

## Secretions and Glands

**Paracrine** – secretion that signals to the neighboring/adjacent cell

- Neuron to neuron (synaptic cleft)
- Neuromuscular junctions
- Localized communication

**Autocrine** – secretion that signals to the same cell

- Feedback
- Localized communication

**Exocrine** – secretion to the external environment through ducts

- Salivary, alimentary, lacrimal

**Endocrine** – secretions from glands into the blood stream that signal to distant cells

- Wide-spread/systemic
- Long-lasting effects

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## Endocrine System

- Features organs that secrete hormones into the blood
- Exist as a series of organs that signal to each other in sequence
- Referred to as an axis
- Signal from brain to the pituitary to an organ → hypothalamic-pituitary-adrenal axis
- All signals originally come from the hypothalamus in the brain
- Hormones secreted interact with distant cells that express the corresponding hormone receptor
- Receptors may reside on the plasma membranes, in the cytoplasm or in the nucleus

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### Mechanisms of Intercellular Communication

Mechanism	Transmission	Chemical Mediators	Distribution of Effects
 <p>Direct communication</p>	Through gap junctions	Ions, small solutes, lipid-soluble materials	Usually limited to adjacent cells of the same type that are interconnected by connexons
 <p>Paracrine communication</p>	Through extracellular fluid	Paracrine factors	Primarily limited to the local area, where paracrine factor concentrations are relatively high; target cells must have appropriate receptors
 <p>Endocrine communication</p>	Through the bloodstream	Hormones	Target cells are primarily in other tissues and organs and must have appropriate receptors
 <p>Synaptic communication</p>	Across synaptic clefts	Neurotransmitters	Limited to very specific area; target cells must have appropriate receptors

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## Classes of Hormones

### Peptide/protein

- Amino acid chains
- Can be complex proteins with carbohydrate modification
- Multiple peptides might arise from a single protein
- Some pro-hormones processed into multiple hormones

### Lipid

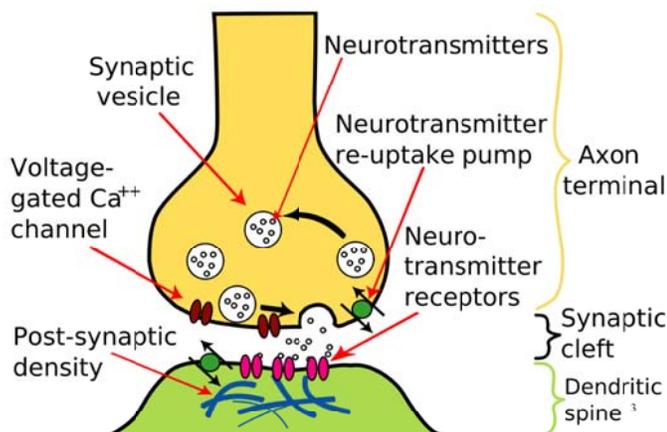
- **Eicosanoids** – signaling molecules derived from fatty acid chains
- **Steroids** – derived from cholesterol

### Monoamine

- Derived from amino acids
- Modified by a decarboxylase enzyme
- Neurotransmitters like dopamine, norepinephrine

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## Synapse → Paracrine signaling



### The three types of hormones and paracrine factors in the body

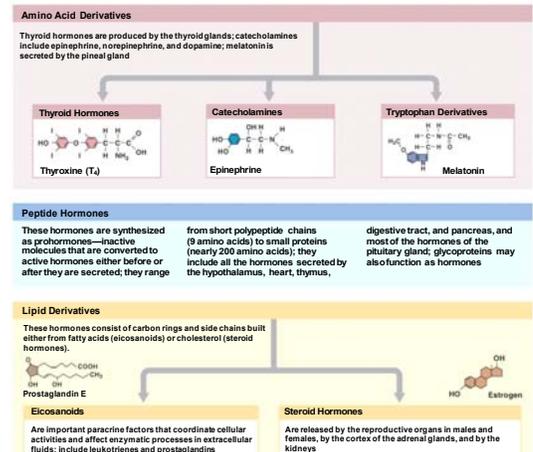


Figure 16.1

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## Hormones and receptors

- To be sensitive to a hormone, a target cell must have the appropriate protein receptor
- Without the receptor, the circulating hormone has no effect
- Cells have receptors for many different hormones
- Different combinations of receptors produce differential effects on specific tissues
- Two possible receptor locations on target cells**

### 1) Receptor in plasma membrane

- Water-soluble hormones cannot cross plasma membrane
- Act as **first messenger**, relaying message to an intracellular intermediary (second messenger)
- Second messenger** then affects enzyme activity and changes cellular metabolic reactions

### 2) Receptor in cytoplasm or nucleus

- Lipid-soluble hormones diffuse through plasma membrane
- Steroids**
  - Affect DNA transcription rate and protein synthesis
  - Change synthesis of enzyme and structural proteins affecting cell's metabolic activity and structure
- Thyroid hormones**
  - Bind to receptors on mitochondria, affecting energy production
  - Bind to receptors in nucleus, affecting cell's metabolic activity and structure

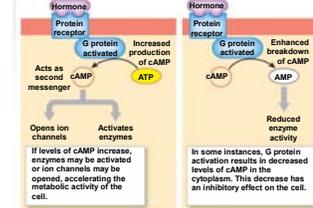
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## G-Protein Coupled Receptor



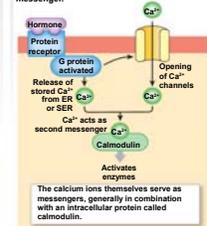
### Effects on cAMP Levels

Many G proteins, once activated, exert their effects by changing the concentration of cyclic-AMP, which acts as the second messenger within the cell.



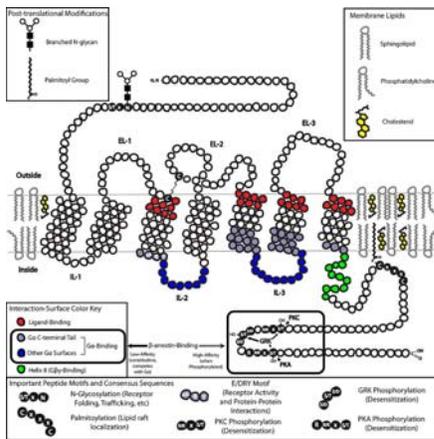
### Effects on Ca<sup>2+</sup> Levels

Some G proteins use Ca<sup>2+</sup> as a second messenger.



