Business

- Reminder: Study for Quiz #2
  - Partial study guide in “Sample Exams” section of SG

- Homework 11 in SG
  - Omit #11
  - Due in lab this week
The Endocrine System

Part One
Overview

- Acts with the nervous system to coordinate and integrate the activity of body cells
- Influences metabolic activities by means of hormones
- Responses occur more slowly but tend to last longer than those of the nervous system
- Endocrine glands: pituitary, thyroid, thymus, pancreas, parathyroid, adrenal, and pineal glands
Overview

Nervous System
• Nerve impulses
• Neurotransmitters
• Faster responses
• Brief effects
• Acts on specific target

Endocrine System
• Hormones
• Slower responses
• Longer effects
• Broader influence
Hormones

- Chemical substances secreted by cells
- Long-distance chemical signals that travel in the blood or lymph
- Most are either amino-acid based or steroid molecules
Chemistry of Hormones

• Two main classes
  1. Amino acid-based hormones
     • Amines, thyroxine, peptides, and proteins
  2. Steroids
     • Synthesized from cholesterol
     • Gonadal and adrenocortical hormones
Figure 16.4 Three types of endocrine gland stimuli.

<table>
<thead>
<tr>
<th>(a) Humoral Stimulus</th>
<th>(b) Neural Stimulus</th>
<th>(c) Hormonal Stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>① Capillary blood contains low concentration of $\text{Ca}^{2+}$, which stimulates...</td>
<td>① Preganglionic sympathetic fibers stimulate adrenal medulla cells...</td>
<td>① The hypothalamus secretes hormones that...</td>
</tr>
<tr>
<td>② ...secretion of parathyroid hormone (PTH) by parathyroid glands*</td>
<td>② ...to secrete catecholamines (epinephrine and norepinephrine)</td>
<td>② ...stimulate the anterior pituitary gland to secrete hormones that...</td>
</tr>
<tr>
<td>③</td>
<td></td>
<td>③ ...stimulate other endocrine glands to secrete hormones</td>
</tr>
</tbody>
</table>

*Parathyroid hormone (PTH)
Target Cell Specificity

- A hormone may have more than one type of target cell
- Specific receptors
- Hormone effects are due to alteration of cell’s activity
  - Effects vary
Target Cell Activation

- Target cell activation depends on three factors
  1. Blood levels of the hormone
  2. Relative number of receptors on or in the target cell
  3. Affinity of binding between receptor and hormone
Target Cell Activation

- Hormone concentration depends on
  - Rate of release and synthesis
  - Speed of inactivation

- Hormones influence the number of their receptors
  - Up-regulation - target cells form more receptors in response to the hormone
  - Down-regulation - target cells lose receptors in response to the hormone
How Hormones Work

- Slow acting
  - Fatty acids or steroids
- Fast acting
  - Proteins or peptides
Slow Acting Hormones

lipid soluble $\rightarrow$ cross cell membrane $\rightarrow$ enters nucleus $\rightarrow$
interacts with DNA $\rightarrow$ changes cell function by initiating gene transcription

- Relatively long lasting effects
- Examples: testosterone and estrogen
The steroid hormone diffuses through the plasma membrane and binds an intracellular receptor. The receptor-hormone complex enters the nucleus. The receptor-hormone complex binds a hormone response element (a specific DNA sequence). Binding initiates transcription of the gene to mRNA. The mRNA directs protein synthesis.
Fast Acting Hormones

- bind to receptor protein (hormone is first messenger) ➔
- second messenger (cyclic-AMP) ➔ activates enzymes ➔ rapid change in cell function

- Relatively short term effects
- May be greatly amplified
1. **Hormone (1st messenger) binds receptor.**

Receptor

G protein (G_s)

2. **Receptor activates G protein (G_s).**

3. **G protein activates adenylate cyclase.**

4. **Adenylate cyclase converts ATP to cAMP (2nd messenger).**

5. **cAMP activates protein kinases.**

Triggers responses of target cell (activates enzymes, stimulates cellular secretion, opens ion channel, etc.)

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**Hormones that act via cAMP mechanisms:**

- Epinephrine
- ACTH
- FSH
- LH
- Glucagon
- PTH
- TSH
- Calcitonin

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Extracellular fluid

Cytoplasm
Cellular Hormones

- Some cells have endocrine capacity
  - Intestine $\rightarrow$ secretin and cholecystokinin
  - Kidney $\rightarrow$ erythropoeitin
Pituitary Gland

- 2 lobes

1. Anterior pituitary lobe (adenohypophysis)
   - Glandular tissue
   - Releases hormones formed within pituitary

2. Posterior pituitary lobe (neurohypophysis):
   - Glial-like supporting cells and nerve fibers
   - Releases hormones formed within hypothalamus
When appropriately stimulated, hypothalamic neurons secrete releasing and inhibiting hormones into the primary capillary plexus.

Hypothalamic hormones travel through the portal veins to the anterior pituitary where they stimulate or inhibit release of hormones from the anterior pituitary.

Anterior pituitary hormones are secreted into the secondary capillary plexus.

