



Lecture 3

The Endocrine System Physiology

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Physiology of the system

Physiology is the study of how the human body works. It describes the chemistry and physics behind basic body functions, from how molecules behave in cells to how systems of organs work together. It helps us understand what happens in a healthy body in everyday life and what goes wrong when someone gets sick.

Anatomy - the internal and external structures of the body and their physical relationships

Physiology - the study of the functions of those structures

The **endocrine system**, made up of all the body's different hormones, regulates all biological processes in the body from conception through adulthood and into old age, including the development of the brain and nervous system, the growth and function of the reproductive system, as well as the metabolism and blood sugar

Endocrine - General

Major Control System of **Homeostasis**
Negative Feedback

Ductless Glands; Produce Hormones

Diffuse into Blood

Slow Initial Effects, but Effects **Persist**
much longer

Hormones act on specific Targets

The Endocrine System

- Second messenger system of the body
- Uses chemical messages (hormones) that are released into the blood
- Hormones control several major processes
 - Reproduction
 - Growth and development
 - Mobilization of body defenses
 - Maintenance of much of homeostasis
 - Regulation of metabolism

Hormone Overview

- Hormones are produced by specialized cells
- Cells secrete hormones into extracellular fluids
- Blood transfers hormones to target sites
- These hormones regulate the activity of other cells

Glands vs. Nerves

Endocrine System

- System of glands
- Hormones are transmitted through blood stream
- Slow, but chemical response lasts longer

Chemical messengers
• Feedback loops
• Regulate physiological activities to maintain homeostasis
Respond to stimuli

Nervous System

- Signals travel along neurons via neurotransmitters
- Fast electrical action potentials
- Short-acting changes to the body

Endocrine Organs

- Pineal Gland
- Hypothalamus
- Pituitary
 - Anterior
 - Posterior
- Thyroid Gland
- Parathyroid Glands
- Thymus
- Adrenal Glands
 - Cortex
 - Medulla
- Pancreas
- Gonads
- Kidney/adipocytes/
small intestine

Mechanisms of Hormone Action

- Hormones affect only certain tissues or organs (target cells or organs)
- Target cells must have specific protein receptors
- Hormone binding influences the working of the cells

Effects Caused by Hormones

- Changes in plasma membrane permeability or electrical state
- Synthesis of proteins, such as enzymes
- Activation or inactivation of enzymes
- Stimulation of mitosis

Steroid Hormone Action

- Diffuse through the plasma membrane of target cells
- Enter the nucleus
- Bind to a specific protein within the nucleus
- Bind to specific sites on the cell's DNA
- Activate genes that result in synthesis of new proteins

Control of Hormone Release

- Hormone levels in the blood are maintained by negative feedback
- A stimulus or low hormone levels in the blood triggers the release of more hormone
- Hormone release stops once an appropriate level in the blood is reached

Hormonal Stimuli of Endocrine Glands

- Endocrine glands are activated by other hormones

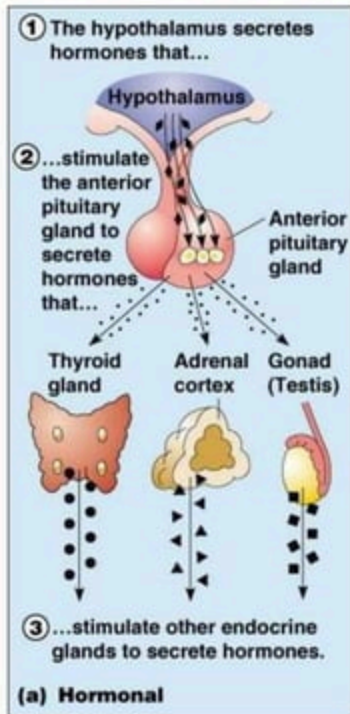


Figure 9.2a

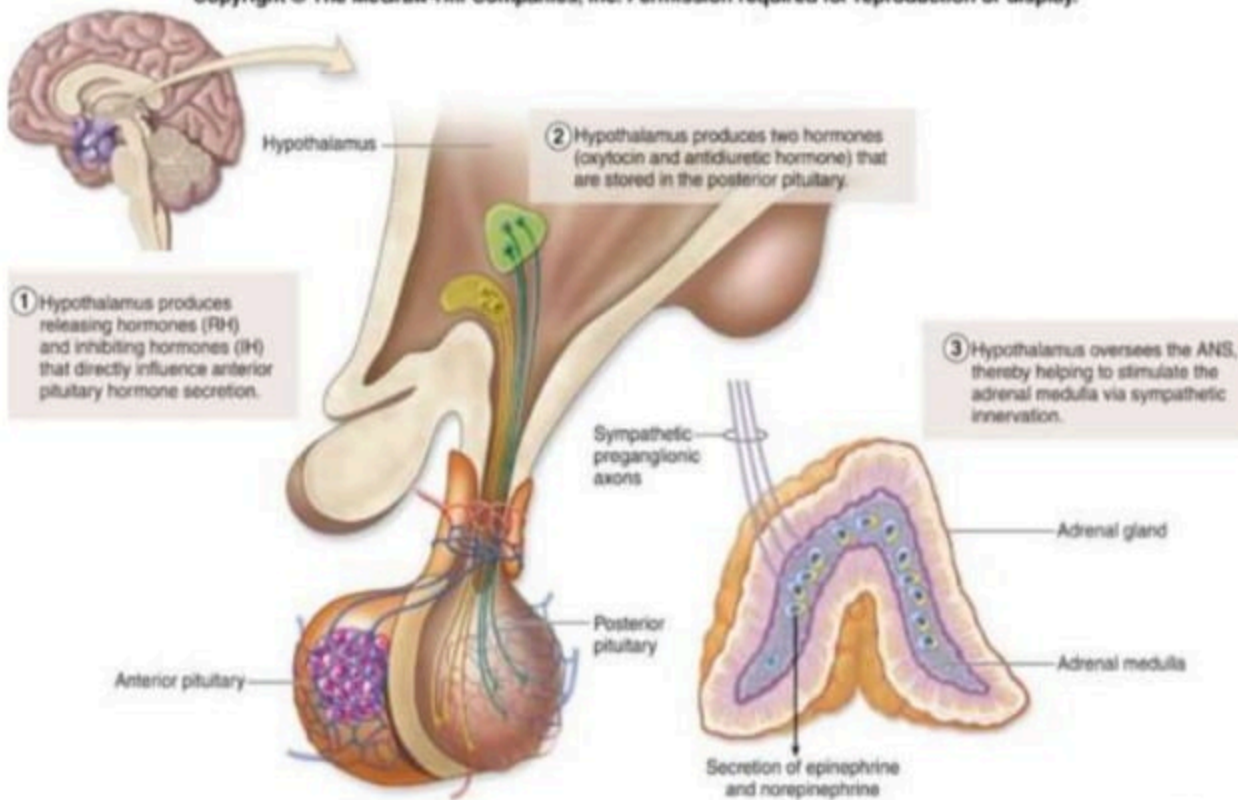
Hypothalamic Control of the Endocrine System

- Master control center of the endocrine system
- Hypothalamus oversees most endocrine activity:
 - special cells in the hypothalamus secrete hormones that influence the secretory activity of the **anterior pituitary gland**
 - called regulatory hormones
 - releasing hormones (RH)
 - inhibiting hormones (IH)
- Hypothalamus has indirect control over these endocrine organs.

Hypothalamic Control of the Endocrine System

- Hypothalamus produces two hormones that are transported to and stored in the **posterior pituitary**.
 - **oxytocin** (**paraventricular nucleus**)
 - **antidiuretic hormone (ADH)** (**supraoptic nucleus**)
- Hypothalamus directly oversees the stimulation and hormone secretion of the **adrenal medulla**.
 - An endocrine structure that secretes its hormones in response to stimulation by the **sympathetic** nervous system.
- Some endocrine cells are **not** under direct control of hypothalamus.

