The Endocrine System
Overview of the Endocrine System

- System of ductless glands that secrete hormones
  - Hormones are “messenger molecules”
  - Circulate in the blood
  - Act on distant target cells
  - Target cells respond to the hormones for which they have receptors
  - The effects are dependent on the programmed response of the target cells
  - Hormones are just molecular triggers

- Basic categories of hormones
  - Amino acid based: modified amino acids (or amines), peptides (short chains of amino acids), and proteins (long chains of amino acids)
  - Steroids: lipid molecules derived from cholesterol
Endocrine Organs

- Purely endocrine organs
  - Pituitary gland
  - Pineal gland
  - Thyroid gland
  - Parathyroid glands
  - Adrenal: 2 glands
    - Cortex
    - Medulla

- Endocrine cells in other organs
  - Pancreas
  - Thymus
  - Gonads
  - Hypothalamus
Mechanisms of hormone release

(a) **Humoral**: in response to changing levels of ions or nutrients in the blood
(b) **Neural**: stimulation by nerves
(c) **Hormonal**: stimulation received from other hormones
Learn the 3 endocrine organs on this slide:
Hypothalamus
Pituitary (hypophysis)
Pineal
The Pituitary

Sits in hypophyseal fossa: depression in sella turcica of sphenoid bone

Pituitary secretes 9 hormones

Two divisions:

- Anterior pituitary (adenohypophysis)
  1. TSH
  2. ACTH
  3. FSH
  4. LH
  5. GH
  6. PRL
  7. MSH

- Posterior pituitary (neurohypophysis)
  8. ADH (antidiuretic hormone), or vasopressin
  9. Oxytocin

The first four are “tropic” hormones, they regulate the function of other hormones.
What the letters stand for…

- TSH: thyroid-stimulating hormone
- ACTH: adrenocorticotrophic hormone
- FSH: follicle-stimulating hormone
- LH: luteinizing hormone
- GH: growth hormone
- PRL: prolactin
- MSH: melanocyte-stimulating hormone
- ADH: antidiuretic hormone
- Oxytocin
Hypothalamus controls anterior pituitary hormone release

- Releasing hormones (releasing factors)
  Secreted like neurotransmitters from neuronal axons into capillaries and veins to anterior pituitary (adenohypophysis)
  - TRH-----turns on TSH
  - CRH-----turns on ACTH
  - GnRH (=LHRH)---turns on FSH and LH
  - PRF-----turns on PRL
  - GHRH----turns on GH

- Inhibiting hormones
  - PIF-----turns off PRL
  - GH inhibiting hormone ---turns off GH
What the letters mean...

- **Releasing hormones (releasing factors) of hypothalamus**
  - Secreted like neurotransmitters from neuronal axons into capillaries and veins to anterior pituitary (adenohypophysis)
  - TRH (thyroid releasing hormone) -----turns on* TSH
  - CRH (corticotropin releasing hormone) -----turns on ACTH
  - GnRH (gonadotropin releasing hormone) ---turns on FSH and LH
  - PRF (prolactin releasing hormone) -----turns on PRL
  - GHRH (growth hormone releasing hormone) ----turns on GH

- **Inhibiting hormones of hypothalamus**
  - PIF (prolactin inhibiting factor) -----turns off PRL
  - GH (growth hormone) inhibiting hormone ---turns off GH

*The hypothalamus controls secretion of hormones which in their turn control the secretion of hormones by the thyroid gland, the adrenal cortex and gonads: in this way the brain controls these endocrine glands*

*Note: “turns on” means causes to be released*
So what do the pituitary hormones do?