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## G-Protein Coupled Receptor



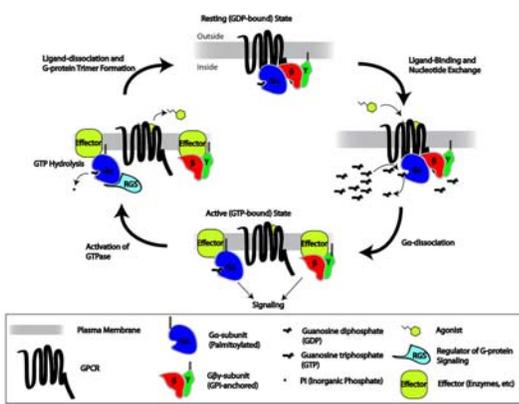
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## G-Protein Coupled Receptor

- Referred to as metabotropic receptors
- Modulate the cell directly
- Signal transferred to the interior of the cell setting forth metabolic changes
- Cascade of events that amplify the message through second messengers
  - cAMP (cyclic AMP)
  - Ca<sup>2+</sup>
- Activation of protein kinases (phosphorylates proteins)
- Activation of protein phosphatases
- Phosphorylation activates/deactivates proteins by changing conformation
- Signal can be long-term if affecting transcription factors

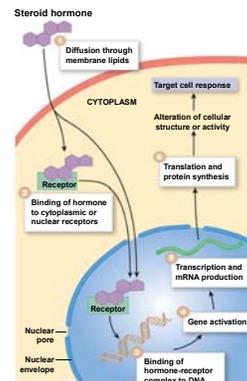
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## G-Protein Coupled Receptor

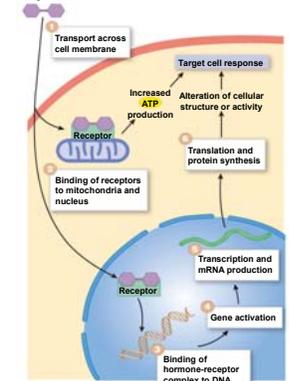


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The events associated with the binding of a steroid hormone to receptors in the cytoplasm or nucleus



The events associated with the binding of a thyroid hormone to receptors on mitochondria and within the nucleus



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## Nuclear Receptors

**Central Dogma of Molecular Biology**

replication (DNA → DNA)  
DNA Polymerase

transcription (DNA → RNA)  
RNA Polymerase

translation (RNA → Protein)  
Ribosome

DNA → RNA → Protein

**Structural Organization of Nuclear Receptors**

1D: A B C D E

3D: DNA binding domain (DBD), DNA, Ligand, Ligand binding domain (LBD)

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## Organs of the endocrine system (purple) and other organs containing tissues that secrete hormones (tan)

**Hypothalamus**  
Secretes hormones involved with fluid balance, smooth muscle contraction, and the control of hormone secretion by the anterior pituitary gland

**Pituitary Gland**  
Secretes multiple hormones that regulate the endocrine activities of the adrenal cortex, thyroid gland, and reproductive organs, and a hormone that stimulates melanin production

**Thyroid Gland**  
Secretes hormones that affect metabolic rate and calcium levels in body fluids.

**Adrenal Glands**  
Secretes hormones involved with mineral balance, metabolic control, and resistance to stress; the adrenal medulla releases E and NE during sympathetic activation

**Pancreas (Pancreatic Islets)**  
Secretes hormones regulating the rate of glucose uptake and utilization by body tissues

**Pineal Gland**  
Secretes melatonin, which affects reproduction function and helps establish circadian (day/night) rhythms

**Parathyroid Glands**  
Secretes a hormone important to the regulation of calcium ion concentrations in body fluids

**Organs with Secondary Endocrine Functions**

- Heart:** Secretes hormones involved in the regulation of blood volume
- Thymus:** Secretes hormones involved in the stimulation and coordination of the immune response
- Digestive Tract:** Secretes numerous hormones involved in the coordination of system functions, glucose metabolism, and appetite
- Kidneys:** Secretes hormones that regulate blood cell production and the rates of calcium and phosphate absorption by the intestinal tract
- Gonads:** Secretes hormones affecting growth, metabolism, and sexual characteristics, as well as hormones coordinating the activities of organs in the reproductive system

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## Nuclear Receptors

- Function through activation or repression of transcription
- Nuclear receptors bind to specific DNA sequences
- Directly alter transcriptional program in cells for long-term consequences
- GPCRs modify transcription factors less directly since nuclear receptors are the transcription factors

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## It all starts in the brain

**Hypothalamus** provides highest level of endocrine function through three mechanisms

- Has neurons that secrete two hormones released from posterior pituitary
  - Antidiuretic hormone** (from supraoptic nucleus) aka **Vasopressin**
  - Oxytocin** (from paraventricular nucleus)
- Secretes **regulatory hormones** or **tropic hormones** that control anterior pituitary gland endocrine cells
  - Released from **median eminence** of infundibulum
  - hypophyseal portal system** (hypophysis, pituitary gland) fenestrated capillaries that transport tropic hormones to pituitary
- Two regulatory hormone types
  - Releasing hormones** (stimulate hormone release)
  - Inhibiting hormones** (prevent hormone release)
- Contains autonomic (sympathetic) neurons that stimulate release of hormones from adrenal medulla → direct innervation

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**Transcription:** RNAP binds to the promoter region of a gene, synthesizing a complementary RNA strand (mRNA) using the coding strand as a template.