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Humoral Stimuli of Endocrine Glands

- Changing blood levels of certain ions stimulate hormone release

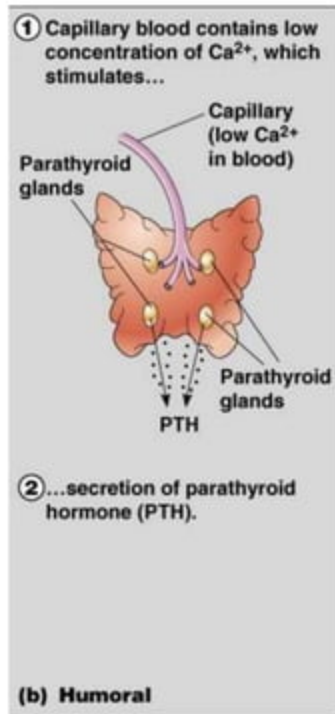


Figure 9.2b

Neural Stimuli of Endocrine Glands

- Nerve impulses stimulate hormone release
- Most are under control of the sympathetic nervous system

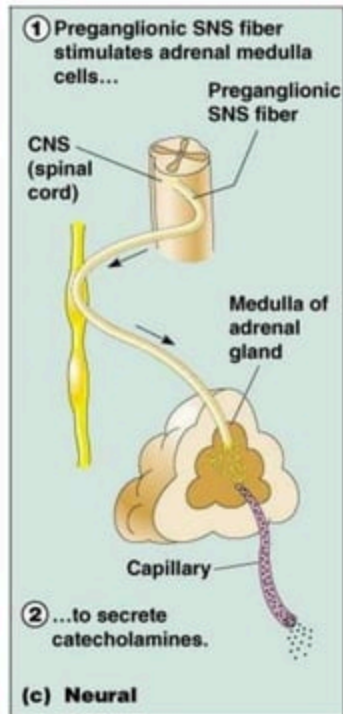
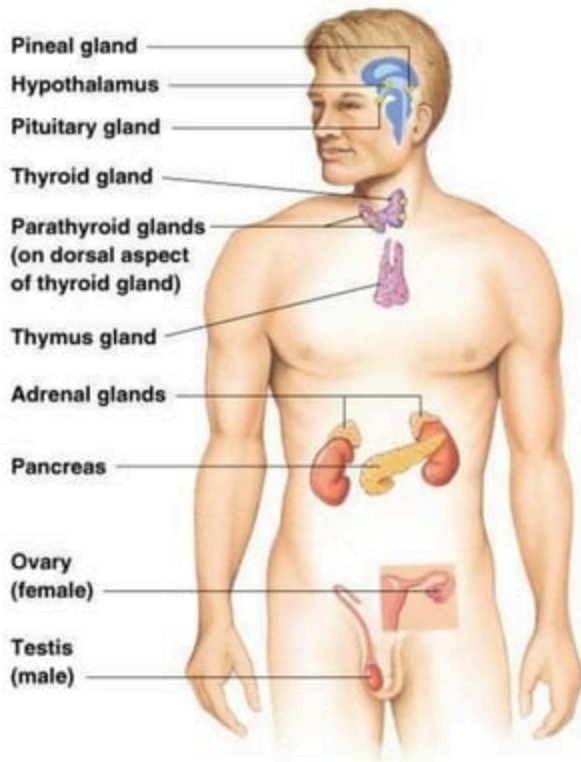


Figure 9.2c

Location of Major Endocrine Organs



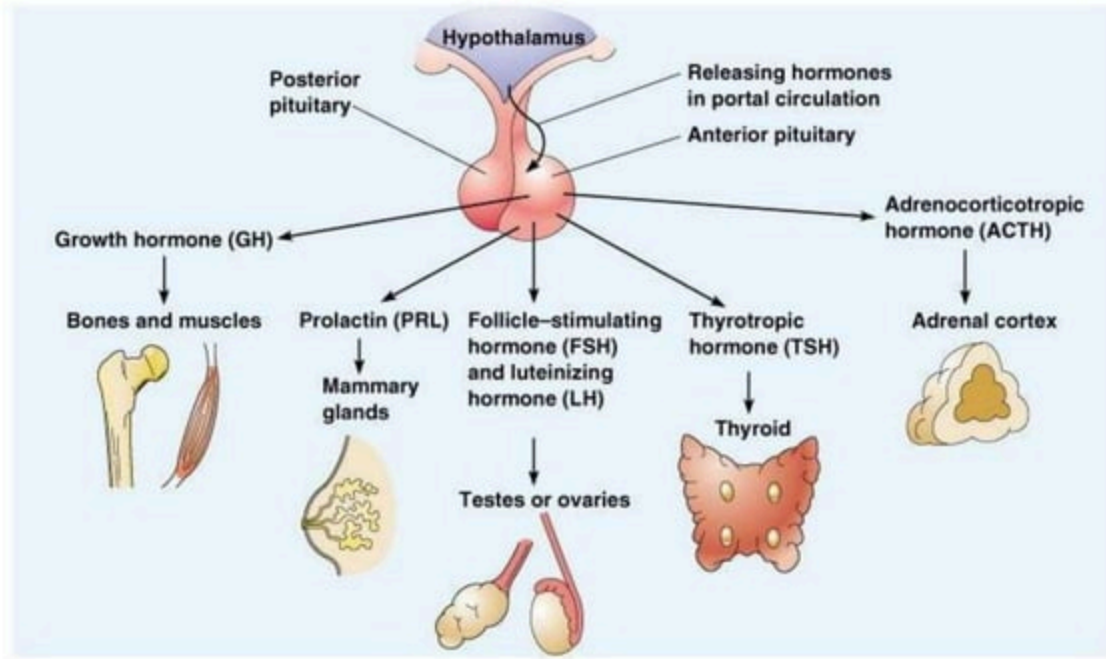
Pituitary Gland

- Size of a grape
- Hangs by a stalk from the hypothalamus
- Protected by the sphenoid bone
- Has two functional lobes
 - Anterior pituitary – glandular tissue
 - Posterior pituitary – nervous tissue

