The Endocrine System
General Functions of Hormones

- Help regulate:
  - extracellular fluid
  - metabolism
  - biological clock
  - contraction of cardiac & smooth muscle
  - glandular secretion
  - some immune functions

- Growth & development
- Reproduction
Endocrine Glands Defined

- **Exocrine glands**
  - secrete products into ducts which empty into body cavities or body surface
  - sweat, oil, mucous, & digestive glands

- **Endocrine glands**
  - secrete products (hormones) into bloodstream
  - pituitary, thyroid, parathyroid, adrenal, pineal
  - other organs secrete hormones as a 2nd function
    - hypothalamus, thymus, pancreas, ovaries, testes, kidneys, stomach, liver, small intestine, skin, heart & placenta
Hormone Receptors

- Hormones only affect target cells with specific membrane proteins called receptors
Circulating & Local Hormones

- **Circulating hormones**
  - act on distant targets
  - travel in blood

- **Local hormones**
  - paracrines act on neighboring cells
  - autocrines act on same cell that secreted them
Lipid-soluble Hormones

- **Steroids**
  - lipids derived from cholesterol

- **Thyroid hormones**

- **Nitric oxide is gas**
Water-soluble Hormones

- Amine, peptide and protein hormones
  - modified amino acids or amino acids put together
  - serotonin, melatonin, histamine, epinephrine

- Eicosanoids
  - derived from arachidonic acid (fatty acid)
  - prostaglandins or leukotrienes
Hormone Transport in Blood

- Protein hormones circulate in free form in blood
- Steroid (lipid) & thyroid hormones must attach to transport proteins synthesized by liver
  - improve transport by making them water-soluble
  - slow loss of hormone by filtration within kidney
  - create reserve of hormone
General Mechanisms of Hormone Action

- Hormone binds to cell surface or receptor inside target cell
- Cell may then
  - synthesize new molecules
  - change permeability of membrane
  - alter rates of reactions
- Each target cell responds to hormone differently
  - liver cells---insulin stimulates glycogen synthesis
  - adipose---insulin stimulates triglyceride synthesis
Action of Lipid-Soluble Hormones

- Hormone diffuses through phospholipid bilayer & into cell
- Binds to receptor turning on/off specific genes
- New mRNA is formed & directs synthesis of new proteins
- New protein alters cell’s activity
Action of Water-Soluble Hormones

- Can not diffuse through plasma membrane
- Hormone receptors are integral membrane proteins
- Receptor protein activates G-protein in membrane
- Results in amplification of hormone effects
Amplification of Hormone Effects

• Single molecule of hormone binds to receptor
• Activates 100 G-proteins
• Each activates an adenylate cyclase molecule which then produces 1000 cAMP
• Each cAMP activates a protein kinase, which may act upon 1000’s of substrate molecules
• One molecule of epinephrine may result in breakdown of millions of glycogen molecules into glucose molecules
Control of Hormone Secretion

• Regulated by signals from nervous system, chemical changes in the blood or by other hormones

• Negative feedback control (most common)
  – decrease/increase in blood level is reversed

• Positive feedback control
  – the change produced by the hormone causes more hormone to be released

• Disorders involve either hyposcretion or hypersecretion of a hormone
Negative Feedback Systems

- Decrease in blood levels
- Receptors in hypothalamus & thyroid
- Cells activated to secrete more TSH or more T3 & T4
- Blood levels increase
Positive Feedback

• Oxytocin stimulates uterine contractions
• Uterine contractions stimulate oxytocin release
Hypothalamus and Pituitary Gland

- Both are master endocrine glands since their hormones control other endocrine glands
- Hypothalamus is a section of brain above where pituitary gland is suspended from stalk (surrounds 3rd ventricle)
- Hypothalamus receives input from cortex, thalamus, limbic system & internal organs
- Hypothalamus controls pituitary gland with different releasing & inhibiting hormones (gonadotropin-releasing hormone, growth hormone-releasing hormone, growth hormone-inhibiting hormone)
- Major integrating link between nervous and endocrine systems
Anatomy of Pituitary Gland

- Pea-shaped, 1/2 inch gland found in sella turcica of sphenoid
- Infundibulum attaches it to brain (hypothalamus)
- Anterior lobe (adenohypophysis) = 75% develops from roof of mouth
- Posterior lobe (neurohypophysis) = 25%
  - ends of axons of 10,000 neurons found in hypothalamus
  - neuroglial cells called pituicytes
Development of Pituitary Gland

- Events occurring between 5 and 16 weeks of age
Flow of Blood to Anterior Pituitary

- Controlling hormones enter blood
- Travel through portal veins
- Enter anterior pituitary at capillaries
# Anterior pituitary cells

<table>
<thead>
<tr>
<th>Anterior Pituitary cell</th>
<th>Hormone released</th>
<th>Hypothalamic releasing hormone</th>
<th>Inhibiting hormone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Somatotroph</td>
<td>hGH</td>
<td>GHRH</td>
<td>GHIH (hypoth.)</td>
</tr>
<tr>
<td>Thyrotroph</td>
<td>TSH</td>
<td>TRH</td>
<td>T3 and T4 (thyroid)</td>
</tr>
<tr>
<td>Gonadotroph</td>
<td>FSH, LH</td>
<td>GnRH</td>
<td>Inhibin (FSH) (gonad)</td>
</tr>
<tr>
<td>Lactotrophs</td>
<td>PRL</td>
<td>PRH</td>
<td>PIH (hypoth.)</td>
</tr>
<tr>
<td>Corticotrophs</td>
<td>ACTH</td>
<td>CRH</td>
<td>Glucocorticoids (adrenal gland)</td>
</tr>
</tbody>
</table>
Human Growth Hormone

