Lecture Outline: Signals and the Endocrine System

I. **Endocrine System vs. Nervous System**

A. **Control Systems Comparison**

1. Body's two major control systems: Nervous system and Endocrine system.
2. Fundamental difference: Nature of signals.

B. **Chemical Signals (Hormones vs. Neurotransmitters)**

1. Nervous System: Uses both electrochemical (action potentials) and chemical (neurotransmitters) signals.
2. Endocrine System: Operates on chemical signals only (hormones).
3. Neurotransmitters vs. Hormones:
    a. Can be the exact same chemical.
    b. Difference lies in release and travel:
        (1) Neurotransmitters: Work locally, released into synaptic cleft, act on immediate cell.
        (2) Hormones: Broadcast throughout the body, released by glands into bloodstream, reach all cells with blood supply.
4. Receptor Binding: All chemical signals (neurotransmitters or hormones) require binding to a receptor for an effect.

C. **Hormone Action Mechanisms**

1. Steroid Hormones:
    a. Are lipids, modified cholesterol molecules.
    b. Can pass directly through phospholipid bilayer of cell and nuclear membrane.
    c. Receptors located inside the cell (cytoplasm or nucleoplasm).
    d. Binding causes receptor protein to change shape.

e. Often leads to **direct gene activation**, creating mRNA for protein synthesis.

2. Amino Acid-Based Hormones (Majority of Hormones):
   a. Not lipids, cannot enter the cell.
   b. Receptors located on the cell surface (membrane-bound proteins).
   c. Binding causes receptor shape change.
   d. Activates a **second messenger system** inside the cell (e.g., cyclic AMP).
   e. Hormone is the "first messenger," its job done upon binding; second messenger carries the signal internally.

II. **Major Endocrine Glands and Their Functions**

A. **Hypothalamus and Pituitary Gland**

1. Pituitary Anatomy and Nomenclature:
   a. **Pituitary gland** (also called **Hypophysis**) is two organs in one.
   b. **Anterior Pituitary** (**Adenohypophysis**): Truly a gland.
   c. **Posterior Pituitary** (**Neurohypophysis**): Extension of the brain, not a gland, made of neurons.
2. Hypothalamus-Pituitary Interaction:
   a. Hypothalamus (part of brain) and Pituitary (endocrine system) meet and overlap.
   b. Major way the two control systems control each other.
3. Posterior Pituitary (Neurohypophysis) Hormones:
   a. Produces only two hormones.
   b. Hormones released directly from **axon terminals** of neurons starting in the hypothalamus.
   c. Chemicals are called **neurohormones** because they are released into the bloodstream, not a synaptic cleft.
   d. **Hypothalamohypophysial tract**: Bundle of axons connecting hypothalamus to neurohypophysis.
   e. Specific Neurohormones:
      (1) **Antidiuretic Hormone (ADH)**:

1. Named for antagonizing diuresis (high volume dilute urine).
2. Causes kidneys to produce small amount of concentrated urine to save water.
3. Target tissue: Kidneys.

(2) **Oxytocin**:

1. Involved in **positive feedback** (e.g., childbirth, uterine contractions).
2. Operates on uterine muscles, causing contractions to push fetus.
3. Also involved in **milk ejection** from mammary glands (different from milk production).

4. Anterior Pituitary (Adenohypophysis) Hormones:

a. Hormones are classified as **releasing** or **inhibiting hormones**.

b. Effect is to cause or inhibit other glands from releasing their hormones.

c. Do not directly cause ultimate effects; they control other glands.

d. All are amino acid-based (peptides or proteins), cannot enter cells, bind to surface receptors.

e. Specific Hormones:

(1) **Growth Hormone (GH)**:

1. Important in overall growth.
2. Main targets: Bones and muscles.
3. Important throughout life, especially during growth.

(2) **Prolactin (PRL)**:

1. Promotes **lactation** (production of milk).
2. Causes mammary glands to create milk (stored, not released).

(3) **Follicle-Stimulating Hormone (FSH)** and **Luteinizing Hormone (LH)**:

1. Both classified as **gonadotropins** (act on gonads).
2. Produced by both sexes, named for female functions.

3. FSH: Stimulates follicle (part of ovary that becomes egg).
4. LH: Involved in ovulation, corpus luteum production.
5. In males, they perform different functions in testes.