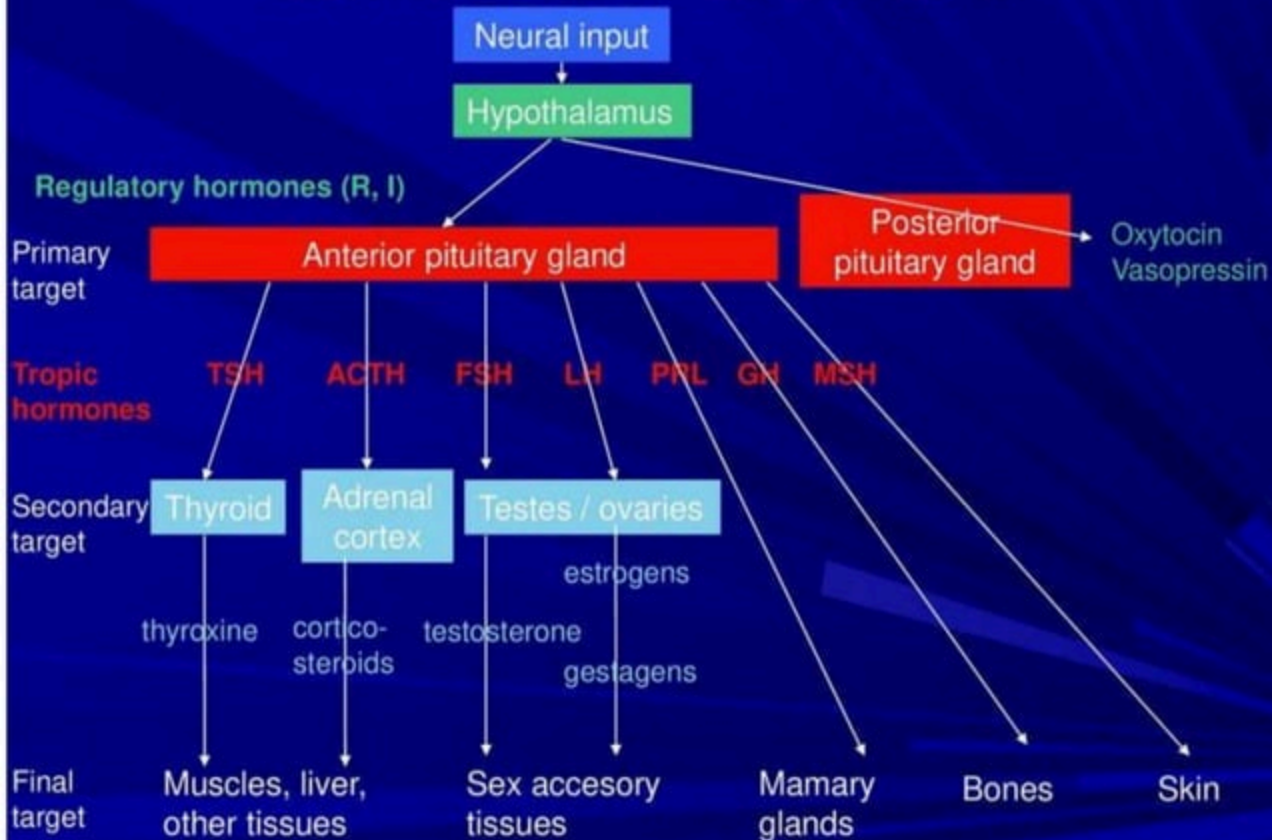
Hormones of the Anterior Pituitary

- Six anterior pituitary hormones
 - Two affect non-endocrine targets
 - Four stimulate other endocrine glands (tropic hormones)
- Characteristics of all anterior pituitary hormones
 - Proteins (or peptides)
 - Act through second-messenger systems
 - Regulated by hormonal stimuli, mostly negative feedback

Hormones of the Anterior Pituitary



NEUROENDOCRINE RELATIONSHIP



MUTUALLY EXCLUSIVE RELATIONSHIP OF ENDOCRINE SYSTEM

Nervous impulse

Hypothalamus

Releasing hormones
(liberins)

Pituitary gland

Pituitary gland
hormones
(tropic hormones)

Peripheral
glands

Specific
hormones

Peripheral
organs/
cells

Short feed-back

Long feed-back

Metabolites:

- Glucose
- Aminoacids
- Fatty acids, cholesterol
- Nucleotides, nucleosides
- Ca²⁺, Na⁺, K⁺, Cl⁻

Hypothalamus

3 hormonal families of the anterior lobe: Table 2.1 (ALL proteins)

TRH
GnRH
CRH

2.



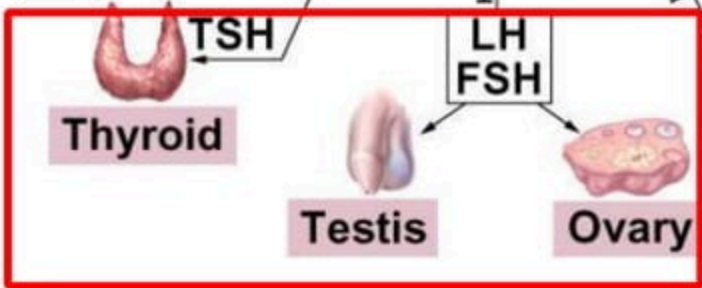
Mammary gland

Liver

IGF

Fat, muscle, bone

1.

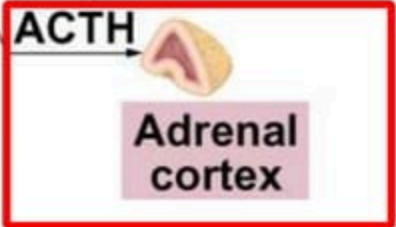


Thyroid

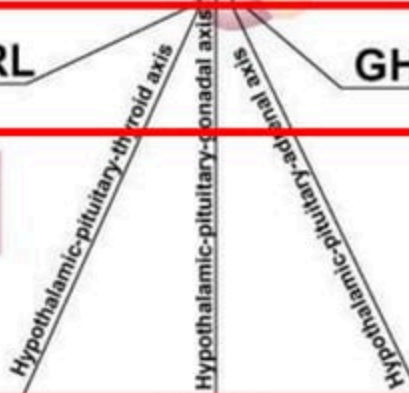
Testis

Ovary

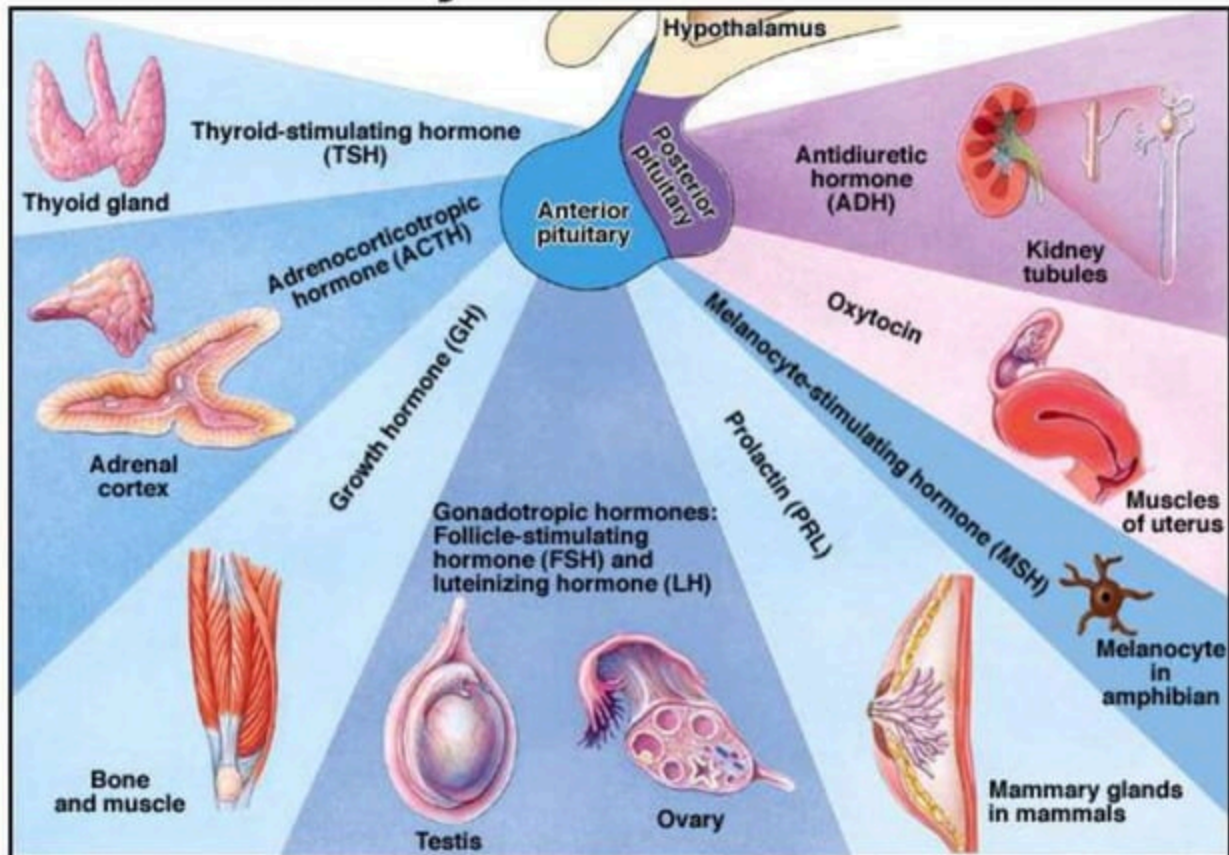
3.