**Translation:** The mRNA is translated by a ribosome, where tRNAs carrying amino acids assemble the polypeptide chain.

**Protein Structure:** The polypeptide chain folds into a functional protein structure.

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## The three mechanisms by which the hypothalamus integrates the activities of the nervous and endocrine systems

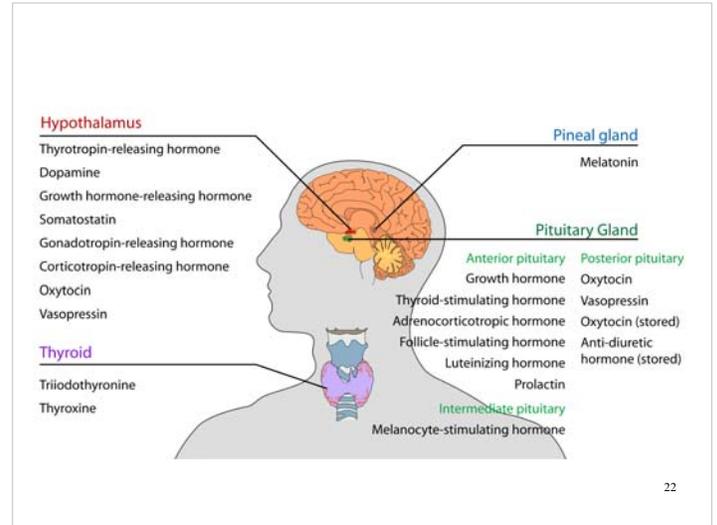
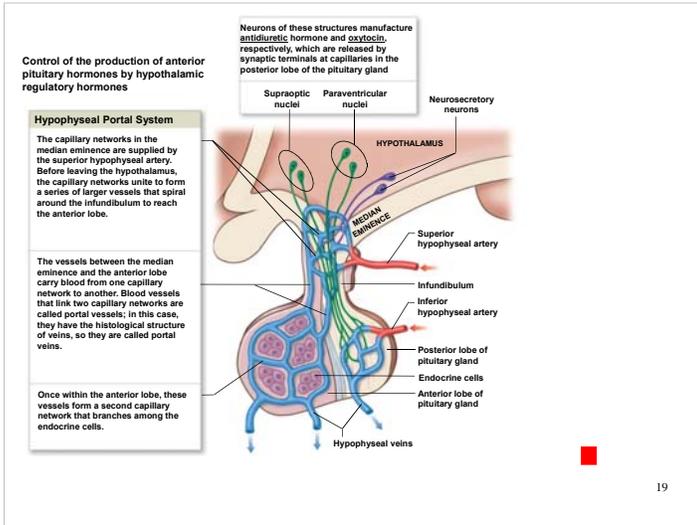
- The hypothalamus functions as an endocrine organ. Hypothalamic neurons synthesize two hormones—antidiuretic hormone (ADH) and oxytocin (OCT)—and transport them along axons within the infundibulum.
- The hypothalamus secretes regulatory hormones, special hormones that control endocrine cells in the pituitary gland. The hypothalamic regulatory hormones control the secretory activities of endocrine cells in the anterior lobe of the pituitary gland.
- The hypothalamus contains autonomic centers that exert direct neural control over the endocrine cells of the adrenal medulla. When the sympathetic division is activated, the adrenal medulla is stimulated directly and immediately.

**Anterior lobe of pituitary gland:** Hormones released control the activities of endocrine cells in the thyroid gland, adrenal cortex, and reproductive organs.

**Posterior lobe of pituitary gland:** ADH and oxytocin are released into the circulation.

**Adrenal gland:** Upon direct neuronal stimulation, the adrenal medulla secretes epinephrine and norepinephrine into the circulation.

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**It all starts in the brain**

- The brain regulates the major functions of the body
- The **hypothalamus** is the portion of the brain that regulates all endocrine systems
- The hypothalamus sends signals to the **pituitary gland**
- Pituitary Gland**
  - Referred to as the **hypophysis**
  - Composed of the anterior and posterior lobes
    - Anterior → **adenohypophysis** (7 hormones)
    - Posterior → **neurohypophysis** (2 hormones)
  - Hormones secreted into portal vessels

Labels: optic chiasm, hypothalamus, sella turcica (bone), pituitary gland.

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**Anterior pituitary hormones**

**Gonadotropins** (regulate gonadal activities)

- Released in response to **gonadotropin-releasing hormone (GnRH)** from hypothalamus

- Follicle-stimulating hormone (FSH)**
  - Females: promotes ovarian follicle development and (in concert with LH) stimulates secretion of **estrogens**
  - Males: promotes maturation of sperm
  - Inhibited by **inhibin** (peptide released by gonads)
- Luteinizing hormone (LH)**
  - Females: induces ovulation, promotes secretion of **estrogen** and **progesterone** (e.g., progesterone)
  - Males: stimulates production of sex hormones (**androgens**), primarily testosterone

Labels: DAYS 1, 7, 14, 21, 28; FOLLICULAR PHASE, LUTEAL PHASE; BASAL BODY TEMPERATURE; HORMONE LEVEL: FSH, LH, ESTROGEN, PROGESTERONE; OVARIAN CYCLE; OVULATION; OVUM; UTERINE CYCLE; MENSES, PROLIFERATIVE, SECRETORY.

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**Pituitary**

- Often called "Master Gland"
- Sits in *sella turcica* (Turkish saddle)
- Adenohypophysis is own gland
- Neurohypophysis is derived from axon terminals from the hypothalamus
- Tropic hormones**
  - Hormones that act on other endocrine glands
  - From hypothalamus
  - Therefore, hypothalamus is the **real master gland**

Label: Sella turcica.

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**Anterior pituitary hormones**

**Thyroid-stimulating hormone (TSH)**

- Stimulates release of thyroid hormones
- Released in response to **thyrotropin-releasing hormone (TRH)** from hypothalamus
- Decreased release when thyroid hormone levels rise (negative feedback)
- Composed of 2 peptide chains

**Thyroid system**

Labels: Hypothalamus, Anterior pituitary gland, Thyrotropin-releasing hormone (TRH), Negative feedback, Thyroid-stimulating hormone (TSH), Thyroid gland, Thyroid hormones (T3 and T4), Increased metabolism, Growth and development, Increased catecholamine effect.