- Produced by somatotrophs (somatostatin) of anterior pituitary
- Within target cells increases synthesis of insulinlike growth factors that act locally or enter bloodstream
  - common target cells are liver, skeletal muscle, cartilage and bone
  - increases cell growth & cell division
Thyroid Stimulating Hormone (TSH)

- Hypothalamus regulates thyrotroph cells
- Thyrotroph cells produce TSH
- TSH stimulates the synthesis & secretion of T3 and T4
- Metabolic rate stimulated
Follicle Stimulating Hormone (FSH)

- GnRH from hypothalamus controls gonadotrophs
- Gonadotrophs release FSH
- FSH functions
  - initiates the formation of follicles within the ovary
  - stimulates follicle cells to secrete estrogen
  - stimulates sperm production in testes
Luteinizing Hormone (LH)

- GnRH from hypothalamus stimulate gonadotrophs
- Gonadotrophs produce LH
- In females, LH stimulates
  - secretion of estrogen
  - ovulation of oocyte from ovary
  - secretion of progesterone
- In males, stimulates interstitial cells to secrete testosterone
Prolactin (PRL)

- Hypothalamus regulates lactotroph cells (PRH)
- Lactotrophs produce prolactin
- Under right conditions, prolactin causes milk production
- Suckling reduces levels of hypothalamic inhibition and prolactin levels rise along with milk production
- Nursing ceases & milk production slows
Adrenocorticotropic Hormone

- Corticotrophin-RH stimulate corticotrophs
- Corticotrophs secrete ACTH & MSH
- ACTH stimulates cells of the adrenal cortex that produce glucocorticoids
Melanocyte-Stimulating Hormone

- Secreted by corticotroph cells
- Releasing hormone from hypothalamus increases its release from the anterior pituitary
- Function not certain in humans (increase skin pigmentation in frogs)
Posterior Pituitary Gland

- Does not synthesize hormones
- Consists of axon terminals of hypothalamic neurons and pituicytes (neuroglia)
- Neurons release two neurotransmitters that enter capillaries
  - antidiuretic hormone
  - oxytocin
Oxytocin

- Two target tissues both involved in neuroendocrine reflexes

- During delivery
  - baby’s head stretches cervix
  - hormone release enhances uterine muscle contraction
  - baby & placenta are delivered

- After delivery
  - suckling & hearing baby’s cry stimulates milk ejection
  - hormone causes muscle contraction & milk ejection
Antidiuretic Hormone (ADH)

- Known as vasopressin
- Functions
  - decrease urine production
  - decrease sweating
  - increase BP by retaining water
Thyroid Gland

- On each side of trachea is lobe of thyroid
- Weighs 1 oz & has rich blood supply
Histology of Thyroid Gland

- Follicle = sac of stored hormone (colloid) surrounded by follicle cells that produced it – T3 & T4

- In between cells called parafollicular cells – produce calcitonin
Actions of Thyroid Hormones

- **T₃ (triiodothyronine) and T₄ (thyroxine) or thyroid hormones from follicular cells**
  - T₃ & T₄ = thyroid hormones responsible for our metabolic rate, synthesis of protein, breakdown of fats, use of glucose for ATP production

- **Calcitonin (CT) from parafollicular cells**
  - Calcitonin = responsible for building of bone & stops reabsorption of bone (lower blood levels of Calcium)
Parathyroid Glands

- 4 pea-sized glands found on back of thyroid gland
Histology of Parathyroid Gland

- Chief (principal) cells produce parathyroid hormone (PTH)
- Oxyphil cell function is unknown
Parathyroid Hormone

- Raise blood calcium levels
  - increase activity of osteoclasts
  - increases reabsorption of Ca+2 by kidney
  - promote formation of calcitriol (vitamin D3) by kidney which increases absorption of Ca+2 and Mg+2 by intestinal tract

- Opposite function of calcitonin
Regulation of Calcium Blood Levels

- High or low blood levels of Ca+2 stimulate the release of different hormones --- PTH or CT
Anatomy of Pancreas

- Organ (5 inches) consists of head, body & tail
- Cells (99%) in acini produce digestive enzymes
- Endocrine cells in pancreatic islets produce hormones
Cell Organization in Pancreas

- Exocrine acinar cells surround a small duct
- Endocrine cells secrete near a capillary
Histology of the Pancreas

- 1 to 2 million pancreatic islets
- Contains 4 types of endocrine cells
Cell Types in the Pancreatic Islets

- Alpha cells (20%) produce glucagon
- Beta cells (70%) produce insulin
- Delta cells (5%) produce somatostatin
- F cells produce pancreatic polypeptide
Regulation of Glucagon & Insulin Secretion

- Low blood glucose stimulates release of glucagon
- High blood glucose stimulates secretion of insulin