Adrenal cortex



Pituitary Gland Hormones



§ Glycoprotein hormone family– TSH, FSH, LH

- 1. TSH**– to stimulate the secretion of thyroid hormone
- 2. FSH & LH**– important for the function of **the testes** and **the ovaries**

FSH– growth of ovarian follicles and formation of sperm

LH (in women)– induce ovulation and the formation of the corpus luteum;
stimulate the ovarian production of estrogen and progesterone

LH (in men)– stimulates the production of Testosterone;

§ Growth hormone and prolactin (Fig. 2.4)

- 1. Growth hormone (GH)** is required for proper adult stature.

Species specificity: primates for primate GH

Metabolic effects

- 2. Prolactin (PRL)** is required for milk production in post-partum women.

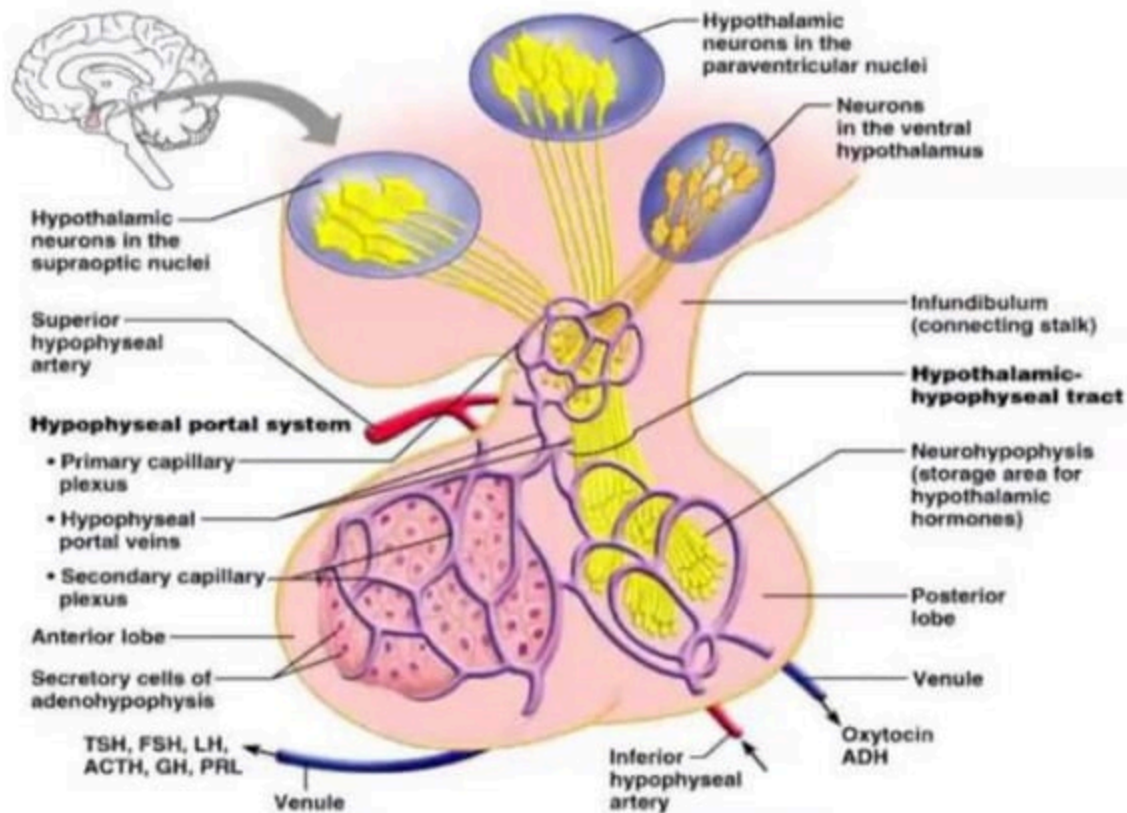
In men or nonlactating women-- not clear; however, evidence suggests it **may has to do** with the immune function.

- 3. Human pracental lactogen (HPL) = human chorionic somatomammotropin**

§ Dopamine and control of prolactin secretion

1. **Dopamin** (an amine) is a prolactin inhibitory factor which can inhibit PRL secretion
2. Dopamine is synthesized in tuberohypophyseal neurons
3. PRL releasing hormone's existence is unclear

Relationship of the pituitary gland & Hypothalamus



Growth Hormone (GH)

- General metabolic hormone
- Major effects are directed to growth of skeletal muscles and long bones
- Causes amino acids to be built into proteins
- Causes fats to be broken down for a source of energy

Functions of Other Anterior Pituitary Hormones

- Prolactin (PRL)
 - Stimulates and maintains milk production following childbirth
 - Function in males is unknown
- Adrenocorticotrophic hormone (ACTH)
 - Regulates endocrine activity of the adrenal cortex
- Thyroid-stimulating hormone (TSH)
 - Influences growth and activity of the thyroid

Functions of Other Anterior Pituitary Hormones

- Gonadotropic hormones
 - Regulate hormonal activity of the gonads
 - Follicle-stimulating hormone (FSH)
 - Stimulates follicle development in ovaries
 - Stimulates sperm development in testes

Functions of Other Anterior Pituitary Hormones

- Gonadotropic hormones (continued)
 - Luteinizing hormone (LH)
 - Triggers ovulation
 - Causes ruptured follicle to become the corpus luteum
 - Stimulates testosterone production in males
 - Referred to as interstitial cell-stimulating hormone (ICSH)

Pituitary - Hypothalamus Relationship

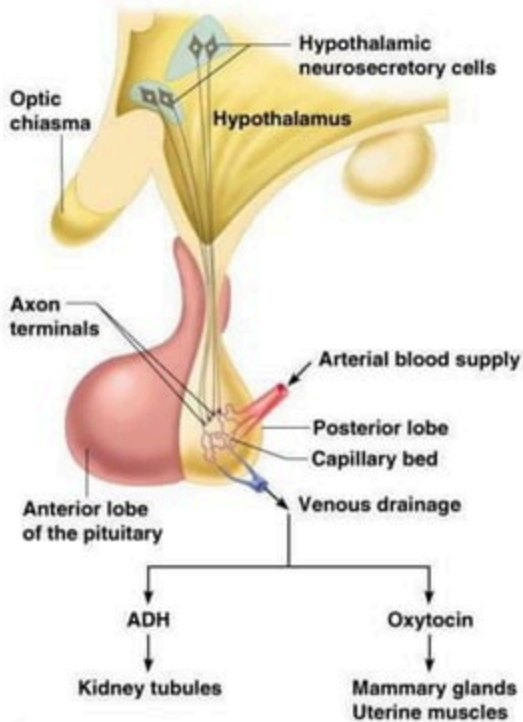
- Release of hormones is controlled by releasing and inhibiting hormones produced by the hypothalamus
- Hypothalamus produces two hormones that are transported to neurosecretory cells of the posterior pituitary
- The posterior pituitary is not strictly an endocrine gland, but does release hormones

Hormones of the Posterior Pituitary

- Oxytocin
 - Stimulates contractions of the uterus during labor
 - Causes milk ejection
- Antidiuretic hormone (ADH)
 - Can inhibit urine production
 - In large amounts, causes vasoconstriction leading to increased blood pressure (vasopressin)

Note: alcohol consumption inhibits ADH secretion

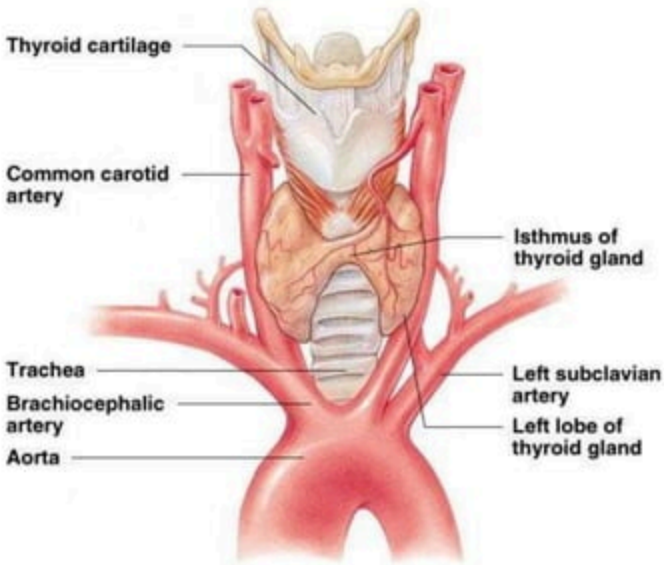
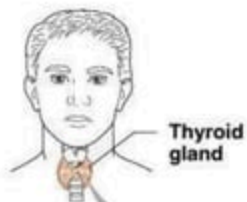
Hormones of the Posterior Pituitary