$\alpha$  chain of TSH, LH and FSH are identical

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## Anterior pituitary hormones

### Proopiomelanocortin (POMC)

- Precursor protein that is proteolytically processed
- Yields MSH, ACTH and  $\beta$ -endorphin
- POMC, LSH and Gonadotropin cells are **basophilic** histologically labeling the lysosomes

### Melanocyte-stimulating hormone (MSH)

- From pars intermedia of anterior lobe
- Stimulates melanocytes of skin to increase melanin production
- In adults, almost none produced

### Adrenocorticotropic hormone (ACTH)

- Stimulates release of steroid hormones from adrenal cortex
  - Specifically those that affect glucose metabolism
- Released in response to **corticotropin-releasing hormone (CRH)** from hypothalamus

### $\beta$ -endorphin

- "endogenous morphine"

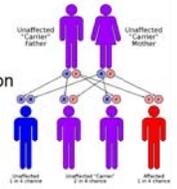
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## Anterior pituitary hormones



### Laron Syndrome

- Missing exon from GH receptor
- Autosomal recessive transmission



### Acromegaly

- Excessive GH production
- Sometimes from tumor



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## Anterior pituitary hormones

### Prolactin (PRL: *pro*-, before + *lac*, milk)

- Works with other hormones to stimulate mammary gland development and milk production
- Released in response to several prolactin-releasing factors
- Inhibited by **prolactin-inhibiting hormone (PIH)**

Typical prolactin values

Proband	Prolactin, $\mu$ g/L
women, follicular phase (n = 803)	12.1
women, luteal phase (n = 699)	13.9
women, mid-cycle (n = 53)	17
women, whole cycle (n = 1555)	13.0
women, pregnant, 1st trimester (n = 39)	16
women, pregnant, 2nd trimester (n = 52)	49
women, pregnant, 3rd trimester (n = 54)	113
Men, 21-30 (n = 50)	9.2
Men, 31-40 (n = 50)	7.1
Men, 41-50 (n = 50)	7.0
Men, 51-60 (n = 50)	6.2
Men, 61-70 (n = 50)	6.9

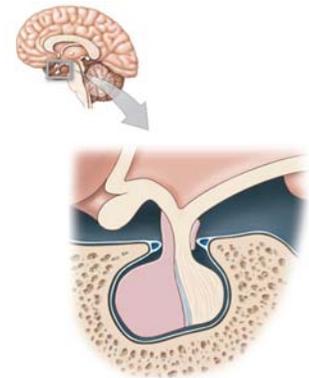
### hyperprolactinemia

- Is the presence of abnormally-high levels of prolactin in the blood
- Results in disruption of menstrual cycle
- Results in lactation (even in men)

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anterior

posterior



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## Anterior pituitary hormones

### Growth hormone (GH)

- Also called somatotropin
- Stimulates cell growth and reproduction by stimulating rate of protein synthesis
- Released in response to **growth hormone-releasing hormone (GH-RH)** and **growth hormone-inhibiting hormone (GH-IH)**

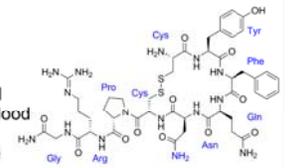


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## Posterior pituitary hormones

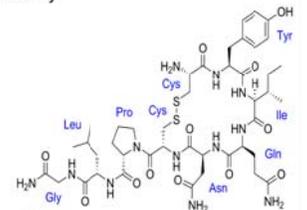
### Antidiuretic hormone (ADH)

- Also known as **arginine vasopressin (AVP)**
- Released in response to a variety of stimuli
- Primarily increased solute concentration of blood (sensed by **osmoreceptors**), or a decrease in blood pressure or volume
- Inhibited by increase in extracellular fluid volume
- Also inhibited by alcohol
- Primary function is to decrease water lost from kidney
- Also causes vasoconstriction



### Oxytocin (OXT: *okytokos*, swift birth)

- Increased release in response to:
  - Childbirth
  - Nursing
  - Sexual arousal (function unknown)
- Sensory input (**neuroendocrine reflex**)
- Stimulates contraction of:
  - Smooth muscle walls of uterus
  - Mammary gland myoepithelial cells releasing milk
- Related to social bonding and interactions and maternal behavior



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## Posterior pituitary hormones

### Posterior Pituitary Hormones

#### ADH

Antidiuretic hormone is most notably released in response to a rise in the solute concentration in the blood or a fall in blood volume or blood pressure. The primary function of ADH is to decrease the amount of water lost at the kidneys. ADH also causes vasoconstriction, which helps elevate blood pressure. ADH release is inhibited by alcohol.



Kidney

#### OXT

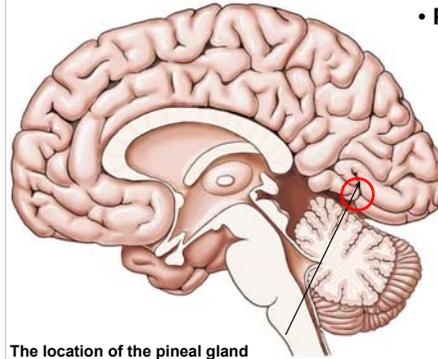
In women, oxytocin stimulates smooth muscle contraction in the wall of the uterus, promoting labor and delivery, and after labor it stimulates the contraction of myoepithelial cells around the secretory alveoli and the ducts of the mammary glands, promoting the ejection of milk. Circulating concentrations of oxytocin rise during sexual arousal and peak at orgasm in both sexes.



