Hormones

Chapter 12

Endocrine System Function

• Major control and communication system
• Controls activities that require long duration
  – digestion and energy metabolism
  – osmoregulation, water balance, ion balance and
    excretion
  – growth and development
  – reproduction

Endocrine Systems

• Invertebrates
  – Most hormones arise from neurosecretory
    cells in CNS
  – Hormones typically released directly to
    target tissues
  – Principally involved in regeneration, growth,
    development, and reproduction
  – Little homeostatic function

• Vertebrates
  – Much greater prevalence of non-neural
    endocrine glands
  – More complex control pathways
    • One hormone stimulates the release of another.
    – Greater involvement in homeostasis

Hormones

• Chemical signals broadcast to other cells
• Endocrine
  – signals circulated throughout the body
• Paracrine
  – signals broadcast locally within tissues
• Autocrine
  – Signals act directly on the cell that releases it

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

Figs. 14.1-14.3
Mechanism of Action: 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)

Mechanism of Action: 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, DAG-IP3
- 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

Vertebrate Endocrinology

Hypothalamus-Pituitary Axis

- **Hypothalamus** (brain region)
  - controls release of pituitary hormones
    - Neural control of endocrine function
- **Pituitary gland**
  - Two distinctive lobes (posterior and anterior)
  - Linked to hypothalamus by infidibulum

Posterior Pituitary (Neurohypophysis)

- Composed of neurosecretory cells
- Hormones released when neurons undergo action potentials

Posterior Pituitary Hormones

- **ADH (Anti-Diuretic Hormone)**
  - Arginine vasopressin (mammals) or arginine vasotocin (other verts)
  - increases reabsorption of H2O by kidneys
  - induces vasoconstriction in arterioles - ↑ BP
  - Sexual behavior (amphibians) and oviposition (reptiles and birds)
  - Skin permeability (amphibians)
- **Oxytocin**
  - Uterine contraction during childbirth
  - milk letdown during breast feeding
  - male function unclear (↑ occurs in both sexes during sexual arousal)
Anterior Pituitary (Adenohypophysis)

- Composed of epithelial cells
- Different cell types secrete various peptide hormones
- Secretion controlled by hormonal release from hypothalamus into hypothalamo-hypophyseal portal system

Anterior Pituitary Hormones

- **TSH (Thyroid Stimulating Hormone, Thyrotropin)**
  - Stimulates thyroid gland
  - Release thyroid hormones
  - Stimulates thyroid growth

- **ACTH (Adrenocorticotropin)**
  - Stimulates adrenal cortex to release glucocorticoids

Anterior Pituitary Hormones

- **PRL (Prolactin)**
  - Breast development and milk production during pregnancy
  - Development and maintenance of corpus luteum (non-primate mammals)
  - Crop milk secretion in pigeons, brood patch development in birds
  - Controls sensitivity of testes to LH
  - Enhances uptake / inhibits secretion of ions in fish and amphibians
  - Lots of other modulatory functions

Anterior Pituitary Hormones

- **MSH (Melanocyte Stimulating Hormone)**
  - Integument pigmentation

- **GH (Growth Hormone, Somatotropin)**
  - Stimulates growth, protein synthesis, fat breakdown and ↑ blood glucose levels
  - Functions indirectly through somatomedins (e.g., insulin-like growth factors)

Anterior Pituitary Hormones

- **FSH (Follicle Stimulating Hormone, Follitropin)**
  - regulates female sex hormones, egg development
  - Stimulates Sertoli cells to release local mediators that induce spermatogenesis development

- **LH (Luteinizing Hormone, Lutropin)**
  - ovulation, regulation of female sex hormones
  - induces corpus luteum formation after ovulation
  - Induces secretion of androgens by Leydig cells of testes

“Adrenal” Glands

- Releases hormones in response to stress
  - glucocorticoids (e.g., cortisol)
    - Elevate blood glucose
    - Anti-inflammatory and Immunosuppression
  - mineralocorticoids (e.g., aldosterone)
    - Na+/K+ balance, blood pressure regulation
  - androgens (e.g., DHEA)
    - sexual characteristics
    - epinephrine (“flight vs. fight”)
    - ↑ blood glucose, lipolysis
    - ↑ thermogenesis (shivering and non-)
    - ↑ cardiovascular / respiratory activity
Thyroid Gland (Tetrapods)

- **Thyroid hormones (TH)**
  - **Thyrozone (T<sub>3</sub>) and triiodothyronine (T<sub>3</sub>)**
    - Increase metabolic rate and body heat production (endotherms)
    - Metamorphosis in amphibians
    - Growth and development

Pancreas

- Endocrine cells located in **Islets of Langerhans**
- Contain two 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

Glucagon

- 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

Gonads (Testes and Ovaries)

- Produce steroid hormones
  - androgens (e.g., testosterone)
    - sperm development
    - reproductive tract maturation
    - secondary sex characteristics
    - sexual behavior (M and F)
  - estrogens and progesterone
    - oocytic development
    - reproductive tract development
    - secondary sex characteristics

Comparative Endocrinology: Insect Molting / Metamorphosis

- Development patterns in insects:
  - **Hemimetabolous**
    - go through nympha stages (instars) and slowly transform into adults
  - **Homometabolous**
    - Go through prolonged larval stage, then develop into pupa, then adult
- Development in both occurs through similar endocrine control
Key Hormones

- **Prothoracicotropic Hormone (PTTH)**
  - Peptide hormone secreted by neurosecretory cells brain
  - Stimulates release of ecdysone
- **Ecdysone**
  - Steroid hormone produced by prothoracic gland
  - Stimulates molting and development
- **Juvenile hormone (JH)**
  - Terpenoid hormone produced by corpus allatum
  - Stimulates retention of juvenile characters

Hormone Function: Molting

- Growth of juvenile stimulates PTTH secretion
- Stimulates **ecdysis** (molting)
  - Cuticle detaches from epithelium
  - Muscular contractions pull insect away from cuticle
  - New cuticle forms

Hormone Function: Metamorphosis

- Levels of JH initially high
  - Retains juvenile characters
- Levels begin to fall as larva grows
- When JH falls to below a certain level → pupation
- Continue to fall to during pupation
- At minimum JH production, adult form develops
- JH levels rise in adult
  - Stimulate reproductive development

Additional Important Hormones

- **Eclosion Hormone (EH)**
  - Stimulates inka cells to secrete PETH and ETH
- **Pre-ecdysis Triggering Hormone (PETH)**
  - Coordinates muscle contractions that pull epidermis away from old cuticle
- **Ecdysis Triggering Hormone (ETH)**
  - Coordinates contractions that allow final escape from the old cuticle
- **Bursicon**
  - Tanning/hardening of new cuticle after molting