The four tropic ones regulate the function of other hormones:

- TSH stimulates the thyroid to produce thyroid hormone
- ACTH stimulates the adrenal cortex to produce corticosteroids: aldosterone and cortisol
- FSH stimulates follicle growth and ovarian estrogen production; stimulates sperm production and androgen-binding protein
- LH has a role in ovulation and the growth of the corpus luteum; stimulates androgen secretion by interstitial cells in testes
The others from the anterior pituitary…

- GH (aka somatotropin hormone) stimulates growth of skeletal epiphyseal plates and body to synthesize protein
- PRL stimulates mammary glands in breast to make milk
- MSH stimulates melanocytes; may increase mental alertness
From the posterior pituitary (neurohypophysis) *structurally part of the brain*

- ADH (antidiuretic hormone AKA vasopressin) stimulates the kidneys to reclaim more water from the urine, raises blood pressure
- Oxytocin prompts contraction of smooth muscle in reproductive tracts, in females initiating labor and ejection of milk from breasts
The Thyroid Gland

- Anterior neck on trachea just inferior to larynx
- Two lateral lobes and an isthmus
- Produces two hormones
  - Thyroid hormone: tyrosine based with 3 or 4 iodine molecules
    - T4 (thyroxine) and T3
  - Calcitonin involved with calcium and phosphorus metabolism
- Thyroid is composed of spherical follicles
  - Follicle cells: produce thyroglobulin, the precursor of thyroid hormone (thyroxin)
  - Colloid lumen is of thyroglobulin
  - Parafollicular “C” cells: produce calcitonin
An example of a feedback loop

**generic**
- A certain item in the blood decreases
- A certain area of the brain senses this decrease
- A certain hormone is released
- This hormone stimulates the release of another hormone
- This other hormone stimulates the release of the hormone which was sensed to be decreased in the first place, causing it to be increased to desired level

**particular example: thyroid hormone**
- Thyroxine (thyroid hormone)
- Hypothalamus
- TRF from the hypothalamus
- TSH from anterior pituitary
- Thyroxine from the thyroid (TSH has caused cleavage of thyroglobulin into thyroxine)
Some Effects of Thyroid Hormone (Thyroxine)

- Increases the basal metabolic rate
  - The rate at which the body uses oxygen to transform nutrients (carbohydrates, fats and proteins) into energy
- Affects many target cells throughout the body; some effects are
  - Protein synthesis
  - Bone growth
  - Neuronal maturation
  - Cell differentiation
The Effects of Calcitonin

- Secreted from thyroid parafollicular (C) cells when blood calcium levels are high
- Calcitonin lowers Ca++ by slowing the calcium-releasing activity of osteoclasts in bone and increasing calcium secretion by the kidney
- Acts mostly during childhood
The Parathyroid Glands

- Most people have four
- On posterior surface of thyroid gland (sometimes embedded)
Parathyroids (two types of cells)

- Rare chief cells
- Abundant oxyphil cells (unknown function)

- Chief cells produce PTH
  - Parathyroid hormone, or parathormone
  - A small protein hormone
Function of PTH (parathyroid hormone or “parathormone”)

- *Increases blood Ca++ (calcium) concentration when it gets too low*
- Mechanism of raising blood calcium
  1. Stimulates osteoclasts to release more Ca++ from bone
  2. Decreases secretion of Ca++ by kidney
  3. Activates Vitamin D, which stimulates the uptake of Ca++ from the intestine
- Unwitting removal during thyroidectomy was lethal
- *Has opposite effect on calcium as calcitonin (which lowers Ca++ levels)*
Adrenal (suprarenal) glands
(“suprarenal” means on top of the kidney)

- Each is really two endocrine glands
  - Adrenal cortex (outer)
  - Adrenal medulla (inner)
Adrenal Gland

- Adrenal cortex
  - Secretes lipid-based steroid hormones, called “corticosteroids” – “cortico” as in “cortex”
    - MINERALOCORTICOIDS
      - Aldosterone is the main one
    - GLUCOCORTICOIDS
      - Cortisol (hydrocortisone) is the main one

- Adrenal medulla
  - Secretes epinephrine and norepinephrine
Aldosterone, the main *mineralocorticoid*

- Secreted by adrenal cortex in response to a decline in either blood volume or blood pressure (e.g. severe hemorrhage)
  - Is terminal hormone in renin-angiotensin mechanism
- Prompts distal and collecting tubules in kidney to reabsorb more sodium
  - Water passively follows
  - Blood volume thus increases
Cortisol, the most important glucocorticoid

