Endocrinology: Chapter 11

Endocrine System Function
• Major control and communication system
• Controls…
  – body fluid composition and volume
  – nutrient levels
  – growth and development
  – reproduction
  – physiological cycles (“biological clocks”)

Nervous vs. Endocrine Control
• The nervous system controls rapid, precise responses (ex. reflex)
• The endocrine system controls activities that require long duration (ex. body growth)
  – energetically more efficient
• Specific actions of chemical messengers are at the level of the target cell
• These two systems interact and regulate each other

The Endocrine System
• Endocrine glands
  – Lack ducts
  – Secrete products into the interstitial fluid
• Endocrine organs may be solely endocrine or multifunctional

Major Endocrine Organs
• Pituitary and Hypothalamus
• Adrenal glands (2)
• Thyroid
• Parathyroid glands (4)
• Pancreas
• Ovaries, Testes

Additional Endocrine Organs

Table 11.1
Hormones

Chemicals that are broadcast throughout the body which induce physiological changes in specific target cells.

Hormone Classes

- **Amines**
  - hormones derived from tyrosine and tryptophan
  - adrenal medulla hormones, thyroid hormones, pineal gland hormones
- **Peptide Hormones**
  - made from polypeptide chains
  - most hormones (insulin, FSH)
- **Steroids**
  - derivatives of cholesterol
  - adrenal cortex hormones, gonadal hormones

Mechanism of Action: Hormones

- **Steroids & Thyroid Hormones**
  - nonpolar
  - pass directly through the cell membrane
  - bind to protein receptor in cytoplasm or in nucleus
  - protein binds to gene on DNA in the nucleus
  - stimulates expression of that gene (protein production)

- **Peptides and Most Amines**
  - polar
  - cannot pass through hydrophobic lipid bilayer
  - bind to receptor proteins on cell surface
  - activation of membrane-bound enzymes
  - production of a second messenger inside the cell
    - e.g. cAMP
  - 2nd messenger activates or deactivates various enzymes

Hormonal Regulatory Mechanisms

- **Regulating hormone levels**
  - e.g. Negative feedback
  - Change causes change in opposite direction
  - e.g. thyroxine/TSH
- **Regulating tissue response**
  - e.g. down regulation
  - Decrease # of receptors on target cell with chronically elevated hormone levels

Hypothalamus-Pituitary Axis

- **Hypothalamus**
  - part of the diencephalon
  - controls release of pituitary hormones
    - Neural control of endocrine function
- **Pituitary gland**
  - extends from the inferior surface of the hypothalamus
  - Two distinctive lobes (posterior and anterior)
  - Linked to hypothalamus by infundibulum
Posterior Pituitary

- Composed of nervous tissue
- Neurosecretory cells produce two peptide hormones
- Released when neurons undergo an AP

Posterior Pituitary Hormones

- **ADH (Anti-Diuretic Hormone)**
  - Increases reabsorption of H2O by kidneys
  - Induces vasoconstriction in arterioles - ↑ BP
  - Stim. by H2O deficit, ↓ BP
- **Oxytocin**
  - Uterine contraction during childbirth
  - Milk letdown during breastfeeding
  - Male function unclear (↑ occurs during ejaculation)

Anterior Pituitary

- Composed of epithelial cells
- Different cell types secrete one of six peptide hormones

Anterior Pituitary Hormones

- **TSH (Thyroid Stimulating Hormone)**
  - Synthesis/release of thyroid hormones
  - Thyroid growth
- **ACTH (Adrenocorticotrophin)**
  - Activates adrenal cortex to release glucocorticoids
- **GH (Growth Hormone, or Somatotropin)**
  - Stimulates secretion of growth factors from various tissues
  - GF’s stimulate growth, protein synthesis, fat breakdown and ↑ blood glucose levels
- **PRL (Prolactin)**
  - Breast development and milk production during pregnancy
  - Modulatory roles in male reproduction and ion balance

Anterior Pituitary Hormones

- **LH (Luteinizing Hormone)**
  - Females
    - Ovulation, regulation of female sex hormones
    - Induces corpus luteum formation after ovulation
  - Males
    - Regulation of male sex hormones (androgens)
Anterior Pituitary Hormones

- **FSH** (Follicle Stimulating Hormone)
  - Females: regulates female sex hormones, egg development
  - Males: induces local mediator secretion from Sertoli cells that trigger sperm development

Hypothalamal Control of the Anterior Pituitary

- Hypothalamic neurons produce releasing/inhibiting hormones
  - Stimulate or inhibit secretion of hormones from the anterior pituitary
- Released into Hypothalamo-hypophyseal portal blood vessels

Hypothalamal Regulatory Hormones

- **TRH** (thyrotrophin-releasing hormone)
  - stimulates TSH release
- **CRH** (corticotrophin-releasing hormone)
  - stimulates ACTH release
- **GHRH** (growth hormone releasing hormone)
  - stimulates GH release
- **Somatostatin**
  - inhibits GH release
- **PHI** (prolactin inhibiting hormone)
  - inhibits prolactin release
- **GnRH** (gonadotrophin-releasing hormone)
  - stimulates FSH and LH release