(b) Relationship between the anterior pituitary and the hypothalamus
Anterior Pituitary Hormones

- Growth hormone (GH)
- Thyroid stimulating hormone (TSH)
- Adrenocorticotropic hormone (ACTH)
- Follicle stimulating hormone (FSH)
- Luteinizing hormone (LH)
- Prolactin (PRL)
- Melanocyte stimulating hormone (MSH)
Growth Hormone (GH)

- Stimulates most cells, but targets bone and skeletal muscle
- Promotes protein synthesis, encourages use of fats for fuel, and breakdown of glycogen
Imbalances of Growth Hormone

- Hypersecretion
  - Gigantism
  - Acromegaly
- Hypossecretion
  - Pituitary dwarfism
  - Simmond’s disease
(a) A 22-year old man with pituitary gigantism shown beside his identical twin

Figure 18.22a Tortora - PAP 12/e
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Acromegaly
Growth hormone

Feedback
- Inhibits GHRH release
- Stimulates GHIH release
- Inhibits GH synthesis and release

Hypothalamus secretes growth hormone—releasing hormone (GHRH), and somatostatin (GHIH)

Anterior pituitary

Growth hormone

Indirect actions (growth-promoting)
- Liver and other tissues
  - Produce
  - Insulin-like growth factors (IGFs)

Direct actions (metabolic, anti-insulin)

Liver and other tissues
- Produce
- Insulin-like growth factors (IGFs)

Effects

Skeletal
- Increased cartilage formation and skeletal growth

Extraskeletal
- Increased protein synthesis, and cell growth and proliferation

Fat
- Increased fat breakdown and release

Carbohydrate metabolism
- Increased blood glucose and other anti-insulin effects

Increases, stimulates

Reduces, inhibits

Initial stimulus

Physiological response

Result

Figure 16.6
Thyroid-Stimulating Hormone (TSH)

- Produced by the anterior pituitary
- Stimulates the normal development and secretory activity of the thyroid
- Regulation of TSH release
  - Stimulated by hypothalamus
  - Inhibited by rising blood levels of thyroid hormones
Figure 16.7

Hypothalamus

- TRH

Anterior pituitary

- TSH

Thyroid gland

- Thyroid hormones

Target cells

- Stimulates
- Inhibits
Adrenocorticotropic Hormone (ACTH)

- Secreted by the anterior pituitary
- Stimulates the adrenal cortex to release corticosteroids
Gonadotropins (FSH & LH)

- Follicle-stimulating hormone (FSH) and luteinizing hormone (LH or ICSH)
- Secreted by the anterior pituitary
- Regulate function of ovaries and testes
Gonadotropins

- Regulation of gonadotropin release
  - Triggered by the gonadotropin-releasing hormone (GnRH)
    - Absent from the blood in prepubertal boys and girls
  - Suppressed by gonadal hormones
Prolactin

- Secreted by the anterior pituitary
- Stimulates milk production
  - Blood levels rise toward the end of pregnancy
  - Suckling stimulates PRH release and promotes continued milk production
- Presence in men not well understood
- Hypersecretion
Melanocyte Stimulating Hormone

- Stimulates melanocytes
  - Unknown role in humans
  - May influence brain activity
Control of Anterior Pituitary Hormones
Pituitary-Hypothalamic Relationships

- Hypophyseal portal system
  - Capillary plexuses
  - Hypophyseal portal veins
When appropriately stimulated, hypothalamic neurons secrete releasing and inhibiting hormones into the primary capillary plexus.

Hypothalamic hormones travel through the portal veins to the anterior pituitary where they stimulate or inhibit release of hormones from the anterior pituitary.

Anterior pituitary hormones are secreted into the secondary capillary plexus.

(b) Relationship between the anterior pituitary and the hypothalamus
Releasing Factors

- Releasing factors
  - Growth Hormone Releasing Factor (Hormone)
  - Thyroid Hormone Releasing Factor (Hormone)
- Inhibiting factors
  - Identified for prolactin and GH
- Negative feedback
The Posterior Pituitary

- Contains axons of hypothalamic neurons
- Hormones produced by hypothalamus
- Stores antidiuretic hormone (ADH) and oxytocin
  - Released in response to nerve impulses
Hypothalamic neurons synthesize oxytocin and ADH.

Oxytocin and ADH are transported along the hypothalamic-hypophyseal tract to the posterior pituitary.

Oxytocin and ADH are stored in axon terminals in the posterior pituitary.

Oxytocin and ADH are released into the blood when hypothalamic neurons fire.

(a) Relationship between the posterior pituitary and the hypothalamus
Oxytocin

- Stimulates uterine contractions during childbirth
  - Synthetic versions used to induce labor
- Also triggers milk ejection ("letdown" reflex) in women producing milk
- Plays a role in sexual arousal and orgasm in males and females
- "Cuddle" hormone
Antidiuretic Hormone (ADH)

- Hypothalamic osmoreceptors respond to changes in the solute concentration of the blood...

  solute concentration is high ➔ osmoreceptors transmit impulses to hypothalamic neurons ➔ ADH synthesized and released ➔ inhibit urine formation

  or

  solute concentration is low ➔ ADH inhibited ➔ increased urine production
Homeostatic Imbalances of ADH

- Diabetes insipidus
  - Huge output of urine and intense thirst
  - Treated with ADH administration
Questions?