Uterus

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## Pineal



### • Pinealocytes

- Neurosecretory cells
- produce **melatonin**
- Inhibits reproductive functions (may control human sexual maturation)
- Protects tissues from **free radicals**
- Maintains daily physiological changes (**circadian rhythms**)
- Coordinated by collaterals of visual pathway to coordinate with day-night cycle

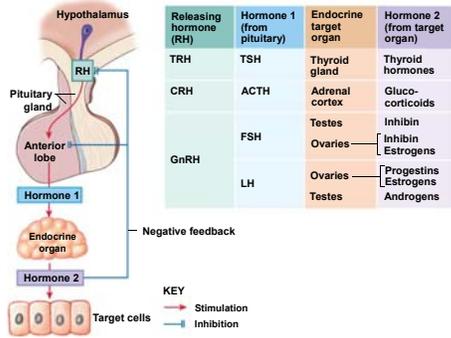
The location of the pineal gland

*"principal seat of the soul"*

-René Descartes → the point of connection between the intellect and the body 34

## Feedback loops

The control of hypothalamic and pituitary hormone secretion by negative feedback



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## Pineal – The Third Eye

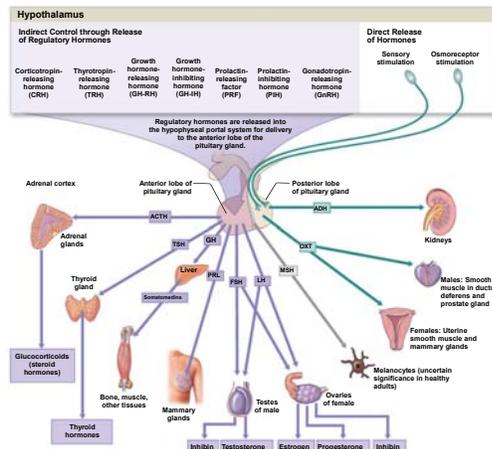


The lizard's third eye can only be seen when it is a baby.



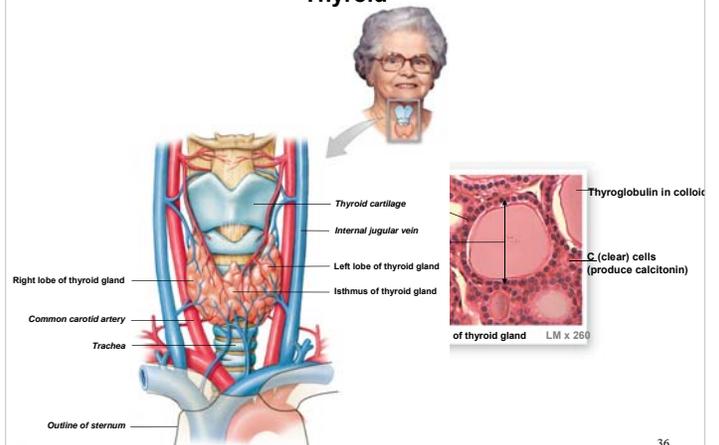
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An overview of the relationships between hypothalamic and pituitary hormones, and some effects of pituitary hormones on target tissues



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## Thyroid



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## Thyroid

- Contains large numbers of **follicles** (hollow spheres lined with follicular cells of simple cuboidal epithelium)
- **Follicular cells secrete thyroglobulin** (molecule containing building block amino acid tyrosine) into colloid within follicles
  - 1) Iodide ions from diet delivered to thyroid gland and taken up by follicular cells
  - 2) Enzymes activate iodide and attach to tyrosine portions of thyroglobulin molecule
  - 3) **T<sub>4</sub> (Thyroxine, 4 iodide molecules)** and **T<sub>3</sub> (3 iodide molecules)** are produced and stored in thyroglobulin
  - 4) Follicle cells remove thyroglobulin from follicle via endocytosis
  - 5) Enzymes break down thyroglobulin, releasing thyroid hormones into cytoplasm
  - 6) T<sub>3</sub> (~90% of thyroid secretions) and T<sub>4</sub> (<10%) diffuse across basement membrane and enter bloodstream
  - 7) ~75% of thyroid hormones travel in the blood attached to transport proteins (**thyroid-binding globulins**)
- **C (clear) cells** in between follicular cells (aka **Parafollicular Cells**)
  - Secrete hormone **calcitonin**
    - Lowers blood Ca<sup>2+</sup>
    - Inhibits intestinal absorption of Ca<sup>2+</sup>

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## Thyroid

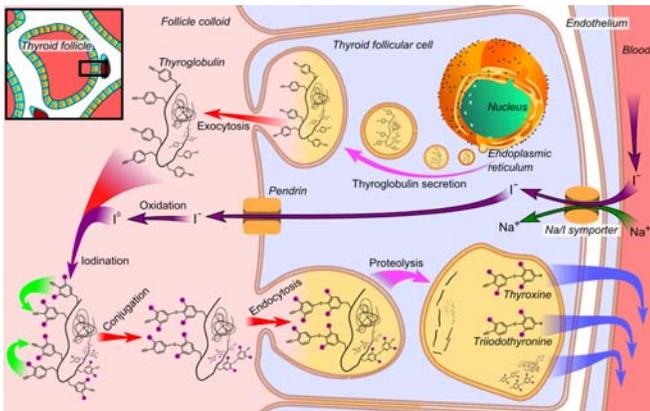
### Hypothyroidism

- weight gain, depression, mania, sensitivity to heat and cold, paresthesia, fatigue, panic attacks, bradycardia, tachycardia, high cholesterol, reactive hypoglycemia, constipation, migraines, muscle weakness, cramps, memory loss, infertility and hair loss
- **Cretinism** - severely stunted physical and mental growth due to untreated congenital deficiency of thyroid hormones and from severe iodine deficiency
- **Hashimoto's disease** - autoimmune disease in which the thyroid gland is attacked by a variety of cell- and antibody-mediated immune processes
  - Thyroiditis from attack of the thyroid by immune system



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## Thyroid



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## Thyroid

### Hyperthyroidism

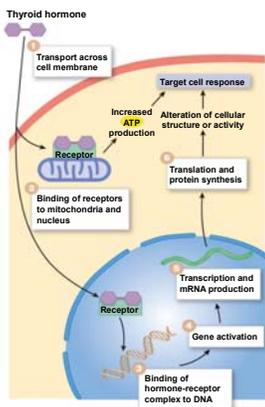
- nervousness, irritability, increased perspiration, heart racing, hand tremors, anxiety, difficulty sleeping, thinning of the skin, fine brittle hair, and muscular weakness
- Weight loss, sometimes significant, may occur despite a good appetite, vomiting may occur, and, for women, menstrual flow may lighten and menstrual periods may occur less often
- **Graves Disease**
  - insomnia, hand tremor, hyperactivity, hair loss, excessive sweating, heat intolerance, weight loss despite increased appetite, diarrhea, frequent defecation, palpitations, muscle weakness and skin being warm as well as moist
  - Autoimmune disease where thyroid autoantibodies (TSHR-Ab) that activate the TSH-receptor (TSHR), thereby stimulating thyroid hormone synthesis and secretion, and thyroid growth (causing a diffusely enlarged goiter)