(Glucocorticoid receptors are found in the cells of most vertebrate tissues)

- It is essential for life
- Helps the body deal with stressful situations within minutes
  - Physical: trauma, surgery, exercise
  - Psychological: anxiety, depression, crowding
  - Physiological: fasting, hypoglycemia, fever, infection
- Regulates or supports a variety of important cardiovascular, metabolic, immunologic, and homeostatic functions including water balance

People with adrenal insufficiency: these stresses can cause hypotension, shock and death: must give glucocorticoids, eg for surgery or if have infection, etc.
Cortisol, continued

- Keeps blood glucose levels high enough to support brain’s activity
  - Forces other body cells to switch to fats and amino acids as energy sources
- Catabolic: break down protein
- Redirects circulating lymphocytes to lymphoid and peripheral tissues where pathogens usually are
- In large quantities, depresses immune and inflammatory response
  - Used therapeutically
  - Responsible for some of its side effects
Hormonal stimulation of glucocorticoids

HPA axis (hypothalamic/pituitary/adrenal axis)

- With stress, hypothalamus sends CRH to anterior pituitary (adenohypophysis)
- Pituitary secretes ACTH
- ACTH goes to adrenal cortex where stimulates glucocorticoid secretion
  - Sympathetic nervous system can also stimulate it
- Adrenal cortex also secretes DHEA (dehydroepiandrosterone)
  - Converted in peripheral tissues to testosterone and estrogen (also steroid hormones)
  - Unclear function in relation to stress
Adrenal medulla

- Part of autonomic nervous system
- Spherical chromaffin cells are modified postganglionic sympathetic neurons
  - Secrete epinephrine and norepinephrine
  - Amine hormones
  - Fight, flight, fright
- Vesicles store the hormones
The Pineal Gland

- At the end of a short stalk on the roof of the diencephalon
- Pinealocytes with dense calcium particles
- Can be seen on x-ray (because of Ca++)
- Melatonin helps regulate the circadian rhythm
  - The biological clock of the diurnal (night/day) rhythm
  - Complicated feedback via retina’s visual input
The Pancreas

*Exocrine and endocrine cells*

- **Acinar** cells (forming most of the pancreas)
  - *Exocrine* function
  - Secrete digestive enzymes

- **Islet** cells (of Langerhans)
  - *Endocrine* function
Pancreatic islet endocrine cells

**Alpha cells:** secrete glucagon raises blood sugar mostly in periphery

**Beta cells:** secrete insulin lowers blood sugar central part (are more abundant)

Also rare Delta cells: secrete somatostatin inhibits glucagon
The Gonads (testes and ovaries)

main source of the steroid sex hormones

- Testes
  - Interstitial cells secrete androgens
  - Primary androgen is testosterone
    - Maintains secondary sex characteristics
    - Helps promote sperm formation

- Ovaries
  - Androgens secreted by thecal folliculi
    - Directly converted to estrogens by follicular granulosa cells
  - Granulosa cells also produce progesterone
  - Corpus luteum also secretes estrogen and progesterone
Endocrine cells in various organs

- The heart: atrial natriuretic peptide (ANP)
  - Stimulates kidney to secrete more salt
  - Thereby decreases excess blood volume, high BP and high blood sodium concentration
- GI tract & derivatives: Diffuse neuroendocrine system (DNES)
Endocrine cells in various organs continued

- The heart: atrial natriuretic peptide (ANP)
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- GI tract & derivatives: Diffuse neuroendocrine system (DNES)

- The placenta secretes steroid and protein hormones
  - Estrogens, progesterone
  - CRH
  - HCG

- The kidneys
  - Juxtaglomerular cells secrete renin
    - Renin indirectly signals adrenal cortex to secrete aldosterone
  - Erythropoietin: signals bone marrow to increase RBC production

- The skin
  - Modified cholesterol with uv exposure becomes Vitamin D precursor
  - Vitamin D necessary for calcium metabolism: signals intestine to absorb CA++