(4) **Thyrotropic Hormone (TH)** (also **Thyroid-Stimulating Hormone**):

1. **Thyrotropic** means acting on the thyroid.
2. Target: Thyroid gland.

(5) **Adrenocorticotropic Hormone (ACTH)**:

1. **Corticotropic** means acting on the cortex.
2. Target: **Adrenal cortex** (superficial part of adrenal glands).

B. **Thyroid and Parathyroid Glands**

1. Thyroid Gland Anatomy and Cells:
   a. Located in the neck, butterfly-shaped, wrapped around **thyroid cartilage**.
   b. **Isthmus**: Narrowing connecting the two "wings."
   c. Histology: Made of many **follicles** (sacks).
   d. **Follicle cells** (or follicular cells): Form walls of follicles, produce thyroid hormone.
   e. **Parafollicular cells**: Located between follicles, produce calcitonin.
2. Thyroid Hormones:
   a. **Thyroid Hormone** (actually two hormones: **T4** or **Thyroxine**, and **T3** or **Triiodothyronine**).
   b. T4 has four iodines, T3 has three iodines.
   c. Exception among amino acid-based hormones: **Hydrophobic**, can pass through membranes and enter cells (like steroids).
   d. Main job: Regulate **metabolic rate**.
3. Parathyroid Glands and Hormone:
   a. Usually four small glands embedded in the posterior thyroid gland.
   b. Named for being "by the thyroid," but have a completely different function.

c. Release **Parathyroid Hormone (PTH)**.

4. Calcium Balance Regulation:

a. PTH and Calcitonin have **opposite effects**. PTH is much more important.

b. **Parathyroid Hormone (PTH)**:

(1) Released when blood calcium level **falls below normal**.

(2) Tells **osteoclasts** (bone-breaking cells) to break down bone matrix (hydroxyapatite).

(3) Releases calcium from bone into blood, raising level back to normal.

(4) Essential for life (e.g., heart beating, signal molecule).

g. **Calcitonin**:

(1) Released by parafollicular cells when blood calcium level is **too high**.

(2) Tells **osteoblasts** (bone-building cells) to build bone matrix.

(3) Takes calcium out of blood to make more bone mineral, lowering blood calcium.

C. **Adrenal Glands**

1. Adrenal Gland Anatomy:

a. Two glands, named **adrenal** ("on the kidneys") for their placement, but functionally separate from kidneys.

b. Composed of two functionally distinct parts: **cortex** (superficial) and **medulla** (deeper).

2. Adrenal Medulla Hormones (Short-term Stress Response):

a. Innervated directly by the **nervous system** (neurons from spinal cord).

b. Releases **epinephrine** (also called **adrenaline**) and **norepinephrine** (also **noradrenaline**).

c. **Short-term stress hormones** (fight-or-flight).

d. Effects:

(1) Increase heart rate and blood pressure.

(2) Liver converts **glycogen to glucose** (for fuel).

(3) Dilation of bronchioles (easier airflow).

3. Adrenal Cortex Hormones (Prolonged Stress Response):

a. Stimulated by **hormones**, not neurons (humoral response).

b. All are **steroid hormones** (lipids), can enter cells.

c. Three layers, secreting different hormones:

(1) Outer layer: **Mineralocorticoids** (e.g., Aldosterone).

1. Control **mineral balance** (sodium and potassium).

(2) Middle layer: **Glucocorticoids** (e.g., Cortisol).

1. Control **glucose level** in blood (brain's primary fuel).
2. Tell rest of body to use proteins and fats as fuel, sparing glucose for the brain.
3. **Prolonged stress suppresses immune system** and can lead to other health issues.

(3) Deepest layer: **Sex Hormones** (androgens and estrogens).