Thyroid Gland

- Found at the base of the throat
- Consists of two lobes and a connecting isthmus
- Produces two hormones
 - Thyroid hormone
 - Calcitonin

Thyroid Gland

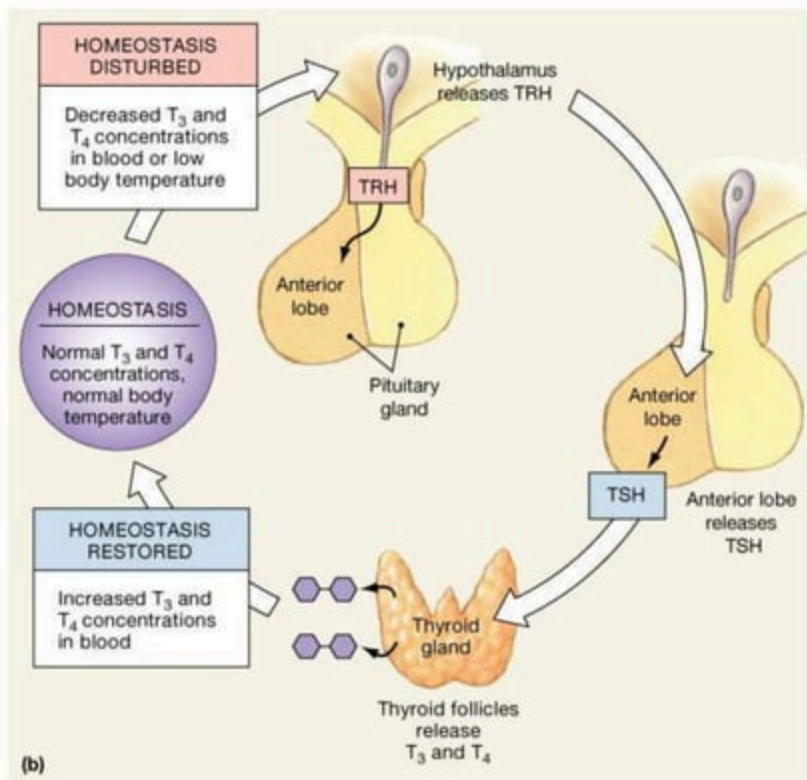


(a)

Thyroid Hormone

- Major metabolic hormone
- Composed of two active iodine-containing hormones
 - Thyroxine (T_4) – secreted by thyroid follicles
 - Triiodothyronine (T_3) – conversion of T_4 at target tissues

Thyroid Follicles



One Major Advantage of this System

The thyroid gland is capable of storing **many weeks worth of thyroid hormone** (coupled to thyroglobulin).

If no iodine is available for this period, thyroid hormone secretion will be maintained.

Calcitonin

- Decreases blood calcium levels by causing its deposition on bone
- Antagonistic to parathyroid hormone
- Produced by C (parafollicular) cells

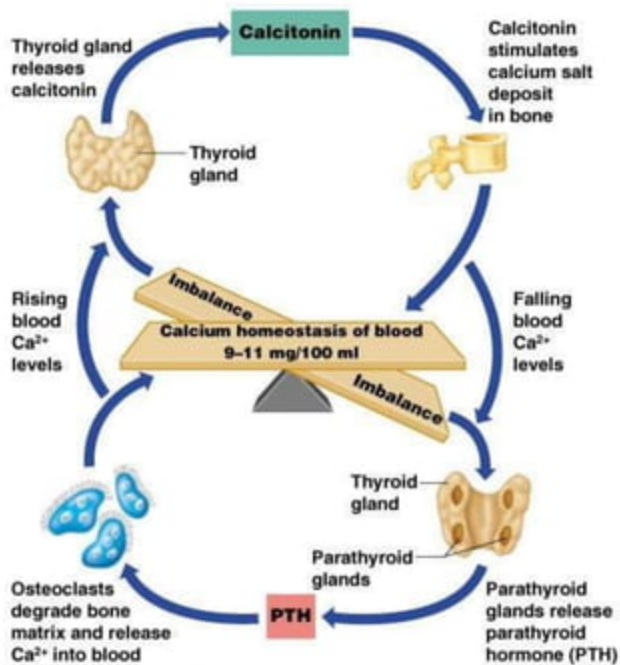


Figure 9.9

Parathyroid Glands

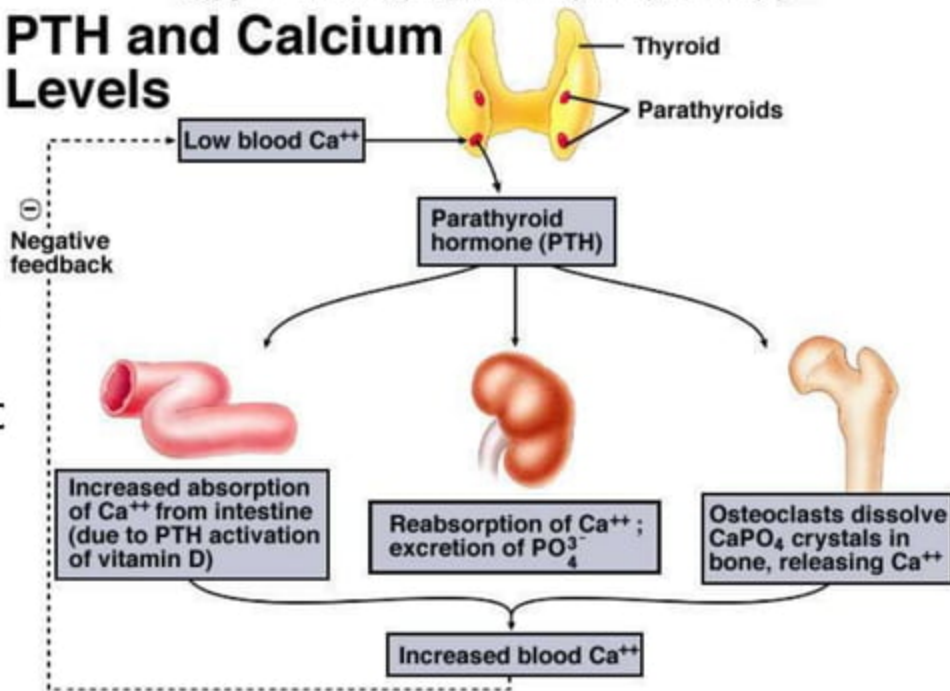
-Make parathyroid hormone (PTH): vital to maintain Ca^{+2} level in body

-Can influence Ca^{+2} reabsorption

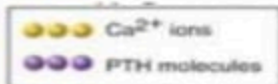
in kidney, Ca^{+2} release from bone, and absorptive of Ca^{+2} in small intestine.