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## Thyroid

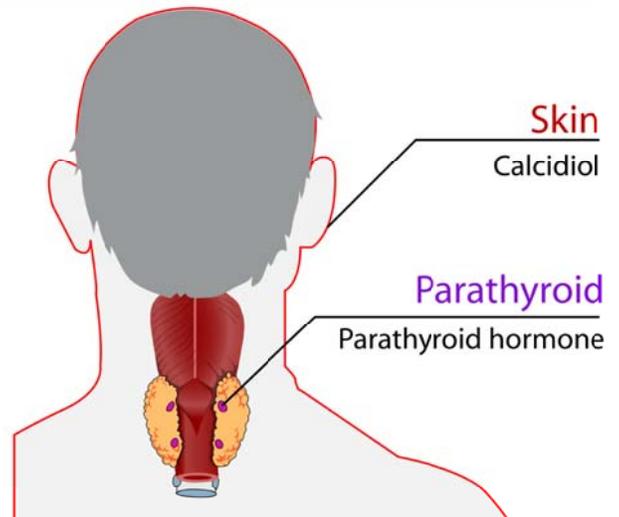
The events associated with the binding of a thyroid hormone to receptors on mitochondria and within the nucleus



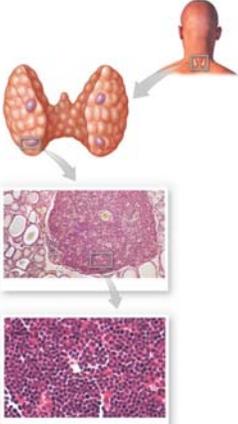
### Effects of Thyroid Hormones on Peripheral Tissues

- Elevated rates of oxygen consumption and energy consumption; in children, may cause a rise in body temperature
- Increased heart rate and force of contraction; generally results in a rise in blood pressure
- Increased sensitivity to sympathetic stimulation
- Maintenance of normal sensitivity of respiratory centers to changes in oxygen and carbon dioxide concentrations
- Stimulation of red blood cell formation and thus enhanced oxygen delivery
- Stimulation of activity in other endocrine tissues
- Accelerated turnover of minerals in bone

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## Parathyroid

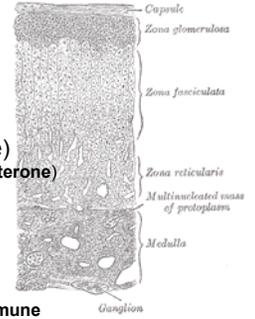


- Oxyphil cells (no known function)
- Parathyroid chief cells → Parathyroid Hormone (PTH)
  - Mobilizes calcium from bone
  - Inhibit osteoblast deposition
  - Activate osteoclast production
    - Erosion of bone
  - Enhances Kidney absorption of  $\text{Ca}^{2+}$
  - Stimulates kidney release of **calcitriol**
  - Increases  $\text{Ca}^{2+}$  and  $\text{PO}_4^{3-}$  absorption in intestine

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## Adrenal Gland - Cortex

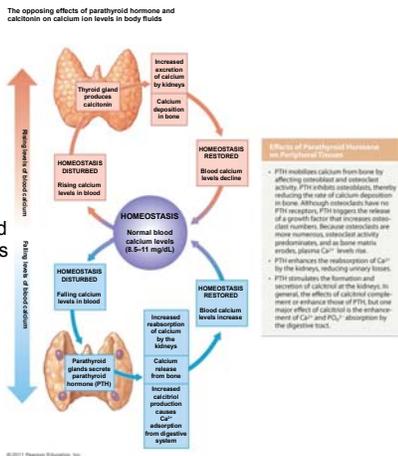
- **Zona glomerulosa**
  - **Mineralocorticoids** (primarily aldosterone)
    - Increases renal reabsorption of  $\text{Na}^+$  and water
    - Especially in presence of ADH
    - Accelerates renal loss of  $\text{K}^+$
- **Zona fasciculata** (*fasciculus*, little bundle)
  - **Glucocorticoids** (primarily **cortisol** and **corticosterone**)
    - Increase rates of liver glucose and glycogen formation
    - Stimulate release of:
      - Amino acids from skeletal muscles
      - Lipids from adipose tissue
    - Promote lipid metabolism
    - Can have **anti-inflammatory effect** and **immune suppressant**
- **Zona reticularis** (*reticulum*, network)
  - Androgens (small amounts)
    - Stimulate pubic hair before puberty
    - **Androstenedione** and **DHEA**



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## Calcium Homeostasis

- PTH and calcitonin from thyroid gland have opposing effects
- In healthy adults, PTH (along with calcitriol) is primary regulator of circulating  $\text{Ca}^{2+}$  concentrations
- Removal of thyroid gland has no effect on  $\text{Ca}^{2+}$
- Calcitonin can be administered clinically in metabolic disorders with excessive calcium

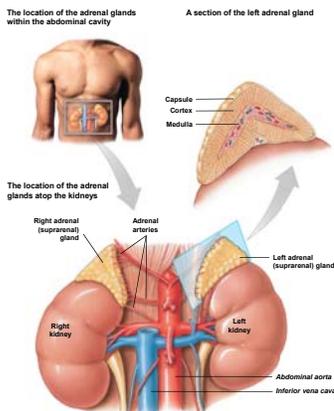


## Adrenal Androgens



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## Adrenal Gland



- Adrenal capsule (thin, outer connective tissue)
- Adrenal cortex
  - Produces >24 steroid hormones collectively known as **adrenocortical steroids** or **corticosteroids**
- Adrenal medulla
  - Produces epinephrine and norepinephrine
  - Developmentally neural in origin

