Chapter 6 Communication, Integration, and Homeostasis

About This Chapter
• Cell-to-cell communication
• Signal pathways
• Novel signal molecules
• Modulation of signal pathways
• Homeostatic reflex pathways

Cell-to-Cell Communication: Overview
• Physiological signals
  – Electrical signals
  – Changes in the membrane potential of a cell
  – Chemical signals
  – Secreted by cells into ECF
  – Responsible for most communication within the body
• Target cells, or targets, respond to signals

Long-Distance Communication
• The nervous system uses a combination of chemical and electrical signals for long distance
cell-to-cell communication
• Neurocrines are chemical signals secreted by neurons
  – Neurotransmitters
  – Neuromodulators
  – Neurohormones

Cytokines
• Cytokines may act as both local and long-distance signals
• All nucleated cells synthesize and secrete cytokines in response to stimuli
• In development and differentiation, cytokines usually function as autocrine or paracrine
  signals
• In stress and inflammation, some cytokines may act on relatively distant targets

G Protein–Coupled Receptors (GPCR)
• Membrane-spanning proteins
• Cytoplasmic tail linked to G protein, a three-part transducer molecule
• When G proteins are activated, they
  – open ion channels in the membrane
  – alter enzyme activity on the cytoplasmic side of the membrane

Integrins
• Membrane-spanning proteins
• Outside the cell, integrins bind to extracellular matrix proteins or to ligands
• Inside the cell, integrins attach to the cytoskeleton via anchor proteins

Gases Are Ephemeral Signal Molecules
• Nitric oxide (NO)
  – Produced by endothelial cells
    – Diffuses into smooth muscle and causes vasodilation
  – Synthesized by the action of nitric oxide synthase (NOS)
  – Activates guanylyl cyclase
Formation of cGMP
- Acts as neurotransmitter and neuromodulator in brain

Gases Are Ephemeral Signal Molecules
- Carbon monoxide (CO)
  - Also activates guanylyl cyclase and cGMP
  - Targets smooth muscle and neural tissue
- Hydrogen sulfide (H₂S)
  - Targets cardiovascular system to relax blood vessels
  - Garlic is major dietary source of precursors

Some Lipids Are Important Paracrine Signals
- Leukotrienes
  - Role in asthma and anaphylaxis
- Prostanoids
  - Prostaglandins
    - Sleep, inflammation, pain, fever
    - Nonsteroidal anti-inflammatory drugs (NSAIDs) help prevent inflammation by inhibiting cyclooxygenase (COX)
  - Thromboxanes
  - Sphingolipids
    - Help regulate inflammation, cell adhesion and migration, and cell growth and death

Modulation of Signal Pathways
- Specificity and competition
- Agonist versus antagonist

Modulation of Signal Pathway Responses
- Down-regulation
  - Decrease in receptor number
- Desensitization
  - By binding a chemical modulator to receptor
- Up-regulation
  - Inserts more receptors in cell membrane
- Termination mechanism
- Disease and drugs

Table 6.1 Some Diseases or Conditions Linked to Abnormal Signaling Mechanisms
- Disease and drugs target signal transduction proteins

Control Systems: Cannon’s Postulates
1. Nervous regulation of internal environment
   - Regulates parameters
2. Tonic control
3. Antagonistic control
4. One chemical signal can have different effects in different tissues

Reflex Pathway Response Loops
- Stimulus
• Sensor or receptor
  — Threshold
• Input signal or afferent pathway
• Integrating center
  — In endocrine pathways, also the sensor
• Output signal or efferent pathway
• Target or effector
• Response
Summary
• Cell-to-cell communication
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Chapter 7 Introduction to the Endocrine System

About This Chapter
• Hormones
• The classification of hormones
• Control of hormone release
• Hormone interactions
• Endocrine pathologies
• Hormone evolution
Hormones: Function
• Control
  — Rates of enzymatic reactions
  — Transport of ions or molecules across cell membranes
  — Gene expression and protein synthesis
Hormones
• Cell-to-cell communication molecules
  — Chemical signals
  — Secreted by a cell or group of cells
  — Transported by blood
  — Distant target tissue receptors
  — Activates physiological response at low concentrations
• Pheromones: elicit physiological or behavioral response on other organisms of the same species
Hormones
• Cellular mechanism of action
  — Depends on binding to target cell receptors
• Initiates biochemical responses
• Half-life indicates length of activity

Hormones: Classification by Chemical Class
• Peptide or protein hormones
• Steroid hormones
• Amino acid–derived or amine hormones

Hormones: Peptides or Proteins
• Preprohormone
  — Large, inactive precursor
• Prohormone
  — Smaller, inactive
  — Proteolytic, post-translational modification
• Peptide/protein hormones
  — Bind surface membrane receptors
  — Cellular response through signal transduction system

Hormones: Steroid
• Cholesterol-derived
  — Lipophilic and easily cross membranes
• Bind carrier proteins in blood
  — Longer half-life
• Cytoplasmic or nuclear receptors
  — Genomic effect to activate or repress genes for protein synthesis
    — Slower acting
• Cell membrane receptors
  — Nongenomic responses

Hormones: Amino Acid–Derived, or Amine
• Derived from one of two amino acids
  — Tryptophan
  — Tyrosine
• Ring structure

Amine Hormones: Examples
• Melatonin
• Catecholamines
  — Epinephrine
  — Norepinephrine
  — Dopamine
• Thyroid hormones

Endocrine Reflex Pathways
• Stimulus
• Sensor
• Input signal
• Integration
• Output (efferent) signal (hormone in blood)
• Targets
• Response physiological action
• Negative feedback

Neurohormones: Major Groups
• Adrenal medulla
  – Catecholamines
• Hypothalamus
  – Posterior pituitary is neural tissue
  – Anterior pituitary is endocrine tissue

Endocrine Control
• A trophic hormone controls the secretion of another hormone
• Hypothalamic-hypophyseal portal system
• Three integrating centers
  – Hypothalamic stimulation—from CNS
  – Anterior pituitary stimulation—from hypothalamic trophic hormones
  – Endocrine gland stimulation—from anterior pituitary trophic hormones (except prolactin)

Hormone Interactions
• Synergism
  – Combined effect is greater than the sum of individual effects
• Permissiveness
  – Need second hormone to get full effect
• Antagonism
  – One substance opposes the action of another
  – Competitive inhibitors vs. functional antagonism
  – Glucagons oppose insulin

Endocrine Pathologies
• Hypersecretion: excess hormone
  – Caused by tumors or exogenous iatrogenic treatment
  – Negative feedback
• Hypossecretion: deficient hormone
  – Caused by decreased synthesis materials or atrophy
  – Absence of negative feedback

Pathologies: Abnormal Receptors
• Down-regulation
  – Decreased number of receptors
  – Hyperinsulinemia
• Receptor and signal transduction abnormalities
  – Testicular feminization syndrome
  – Pseudohypothyroidism

Hormone Evolution
• Evolutionary conservation of hormone function
• Proteomics
  – Calcitonin gene-related peptide example
• Vestigial
  – Melanocyte-stimulating hormone example
• Comparative endocrinology
  – Pineal gland and melatonin example

Summary
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