PTH and Calcium Levels

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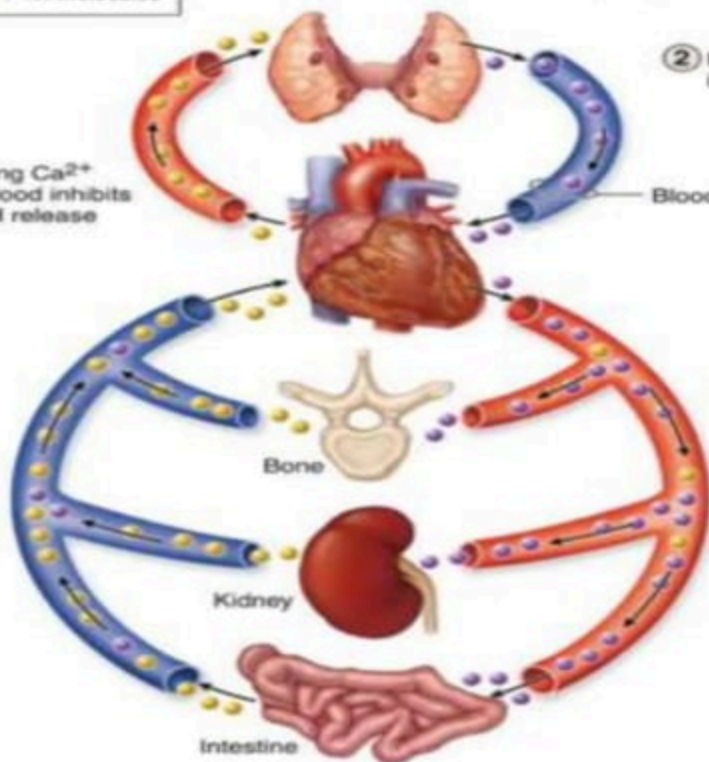
Blood Ca level regulation



① Low blood calcium (Ca^{2+}) levels detected by the parathyroid gland

② Parathyroid hormone (PTH) is secreted into bloodstream

④ Rising Ca^{2+} in blood inhibits PTH release



③ Target organs that respond to PTH, or its effects:

- Osteoclasts resorb bone tissue.
- Kidney retains Ca^{2+} and promotes activation of an inactive form of Vitamin D to calcitriol, an active form of Vitamin D.
- Small intestine increases absorption of more Ca^{2+} under the influence of calcitriol.

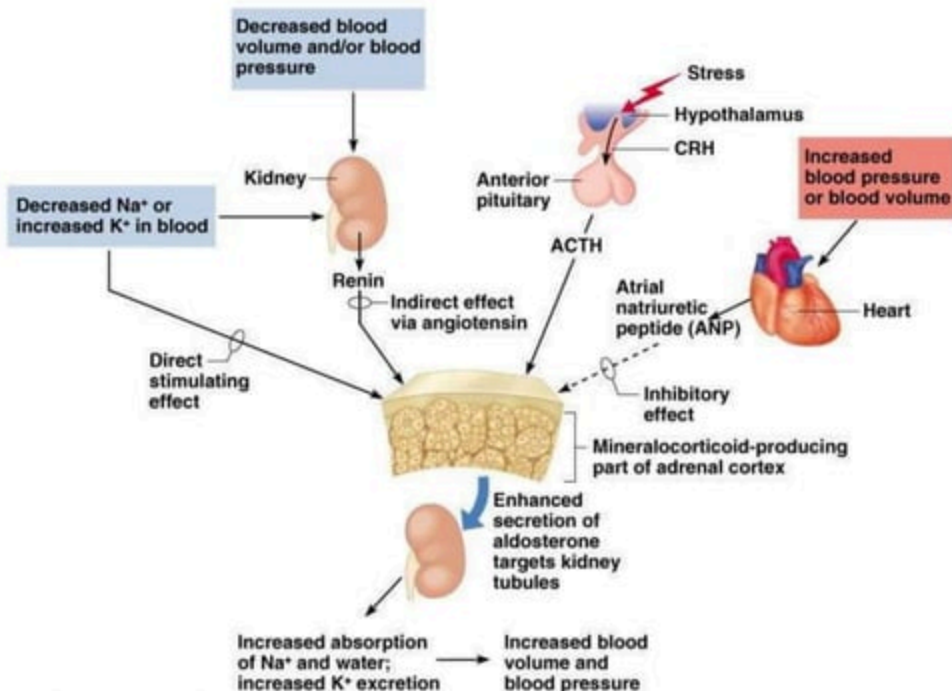
Adrenal Glands

- Two glands
 - Cortex – outer glandular region in three layers
 - Medulla – inner neural tissue region
- Sits on top of the kidneys

Hormones of the Adrenal Cortex

- Mineralocorticoids (mainly aldosterone)
 - Produced in outer adrenal cortex
 - Regulate mineral content in blood, water, and electrolyte balance
 - Target organ is the kidney
 - Production stimulated by renin and aldosterone
 - Production inhibited by atrial natriuretic peptide

Hormones of the Adrenal Cortex



Hormones of the Adrenal Cortex

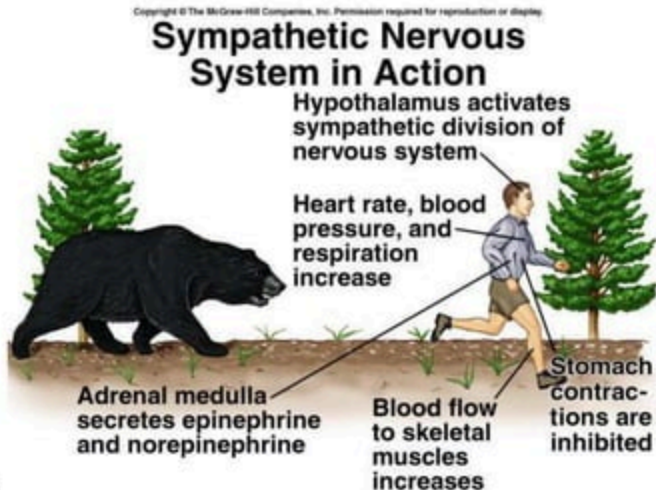
- Glucocorticoids (including cortisone and cortisol)
 - Produced in the middle layer of the adrenal cortex
 - Promote normal cell metabolism
 - Help resist long-term stressors
 - Released in response to increased blood levels of ACTH

Hormones of the Adrenal Cortex

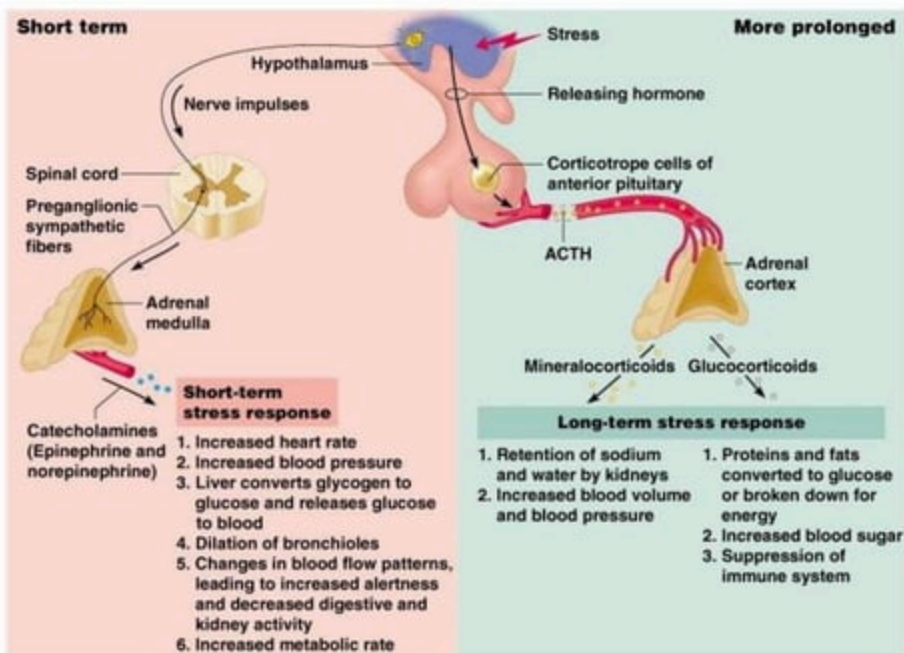
- Sex hormones
 - Produced in the inner layer of the adrenal cortex
 - Androgens (male) and some estrogen (female)

