Endocrine System

Hormones
Why are hormones needed?
- chemical messages from one body part to another
- communication needed to coordinate whole body
- daily homeostasis & regulation of large scale changes
  - solute levels in blood
    - glucose, Ca++, salts, etc.
  - metabolism
  - growth
  - development
  - maturation
  - reproduction
Animals rely on 2 systems for regulation

- **endocrine system**
  - system of ductless glands
    - secrete chemical signals directly into blood
    - chemical travels to target tissue
    - target cells have receptor proteins
    - slow, long-lasting response

- **nervous system**
  - system of neurons
    - transmits “electrical” signal & release neurotransmitters to target tissue
    - fast, short-lasting response
Regulation by chemical messengers

- **Neurotransmitters** released by neurons
- **Hormones** release by endocrine glands

- Neurotransmitters released by neurons
- Hormones release by endocrine glands

- Lock & Key system
- Axon
- Target cell
- Receptor proteins
- Endocrine gland
- Hormone carried by blood
Classes of Hormones

- **Protein-based hormones**
  - polypeptides
    - small proteins: insulin, ADH
  - glycoproteins
    - large proteins + carbohydrate: FSH, LH
  - amines
    - modified amino acids: epinephrine, melatonin

- **Lipid-based hormones**
  - steroids
    - modified cholesterol: sex hormones, aldosterone
How do hormones act on target cells

**Lipid-based hormones**
- **hydrophobic** & lipid-soluble
  - diffuse across cell membrane & enter cells
  - bind to receptor proteins in cytoplasm & nucleus
  - bind to DNA as transcription factors
    - turn on genes

**Protein-based hormones**
- **hydrophilic** & not lipid soluble
  - can’t diffuse across cell membrane
  - bind to receptor proteins in cell membrane
  - trigger secondary messenger pathway
  - activate internal cellular response
    - enzyme action, uptake or secretion of molecules...
**Action of lipid (steroid) hormones**

1. **Steroid hormone** in the **blood** is carried by a **protein carrier**.
2. The **steroid hormone** binds to a **receptor protein** in the **cytoplasm**.
3. The bound steroid hormone becomes a **transcription factor**.
4. The transcription factor influences the **DNA** to produce **mRNA**.
5. The **mRNA** is read by the **ribosome**.
6. The **protein** is produced.
7. The **protein** is secreted.

**Example**: secreted protein = growth factor (hair, bone, muscle, gametes)
Action of protein hormones

1. Protein hormone binds to receptor protein (G Protein).
2. Receptor protein activates cytoplasmic signal.
   - Activates GTP, which activates ATP.
3. ATP activates enzyme, which activates secondary messenger (cAMP).
4. cAMP acts as a secondary messenger.
5. Signal-transduction pathway activates other protein.
6. Other protein activates enzyme in cytoplasm.
7. Enzyme activates target cell response, producing an action.
Ex: Action of epinephrine (adrenaline)

1. Epinephrine binds to the receptor protein in the cell membrane.
2. This activates the G protein.
3. The G protein activates adenylyl cyclase, which produces cAMP.
4. cAMP activates protein kinase-A (PKA).
5. PKA activates phosphorylase kinase.
6. Phosphorylase kinase activates glycogen phosphorylase.
7. Glycogen phosphorylase releases glucose into the cytoplasm, which is then released to the blood.

Signal transduction pathway: epinephrine, receptor protein in cell membrane, cytoplasm, liver cell, glycogen, glucose, response.
Benefits of a 2° messenger system

**Amplification!**

**Cascade multiplier!**

**FAST response!**
Maintaining homeostasis

- Hormone 1 lowers body condition.
- Hormone 2 raises body condition.

This is a Negative Feedback Model.

Specific body condition:
- High activates hormone 1.
- Low activates hormone 2.

Gland:
- Produces hormone 1.
- Produces hormone 2.
Nervous System Control

Controlling Body Temperature

body temperature (37°C)

nerve signals

sweat
dilates surface blood vessels

high

constricts surface blood vessels

low

shiver

hypothalamus

Feedback
Regulation of Blood Sugar

Blood sugar level (90mg/100ml)

- **Insulin**
  - Body cells take up sugar from blood
  - Liver stores glycogen
  - Reduces appetite

- **Glucagon**
  - Liver releases glucose
  - Triggers hunger

Endocrine System Control

- **Beta islet cells** in the islets of Langerhans
- **Alpha islet cells** in the islets of Langerhans
Endocrine System Control

Blood Osmolarity

- Osmoreceptors in hypothalamus
- Blood osmolarity
- Blood pressure

ADH
- Increased water reabsorption
- Increase thirst


gi

High to low feedback loop

Pituitary
- Increased water & salt reabsorption

Nephron
- JuxtaGlomerular Apparatus
- Aldosterone
- Angiotensin
- Angiotensinogen

