Endocrine System

Bio 219
Napa Valley College
Dr. Adam Ross
Just a reminder: From first lecture

How to excel at learning:
Overview

- **Endocrine gland:**
  - Gland that secretes hormones into the ECF; no ducts

- **Hormone:**
  - Chemical messenger that is carried in the blood
    - Can bind to receptor on membrane or inside cell

- **Receptor:**
  - Hormone binds to receptor to cause effect
  - No action without properly functioning receptors
Major Endocrine Glands

- Pineal gland
- Parathyroid gland
- Hypothalamus
- Pituitary gland
- Thyroid gland
- Thymus
- Adrenal gland
- Kidney
- Pancreas
- Ovary (in female)
- Testis (in male)
Comparison: Nervous vs Endocrine

- Nervous System
  - fast response
  - short duration
  - secretes neurotransmitters
  - specific, localized effects

- Endocrine System
  - slow response
  - longer duration
  - secretes hormones
  - widespread effects
Chemical Signaling Molecules

• Neurotransmitters
  • Local effects at synapses

• Hormones
  • Widespread effects based on receptor location

• Neurohormones
  • Hormones released by neurons

• Paracrine
  • Effects on neighboring cells

• Autocrine
  • Cell secretes substance that effects itself

• Endocrine
  • Secretes hormones into internal environment of the body
Two major types of hormones:

• Lipophilic:
  • Steroid hormones, thyroid hormones, etc
    • Cross plasma membrane
    • Bind to cytoplasmic receptors
    • Often cause changes in gene expression

• Non-Lipophilic (Lipophobic)
  • Epi, Insulin, ADH, etc
    • Do not cross plasma membrane
    • Bind to membrane receptors
Mechanism of Action:

• Lipophilic Hormones:
  • Hormone diffuses across plasma membrane
  • Binds to cytosolic receptor
  • Hormone-Receptor complex (HRC) moves to nucleus
  • HRC binds to DNA and acts as a transcription factor
  • Regulates transcription of specific genes (can be up or down)
  • Changes in mRNA levels cause changes in protein levels
  • Leads to changes in activity associated with those proteins
Mechanism of Action:

• Lipophobic Hormones:
  • Hormone binds to receptor on extracellular side of plasma membrane
  • Hormone-Receptor complex is now active and activates signal transduction pathway
  • Activates enzymes within the cell
  • Mostly metabolic effects

• Can be enzyme linked receptors
  • Insulin receptor- tyrosine kinase

• Or G-Protein coupled receptors
  • Adrenergic receptors
Transduction of Message

• When hormone binds to surface receptor, how does message get relayed to rest of cell?
  • Second Messengers
    • Activation of receptor leads to intracellular changes that alter the activity of the cell
Second Messengers

- **3',5'-Cyclic AMP (cAMP)**: Activates protein kinase A (PKA)
- **3',5'-Cyclic GMP (cGMP)**: Activates protein kinase G (PKG) and opens cation channels in rod cells
- **1,2-Diaclylglycerol (DAG)**: Activates protein kinase C (PKC)
- **Inositol 1,4,5-trisphosphate (IP₃)**: Opens Ca²⁺ channels in the endoplasmic reticulum
Second Messengers

• Cyclic AMP Second Messenger Pathway: (eg β-adrenergic)
  • Hormone binds to receptor
  • G protein associated with receptor is activated
  • Activated G-protein activates adenylyl cyclase in the plasma membrane
  • A. cyclase converts ATP to cyclic AMP (cAMP)
  • Cyclic AMP acts as second messenger, activates protein kinase enzymes in the cell
  • Protein Kinase activates other enzymes (or non-enzymatic proteins) via phosphorylation (covalent)
Hormones that act via cAMP mechanisms:
- Epinephrine
- Glucagon
- ACTH
- PTH
- FSH
- TSH
- LH
- Calcitonin

1. Hormone (1st messenger) binds receptor.
2. Receptor activates G protein ($G_\text{S}$).
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.)
- Sympathetic stimulation releases norepinephrine and initiates a cyclic AMP second-messenger system.
Second Messengers:

• Phospholipase-C (DAG-IP$_3$) Second messenger system
  • (α-adrenergic receptors)
  • Activation of G-protein activates Phospholipase-C (PLC) enzyme in membrane
  • PLC cleaves a membrane phospholipid:
    • Forms DAG and IP$_3$
  • IP$_3$ causes calcium release and smooth muscle constriction in vascular tissue
    • Binds to IP$_3$ Receptor
Alpha-1-adrenergic receptor

![Diagram of the alpha-1-adrenergic receptor signaling pathway](image)
Stimulation of hormone secretion

• Neural- neurons synapse onto endocrine cells
• Humoral- substances in blood or interstitial fluid
• Hormonal- by other hormones
Responsiveness to hormones

- Depends on:
- Concentration of hormone in blood
  - Rate of secretion vs rate of degradation/ excretion (half-life)/
- Abundance of receptors
  - Up or Down regulation
- Influence of other hormones/ signals
  - Synergistic
    - One amplifies the other
  - Permissive
    - One allows the other to happen
  - Antagonistic
    - One inhibits the other
Half-Life

- Half life of a hormone is the amount of time it takes for half of the hormone to be eliminated from the body
  - Can be metabolized (often by Liver) or excreted (mostly in urine)