Hormones of the Adrenal Medulla

- Produces two similar hormones (catecholamines)
 - Epinephrine
 - Norepinephrine
- These hormones prepare the body to deal with short-term stress



Roles of the Hypothalamus and Adrenal Glands in the Stress Response



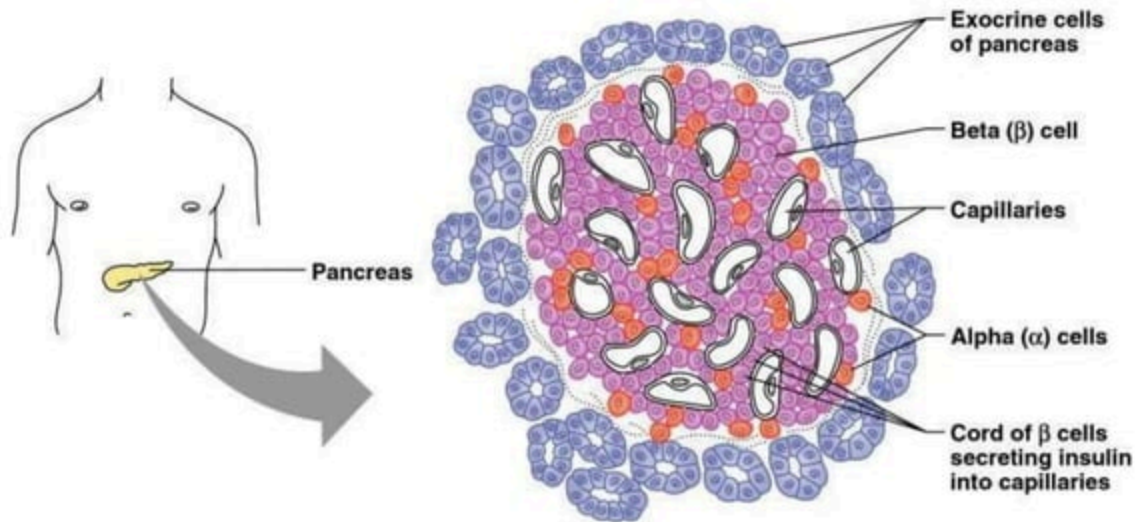
Pancreatic Islets

- The pancreas is a mixed gland
- The islets of the pancreas produce hormones
 - Insulin – allows glucose to cross plasma membranes into cells from beta cells
 - Glucagon – allows glucose to enter the blood from alpha cells
 - These hormones are antagonists that maintain blood sugar homeostasis

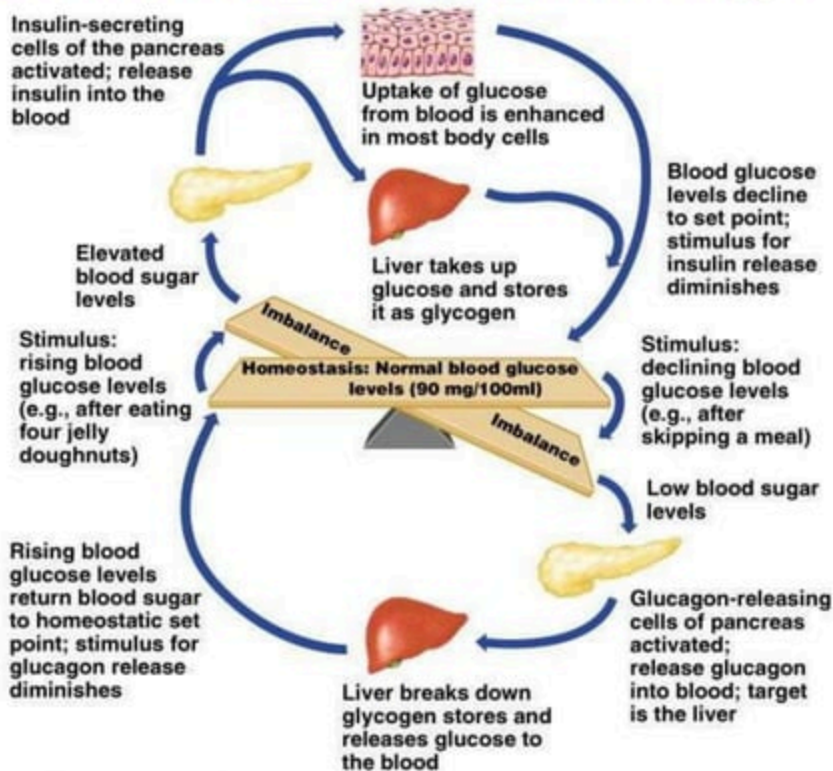
Pancreas

- **Alpha cells** secrete **glucagon** when blood glucose levels drop.
- **Beta cells** secrete **insulin** when blood glucose levels are **elevated**.
- **Delta cells** are stimulated by high levels of nutrients in the bloodstream.
 - synthesize **somatostatin**, also described as growth hormone-inhibiting hormone, or **GHIH**, which **slows** the release of insulin and glucagon and slows the rate of nutrient entry into the bloodstream
- **F cells** are stimulated by protein digestion.
 - secrete pancreatic polypeptide to suppress and regulate somatostatin secretion from delta cells
- **Pancreatic hormones provide for orderly uptake and processing of nutrients.**