Adrenal Gland

- Located above each kidney
- Releases hormones in response to stress
- Medulla hormones (amines)
  - Epinephrine & Norepinephrine
  - similar to effects of sympathetic NS (“flight or fight”)

Adrenal Gland

- Cortex hormones (steroids)
  - glucocorticoids (blood glucose)
    - **Cortisol** – elevates blood glucose and fatty acid levels, inflammation suppression
  - mineralocorticoids (salt)
    - **Aldosterone** – increases K+ secretion and Na+ uptake by kidneys
  - androgens
    - (**DHEA** – secondary sex character development, sexual behavior

Glucocorticoid Regulation

- **Cortisol** - helps body cope with stress
  - Hypothalamus releases CRH
  - Stimulates ACTH from anterior pituitary
  - Stimulates cortisol release from adrenal gland
  - Cortisol inhibits CRH release and desensitizes ant. pit. to its effects
Thyroid Gland

- Produces two groups of hormones
  - **Thyroid hormones (amines)**
    - Thyroxine (T₄) and triiodothyronine (T₃) - Increase metabolic rate and body heat production
  - **Calcitonin (peptide)**
    - Increases bone matrix formation and Ca²⁺ secretion from kidneys
    - Reduces blood Ca²⁺ levels

Thyroxine Regulation

- Secretion regulated by the hypothalamus-pituitary axis
  - Hypothalamus releases TRH
  - TRH stimulates anterior pituitary to release TSH
  - TSH stimulates thyroid to secrete T₄
- Negative feedback of T₄ onto anterior pituitary
  - ↑T₄ ↓TSH release

Thyroid Abnormalities: Hyperthyroidism

- Grave’s Disease
  - Production of thyroid stimulating immunoglobulin
    - Mimics TSH function, not subject to negative feedback regulation
    - Overproduction of thyroid hormones
  - Symptoms
    - ↑BMR = ↓body weight, ↑body temp
    - Hyperexcitability of nervous system
      - Restless behavior, ↑HR, etc.
    - Exophthalmos - bulging eyes

Thyroid Abnormalities: Hypothyroidism

- General symptoms
  - Decreased BMR
  - ↓Body temperature
  - ↑Weight gain
  - ↓Alertness (impaired CNS function)
  - Easily fatigued

Thyroid Abnormalities: Hypothyroidism

- Cretinism
  - Low TH production during infancy
  - Reduced growth rate (dwarfism)
  - Severe mental retardation

Thyroid Abnormalities: Hypothyroidism

- Goiter Formation
  - Reduced thyroid hormone production due to iodine deficiency
  - ↑TSH production
  - Abnormal thyroid growth
Parathyroid Glands

- Four small organs located on posterior surface of the thyroid
- Secrete parathyroid hormone (PTH)
  - promotes bone matrix breakdown
  - Reduces Ca\(^{2+}\) secretion in the kidneys
  - Elevates Ca\(^{2+}\) in blood

Pancreas

- Both an endocrine organ and digestive organ
- Endocrine cells located in Islets of Langerhans
- Contain 2 cell types
  - α cells - secrete glucagon
  - β cells - secrete insulin
- Important in regulating glucose levels of the blood

Insulin

- Induces glucose uptake and utilization by cells (esp. muscle and liver)
- Lowers blood glucose levels
  - promotes removal of glucose from blood
- Promotes formation of glycogen
  - polymer of glucose for storage
- Promotes conversion of glucose into fat in adipose tissue
- Stimulates amino acid uptake by cells and protein formation

Insulin Regulation

- Blood glucose level is the major factor controlling insulin and glucagon secretion
  - ↑ glucose → ↑ insulin → ↓ glucose
  - ↓ glucose → ↓ insulin → ↑ glucose
- Maintenance of blood glucose at homeostatic levels via negative feedback

Glucagon

- Secreted when blood glucose levels are VERY LOW
- Increase in blood glucose:
  - Activates liver enzymes to convert glycogen into glucose
- Stimulates breakdown of stored fat and release of fatty acids into blood
  - used as secondary energy source
- Opposes the actions of insulin

Diabetes Mellitus

- Insulin deficiency or excessive tolerance
  - cells do not take up glucose
  - results in excess glucose in blood (hyperglycemia)
- Problems
  - dehydration
    - lose excessive water from urination
    - blood volume/pressure problems
  - starvation - body cannot use glucose
    - break down of fats, formation of ketone bodies
    - metabolic acidosis
Diabetes Mellitus

Two types:
• Type-I (Insulin-dependent, juvenile-onset)
  – Degeneration of β-cells
  – no endogenous insulin
  – Must give exogenous insulin
• Type-II (non-insulin dependent, adult-onset)
  – Cells desensitized (tolerant) of diabetes
  – Often due to obesity
  – controlled by regulating dietary glucose

Hypoglycemia

• Overproduction of insulin or hypersensitivity
• Reactive hypoglycemia
  – β-cells overproduce insulin in response to increased glucose levels
  – too much glucose driven into cells from blood
  • depressed brain function