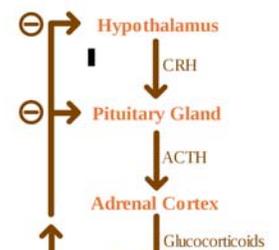
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## Adrenal Cortex diseases



### Addison's Disease

- Deficiency of adrenal cortex steroid production (**hyposecretion**)
- a fatigue, lightheadedness upon standing or while upright, muscle weakness, fever, weight loss, difficulty in standing up, anxiety, nausea, vomiting, diarrhea, headache, sweating, changes in mood and personality, and joint and muscle pains
- Some have marked cravings for salt or salty foods due to the urinary losses of sodium
- Treated with steroids



- Many Addison's patients suffer from hyperpigmentation
- **Hyponatremia** (low sodium level in the blood)
- **Hyperkalemia** (elevated potassium level in the blood)
- **Hypercalcemia** (elevated calcium level in the blood)

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## Adrenal Cortex diseases



### Cushing's syndrome

- Excessive (hypersecretion) exposure to glucocorticoids
- Weight gain → in trunk and face
- Dilatation of facial capillaries → blushing appearance
- Profuse sweating
- Hypertension
- Insulin resistance → diabetes

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## Pancreas

- Islets of Langerhans → Pancreatic Islets
- **Alpha cells**
  - **Glucagon**
    - Raises blood glucose by increasing liver glycogen breakdown
- **Beta cells**
  - **Insulin**
    - Lowers blood glucose by increasing glucose uptake and utilization by cells
    - increasing glycogen production in liver, skeletal muscles
    - Decreased lipolysis
- **Delta cells**
  - **Peptide hormone identical to growth hormone-inhibiting hormone (GH-IH)**
    - Suppresses release of glucagon and insulin
    - Slows rates of food absorption and enzyme secretion in digestive tract
- **F cells**
  - **Pancreatic polypeptide (PP)**
    - Inhibits gallbladder contraction and reduces digestive activity of pancreas and digestive tract

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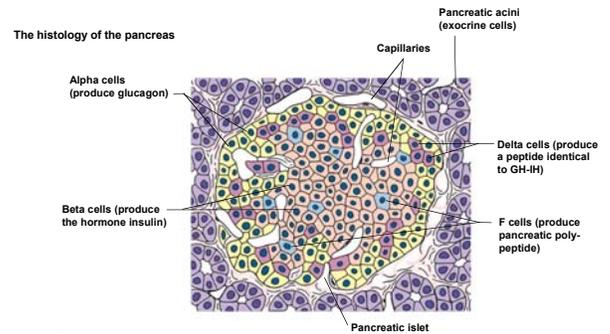
## Adrenal Medulla

- Epinephrine and norepinephrine
  - Derived from neural tissue
  - Receives direct innervation from the sympathetic nervous system
  - Adrenaline and Noradrenaline
  - Catecholamines derived from Dopamine from amino acid Tyrosine
  - Increase cardiac activity
  - Increase blood pressure
  - Increase glycogenolysis → increased blood sugar
  - Increase lipolysis
  - Acute fight or flight → Cortisol from cortex is for chronic stress



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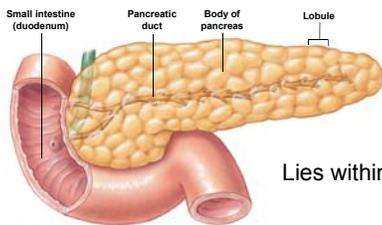
## Pancreas



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## Pancreas

### The surface anatomy of the pancreas



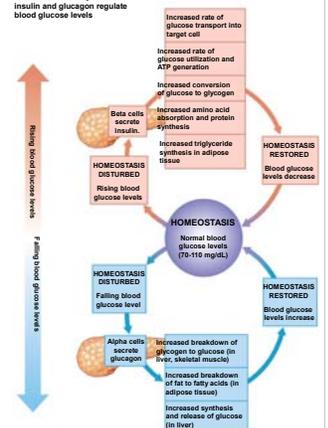
Lies within abdominopelvic cavity

- **Exocrine pancreas (99% of volume)**
  - Cells (**pancreatic acini**) forming glands and ducts that secrete pancreatic fluid and enzymes with digestive function
- **Endocrine pancreas (1%)**
  - Small groups of cells scattered in clusters (**pancreatic islets**) that secrete hormones

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## Pancreas

- The mechanisms by which insulin and glucagon regulate blood glucose levels
- Glucose homeostasis
- Insulin and glucagon are primary hormones controlling blood glucose levels
- Have opposing effects
- As blood glucose rises, beta cells secrete insulin bringing glucose into target cells
- As blood glucose declines, alpha cells secrete glucagon causing liver breakdown of glycogen and glucose release



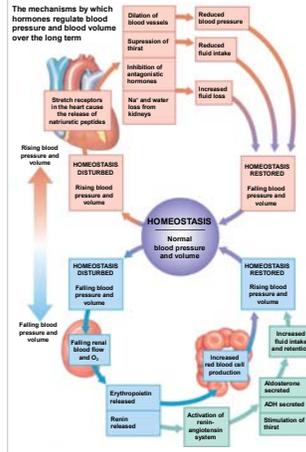
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## Pancreas

- **Diabetes mellitus** (*mellitum*, honey)
  - Characterized by glucose concentrations high enough to overwhelm kidney reabsorption
  - **Hyperglycemia** – high glucose levels in blood
  - **Glycosuria** – glucose in urine → sweet urine
  - **Polysuria** - excessive urine production (diabetes)
  - **Type 1 (insulin dependent) diabetes**
    - Inadequate insulin production from beta cells
    - Individuals must receive exogenous insulin daily
    - Only 5%–10% of all diabetes cases
    - Often develops in childhood (Juvenile Diabetes)
  - **Type 2 (non-insulin dependent) diabetes**
    - Normal insulin levels but target cells do not respond properly (= insulin resistant)
    - Associated with obesity
    - Can be treated with diet, exercise, and drugs

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## Cardiovascular System



January 15, 2007, 12:36 PM  
**Too High a Price for a Wii**  
 By TOM ZELLER, JR.