Adrenal gland

Feedback
Nervous & Endocrine systems linked

- **Hypothalamus** = “master nerve control center”
  - nervous system
  - receives information from nerves around body about internal conditions
  - releasing hormones: regulates release of hormones from pituitary

- **Pituitary gland** = “master gland”
  - endocrine system
  - secretes broad range of “tropic” hormones regulating other glands in body
Thyroid gland

Thyroid-stimulating hormone (TSH)

Kidney tubules

Adrenal cortex

Adrenocorticotropic hormone (ACTH)

Muscles of uterus

Bone and muscle

Gonadotropic hormones:
follicle-stimulating hormone (FSH) & luteinizing hormone (LH)

Testes

Ovaries

Anterior pituitary

Melanocyte in amphibian

Posterior pituitary

Prolactin (PRL)

Melanocyte-stimulating hormone (MSH)

Antidiuretic hormone (ADH)

Oxytocin

Adrenal cortex

Bone and muscle

Growth hormone (GH)

Tropic hormones = target endocrine glands

Hypothalamus
Homology in hormones

What does this tell you about these hormones?

How could these hormones have different effects?

- Prolactin
  - Mammals: milk production
  - Birds: fat metabolism
  - Fish: salt & water balance
  - Amphibians: metamorphosis & maturation

- Same gene family
- Gene duplication?

- Growth hormone
  - Growth & development

How could these hormones have different effects?
Regulating metabolism

- **Hypothalamus**
  - TRH = TSH-releasing hormone

- **Anterior Pituitary**
  - TSH = thyroid stimulating hormone

- **Thyroid**
  - produces thyroxine hormones
  - metabolism & development
    - bone growth
    - mental development
    - metabolic use of energy
    - blood pressure & heart rate
    - muscle tone
    - digestion
    - reproduction

TYROSINE + IODINE → THYROID "THYROID HORMONES",

"Hypothalamus → TSH → Thyroid → Thyroid Hormones → Hypothalamus"
Goiter

Iodine deficiency causes thyroid to enlarge as it tries to produce thyroxine.

- Hypothalamus
  - TRH
  - Anterior pituitary
    - TSH
      - Thyroid
        - tyrosine + iodine
          - thyroxines

- Normal Thyroid
  - Thyroid cartilage
  - Trachea

- Goiter
  - Thyroid cartilage
  - Trachea

[Diagram of goiter showing the thyroid gland and its connection with the hypothalamus and anterior pituitary through TRH and TSH, illustrating the lack of thyroxines due to iodine deficiency.]
Endocrine System Control
Regulation of Blood Calcium

blood calcium level (10 mg/100mL)

↑ kidney reabsorption of Ca++

calcitonin

downregulated

↓ kidney reabsorption of Ca++

Ca++ deposited in bones

↑ Ca++ uptake in intestines

activated Vitamin D

bones release Ca++

parathyroid

parathyroid hormone (PTH)

thyroid

high

low
Female reproductive cycle

- **FSH & LH** stimulate the ovary to release an egg (ovulation).
- The egg matures and is released (ovulation).
- The corpus luteum forms, maintaining the uterus lining.
- If pregnancy occurs, hCG produced by the fertilized egg (zygote) keeps the corpus luteum alive.
- Progesterone builds up the uterus lining.
- If pregnancy does not occur, corpus luteum breaks down, progesterone drops, and menstruation occurs.
- GnRH and FSH & LH regulate the cycle.
Any Questions??

Robert Wadlow
1918-1940
8' 11"
Effects of stress on a body

(A) SHORT-TERM STRESS RESPONSE

Effects of epinephrine and norepinephrine:
1. Glycogen broken down to glucose; increased blood glucose
2. Increased blood pressure
3. Increased breathing rate
4. Increased metabolic rate
5. Change in blood flow patterns, leading to increased alertness & decreased digestive & kidney activity

(B) LONG-TERM STRESS RESPONSE

Effects of mineralocorticoids:
1. Retention of sodium ions & water by kidneys
2. Increased blood volume & blood pressure

Effects of glucocorticoids:
1. Proteins & fats broken down & converted to glucose, leading to increased blood glucose
2. Immune system suppressed

Adrenal medulla secretes epinephrine & norepinephrine

Adrenal cortex secretes mineralocorticoids & glucocorticoids

Spinal cord (cross section)

Nerve signals

Nerve cell

Releasing hormone

Hypothalamus

Anterior pituitary

Blood vessel

ACTH

Adrenal gland

Kidney

Adrenal medulla secretes epinephrine & norepinephrine

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