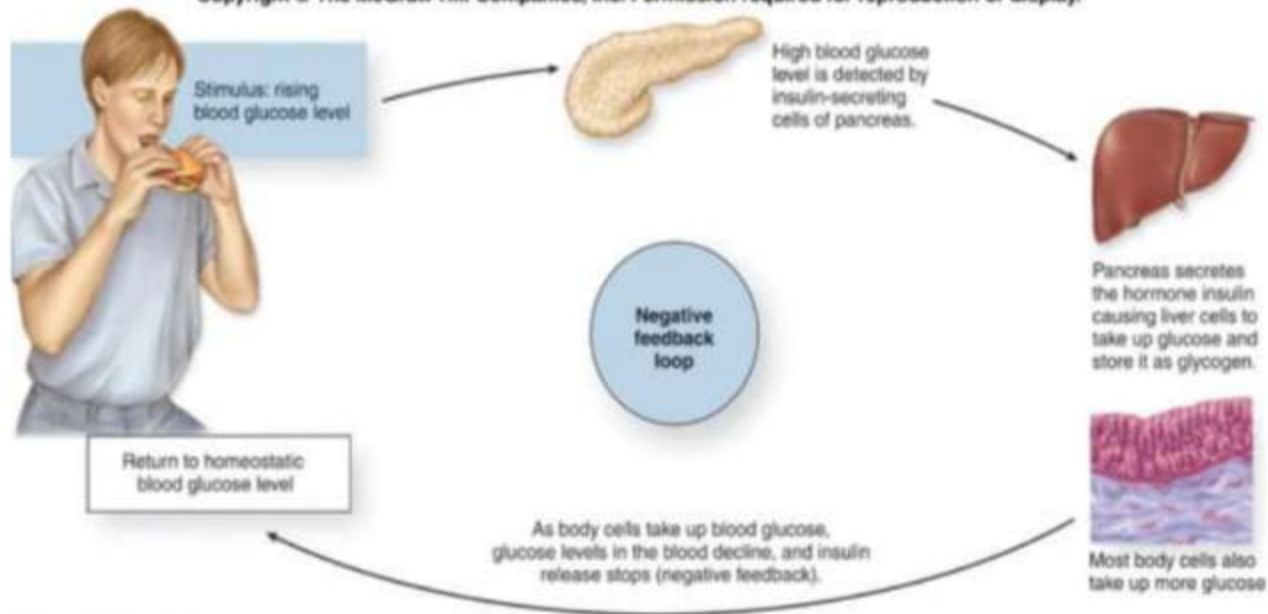
Pancreatic Islets



Pancreatic Hormones and Blood Sugar



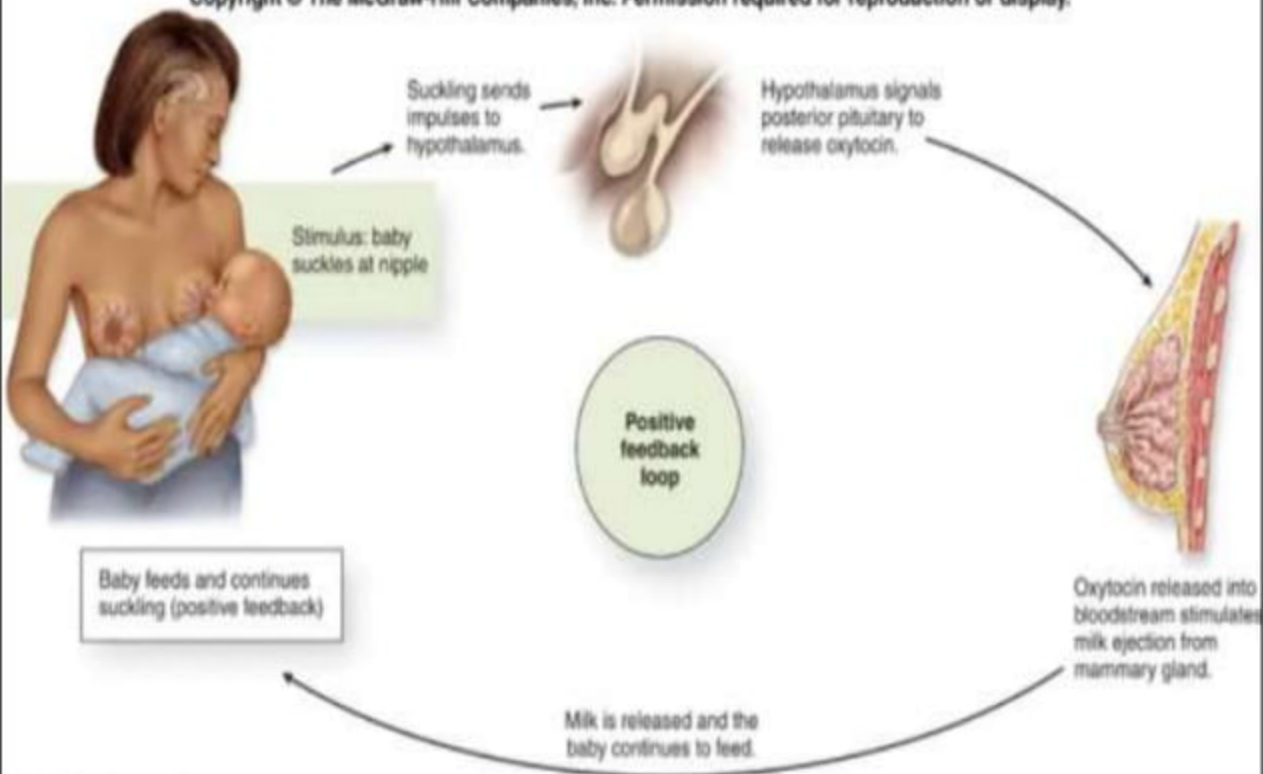
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(a) Negative feedback

Positive Feedback Loop

- Called positive because it accelerates the original process
 - can ensure that the pathway continues to run
 - can speed up its activities.
- Few positive feedback loops in the human endocrine system.
 - Example: milk release from the mammary glands



Pineal Gland

- Found on the third ventricle of the brain
- Secretes melatonin
 - Helps establish the body's wake and sleep cycles, or circadian rhythm (24-hour body clock)
 - Also appears to affect the synthesis of the hypothalamic regulatory hormone responsible for FSH and LH synt
 - Role in sexual maturation is not well understood

Thymus

Thymus

- Located posterior to the sternum
- Largest in infants and children
- Produces thymosin and thymopoietin
 - hormones act by stimulating and promoting the differentiation, growth and maturation of category of lymphocytes called T-lymphocytes (thymus derived lymphocytes)
 - Functions in association with the lymphatic system to regulate and maintain body immunity

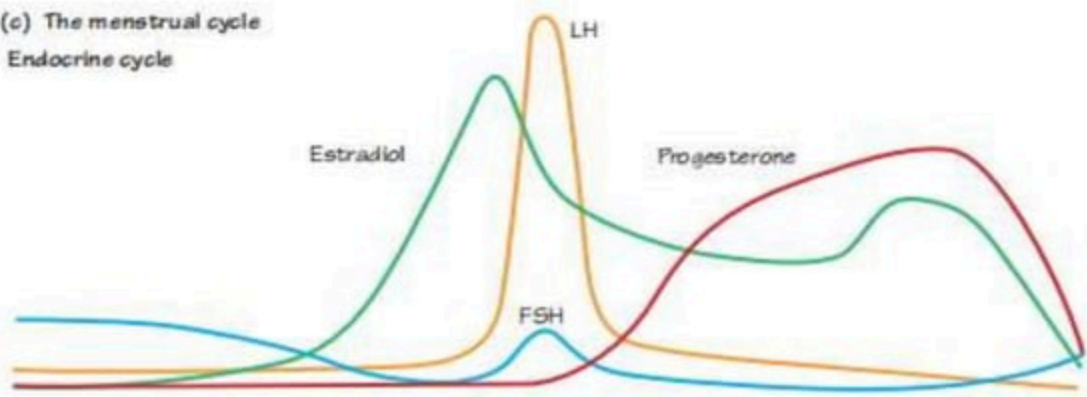
Hormones of the Ovaries

- Estrogens
 - Produced by Graafian follicles or the placenta
 - Stimulates the development of secondary female characteristics
 - Matures female reproductive organs
 - Helps prepare the uterus to receive a fertilized egg
 - Helps maintain pregnancy
 - Prepares the breasts to produce milk

Hormones of the Ovaries

- Progesterone
 - Produced by the corpus luteum
 - Acts with estrogen to bring about the menstrual cycle
 - Helps in the implantation of an embryo in the uterus

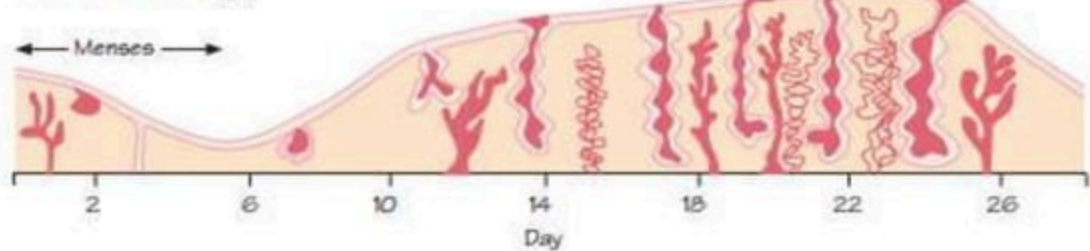
(c) The menstrual cycle
Endocrine cycle



Ovarian morphology



Endometrial histology



Hormones of the Testes

- Interstitial cells of testes are hormone-producing
- Produce several androgens
- Testosterone is the most important androgen
 - Responsible for adult male secondary sex characteristics
 - Promotes growth and maturation of male reproductive system
 - Required for sperm cell production

Other Hormone-Producing Tissues and Organs

- Parts of the small intestine
- Parts of the stomach
- Kidneys
- Heart
- Many other areas have scattered endocrine cells

Endocrine Function of the Placenta

- Produces hormones that maintain the pregnancy
- Some hormones play a part in the delivery of the baby
- Produces HCG in addition to estrogen, progesterone, and other hormones

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)

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^{++}

Developmental Aspects of the Endocrine System

- Most endocrine organs operate smoothly until old age
 - Menopause is brought about by lack of efficiency of the ovaries
 - Problems associated with reduced estrogen are common
 - Growth hormone production declines with age
 - Many endocrine glands decrease output with age