. 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 due to increased blood glucose.
   b. Muscular protein decreases; fat forms an obese trunk but normal arms and legs.
   c. Women may have masculinization from oversecretion of adrenal male sex hormone.

### G. Pancreas (Make use of Pancreatic Reading from class. An excellent source for this topic.)

1. Pancreas lies transverse in abdomen between kidneys and near duodenum.
2. Pancreas is composed of two types of tissue.
   a. Exocrine tissue produces and secretes **digestive juices** into 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 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 main targets.
   b. Adipose tissue cells break fat into glycerol and fatty acids.
   c. Liver uses glycerol and fatty acids as substrates for glucose, raising blood glucose levels.

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**Diabetes Mellitus**

1. **Diabetes mellitus** is a common disease where body cells do not take up or metabolize sugar.
2. Sugar in urine is common laboratory test; blood glucose level is high enough kidneys excrete glucose.
3. 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 build up in blood; resulting reduced blood volume and acidosis can lead to coma and death.
6. In **type I (insulin-dependent) diabetes**, pancreas does not produce insulin.
   a. Viral infection causes white blood cells to destroy pancreatic islets.
   b. Treated with daily administration of insulin, overdose or lack of eating results in hypoglycemia.
   c. Brain has constant sugar requirements; low blood sugar can result in unconsciousness.
   d. An immediate intake of sugar is simple 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. Pancreas does produce insulin but cells do not respond to it.
   c. Initially, this is a result of cells lacking receptors for insulin.
   d. Untreated, type II can have serious symptoms: blindness, kidney disease, circulatory disorders, strokes, etc.
   e. Low fat diet and regular exercise help; oral drugs make cells more sensitive to insulin or stimulate higher levels of insulin production by pancreas.
H. Testes and Ovaries

1. Male testes located in scrotum function as gonads and produce androgens (e.g., testosterone).
   a. Testosterone is male sex hormone.
   b. It stimulates development of male secondary sex characteristics: large vocal cords, pubic hair, etc.
   c. Testosterone is largely responsible for the sex drive and probably aggressiveness.
   d. Anabolic steroids are supplemental testosterone or similar chemicals with serious side effects. (Fig. 49.15)
   e. Testosterone also affects sweat glands, expression of baldness genes, and other effects.
2. Female sex hormones are estrogen and progesterone.
   a. Estrogens secreted at puberty stimulate maturation of ovaries and other sexual organs.
   b. Estrogen is necessary for oocyte development.
   c. It is responsible for development of female secondary sex characteristics: a layer of fat beneath skin, larger pelvic girdle, etc.
   d. Estrogen and progesterone are required for breast development and regulation of uterine cycle.

I. Thymus Gland

1. Thymus is a lobular gland that lies 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 bone marrow pass through thymus and change into T cells.
4. Thymus produces thymosins which aid differentiation of T cells and may stimulate immune cells.

J. Pineal Gland

1. Pineal gland produces melatonin, primarily at night.
2. In mammals, it is located in third ventricle and cannot receive light directly; it receives nerve impulses from the eyes, by way of the optic tract.
4. Pineal gland may also be involved in human sexual development.
   a. Some animals go through a yearly cycle of enlargement of reproductive organs when melatonin levels are low.
   b. Children in whom a brain tumor has destroyed the pineal gland experience puberty earlier.
5. Melatonin may cause seasonal affective disorder where persons are depressed at onset of winter.
What you need to know from notes

- the difference between pheromones and hormones
- the difference between exocrine and endocrine glands
- how steroid and peptide based hormones stimulate target cells
- location of the glands in the body
- how negative feedback helps the endocrine system maintain homeostasis
- the secretions of the glands identified in the notes and their action
- the role of the hypothalamus in maintaining homeostasis
- the role of the thyroid in maintaining a metabolic balance
- the interaction of glucagon and insulin to maintain blood sugar homeostasis
- the interaction of calcitonin and parathyroid hormone to maintain blood calcium homeostasis
- the stress response as it relates to the adrenal cortex and medulla
- what happens when things go wrong for the thyroid, pancreas and adrenal glands as well as Growth Hormone

Summary Charts

<table>
<thead>
<tr>
<th>Gland</th>
<th>Hormone</th>
<th>Chemical Class</th>
<th>Representative Actions</th>
<th>Regulated By</th>
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Table 45.1 Major Vertebrate Endocrine Glands and Some of Their Hormones (Hypothalamus – Parathyroid glands)

Notes

Anatomy and Physiology 10

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<thead>
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