This tragedy speaks for itself.  
 A 28-year-old suburban Sacramento woman died of apparent "water intoxication" after participating in a contest – "Hold Your Wee for a Wii" – sponsored by local radio station 102.5 KEMO. The rules were simple: Participants competed to see how much water they could drink without going to the bathroom. The winner would receive a shiny new Wii video game console, the highly coveted, \$50 must-have from Nintendo.



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## Pancreas



**Clinical Problems Caused by Diabetes Mellitus**

The proliferation of capillaries and hemorrhaging at the retina may cause partial or complete blindness. This condition is called diabetic retinopathy.

Degenerative blockages in cardiac circulation can lead to early heart attacks. For a given age group, heart attacks are three to five more likely in individuals with diabetes than in individuals that do not have the condition.

Degenerative changes in kidneys, a condition called diabetic nephropathy, can lead to kidney failure.

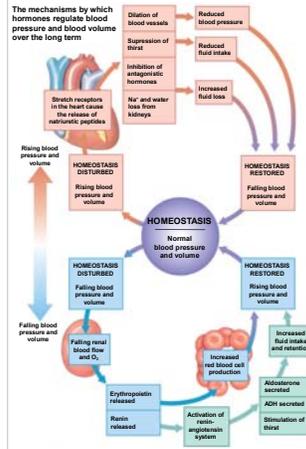
Abnormal blood flow to neural tissues is probably responsible for a variety of problems with peripheral nerves, including abnormal autonomic function. As a group, these disorders are termed diabetic neuropathy.

Blood flow to the distal portions of the limbs is reduced, and peripheral tissues may be damaged as a result. A reduction in blood flow to the feet, for example, can lead to tissue death, ulceration, infection, and the loss of toes or a major portion of one or both feet.



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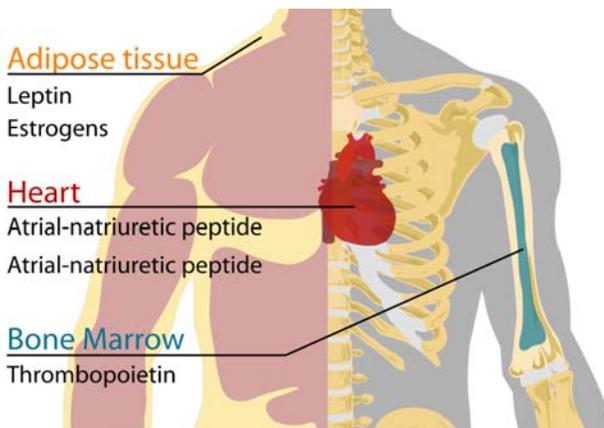
## Cardiovascular System



- Cardiovascular system supplies cells with nutrients
- Nutrients are required for growth/repair
- Nutrients include energy and raw material
- **Erythropoietin (EPO)**
  - Kidney hormone that increases production of erythrocytes
  - Increases O<sub>2</sub> capacity
- **Renin** from kidneys activate **renin-angiotensin system**
  - Leads to increased fluid intake and fluid retention
  - Constricts vessel to increase BP
  - Activates adrenal to produce aldosterone

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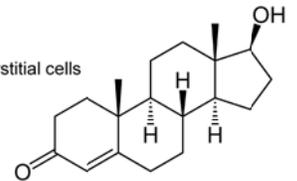
## Cardiovascular System



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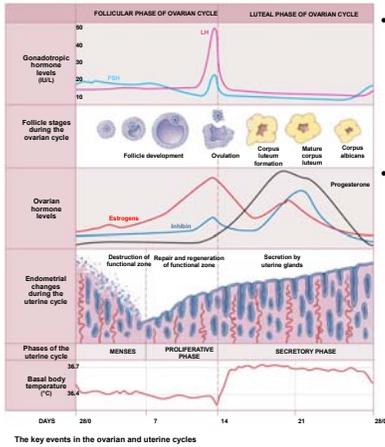
## Reproductive Control - Male

- **Luteinizing hormone (LH)**
  - Stimulates testosterone secretion from interstitial cells
  - Testosterone is the main androgen
    - Mostly as Dihydrotestosterone
- **Follicle-stimulating hormone (FSH)**
  - Stimulates nurse cells to promote spermatogenesis
  - Secrete **androgen-binding protein (ABP)** → carries the lipid in solution
  - Secrete **inhibin** to feed back to anterior pituitary
- **Testosterone**
  - Anabolic steroid
  - promotes secondary sexual characteristics such as increased muscle, bone mass, and the growth of body hair



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## Reproductive Control - Female



- **Follicular Phase**
  - GnRH signals follicle development
  - GnRH → FSH
  - Developing follicles secrete **estrogens (estradiol)**
    - Inhibits LH secretion
    - Endometrial growth
    - Contributes to fat deposition
- **Luteal phase**
  - After ovulation
  - LH surge
  - Completion of primary oocyte meiosis I
  - Forceful rupture of follicular wall
  - Formation of **corpus lutea**
  - Corpus lutea produces **progesterone**
  - Maintains the thick endometrium

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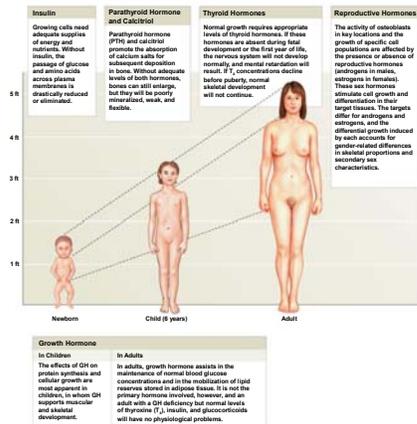
## Reproductive Control - Female

- Without implantation, endometrium sheds → menses
- If implantation → embryo/fetus produces **chorionic gonadotropin**
- **Human Chorionic Gonadotropin (hCG)**
  - Replaces the LH signal to maintain corpus luteum
  - Maintains progesterone output to maintain endometrium
- **RU-486/Mifiprestone**
  - Abortifacient glucocorticoid analog
  - Blocks progesterone receptor to terminate pregnancy

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## Control of Growth

The effects of various hormones on normal growth



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