1. Produced here in addition to gonads.

D. **Pancreas**

1. Pancreas: Endocrine and Exocrine Functions:

a. Dual organ: Part of endocrine system and digestive system.

b. Location: Hairpin loop of the **duodenum** (first part of small intestine).

c. Exocrine function: Produces **digestive enzymes** (pancreatic juice) released into small intestine via ducts. (Not hormones).

2. Pancreatic Islets and Hormones:

a. **Pancreatic Islets** (islands) are endocrine portions.

b. Surrounded by exocrine cells.

c. Two major types of endocrine cells:

(1) **Alpha cells**: Produce **glucagon**.

(2) **Beta cells**: Produce **insulin**.

f. Insulin and glucagon are **antagonistic** (opposite effects) but both

control blood glucose.

3. Glucose Homeostasis:
    a. **Glucagon** (from alpha cells):
        (1) Released when blood glucose level is **too low** (e.g., long time since eating).
        (2) Travels to liver, tells liver to break down stored **glycogen into glucose** and release into bloodstream.
        (3) Raises blood glucose level.
    e. **Insulin** (from beta cells):
        (1) Released when blood glucose level is **too high** (e.g., after absorbing nutrients from a meal).
        (2) Mainly acts on liver and skeletal muscles (not brain).
        (3) Allows non-brain cells to take glucose from blood into themselves.
        (4) Lowers blood glucose level.
        (5) Brain does not require insulin to take up glucose.

E. **Other Endocrine Glands**

1. **Pineal Gland**:
    a. Part of the brain, cone-shaped, pea-sized.
    b. Releases **melatonin**.
    c. Regulates **circadian rhythms** (daily rhythms), important for sleep-wake cycles.
2. **Thymus**:
    a. Located in the mediastinum (middle part of thorax).
    b. Huge in newborns, shrinks with age.
    c. Important for development of **immunity**.
    d. Releases chemicals for proper **maturation of T-cells** (T-lymphocytes), a type of white blood cell for foreign invaders.
3. **Gonads** (Primary Sex Organs):
    a. **Testes** (male): Both exocrine (sperm) and endocrine (testosterone).

b. **Ovaries** (female): Both exocrine (egg/ovum) and endocrine (estrogen, progesterone).

c. **Sex hormones** (androgens, estrogens, progesterone) also produced in adrenal cortex.

(1) **Androgen**: General term for masculizing hormones (andro = man).

(2) **Estrogen**: Generates estrus ("heat").

(3) **Progesterone**: Promotes gestation/pregnancy (prevents spontaneous abortion).

III. **Hormonal Control and Interactions**

A. **Renin-Angiotensin System**:

1. Complex signaling involving multiple organs.
2. Triggered by **decreased blood volume or pressure**.
3. Kidneys sense drop, release **Renin** (enzyme).
4. Renin converts **Angiotensinogen** (from liver) to **Angiotensin I**.
5. Angiotensin I travels to lungs, converted to **Angiotensin II** by **Angiotensin-Converting Enzyme (ACE)**.
6. Angiotensin II causes **vasoconstriction**, increasing blood pressure.
7. Example of inter-system cooperation (urinary, digestive, respiratory, circulatory).
8. **Atrial Natriuretic Peptide (ANP)**: Released by heart atria, tells kidneys to release more sodium into urine, opposing this system.

B. **Stress Response (Short-term vs. Long-term)**:

1. **Short-term stress response** (fight-or-flight):
   a. Involves **adrenal medulla**.
   b. Stimulated by **neurons**.
   c. Releases **epinephrine** and **norepinephrine**.
2. **Prolonged stress response**:
   a. Involves **adrenal cortex**.
   b. Stimulated by **hormones** (humoral).

c. Hypothalamus releases releasing hormones → Anterior Pituitary releases **ACTH** → Adrenal Cortex releases **Glucocorticoids**.

d. **Suppresses immune system**; chronic stress has profound health effects.

C. **Interconnectedness of Systems**:

1. Endocrine glands are spread across many organ systems.
2. Examples: Pancreas (endocrine/digestive), Gonads (endocrine/reproductive), Hypothalamus (nervous/endocrine), Thyroid (endocrine/respiratory system proximity).

```
```