Endocrine System

General Characteristics

- The nervous system and the endocrine system are the two **major regulatory systems** in the body. Together they regulate and coordinate the activity of essentially all other bodily structures ➔ they are major players in maintaining homeostasis.
- The term "**endocrine**" is derived from the Greek words ***endo*** (within) and ***crino*** (to separate)
- The endocrine system is composed of **glands** that secrete their products into the **circulatory system**.
- Products are **intercellular chemical messengers** called **hormones** (Greek ***hormon*** which means "to set in motion").
- **Hormones** act as signals that allow one cell type to communicate with other cell types:
  - Hormones are released into the interstitial fluid by specialized cells, diffuse into the blood and travel to **target tissues**, where they cause a specific response.

Communicating with Target Tissues

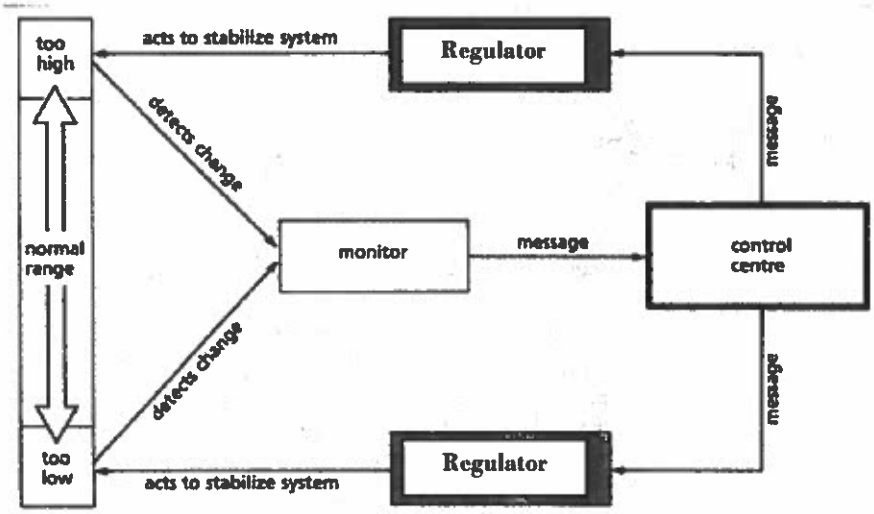
- In the nervous system, **neurons** send **frequency-regulated signals** in the form of all-or-none **action potentials**. The strength of the signal depends on the **frequency**, not the size, of the action potentials.
- The endocrine system communicates with its target tissues using **concentration-regulated signals** which consist of increases or decreases in the concentration of a hormone in the body fluids. A small concentration represents a weak signal and produces a small response, whereas a larger concentration represents a stronger signal and results in a greater response.
- The responses of the endocrine system are usually slower and of longer duration than those of the nervous system.

Chemical Structure of Hormones

- Steroid Hormones **(Lipid-soluble)**
  - ➔ Made from **cholesterol** (lipid compound).
  - ➔ Complex rings of carbon, hydrogen and oxygen molecules.
  - ➔ Soluble in fat → important because this means they can cross (diffuse across) the **phospholipid bilayer** of cell membranes.
  - ➔ Includes estrogen, progesterone, testosterone, aldosterone and cortisol.
- Protein Hormones **(Water-soluble)**
  - ➔ Contain chains of **amino acids**.
  - ➔ Soluble in water.
  - ➔ Includes insulin, growth hormone, and epinephrine.

Control of Secretion Rate

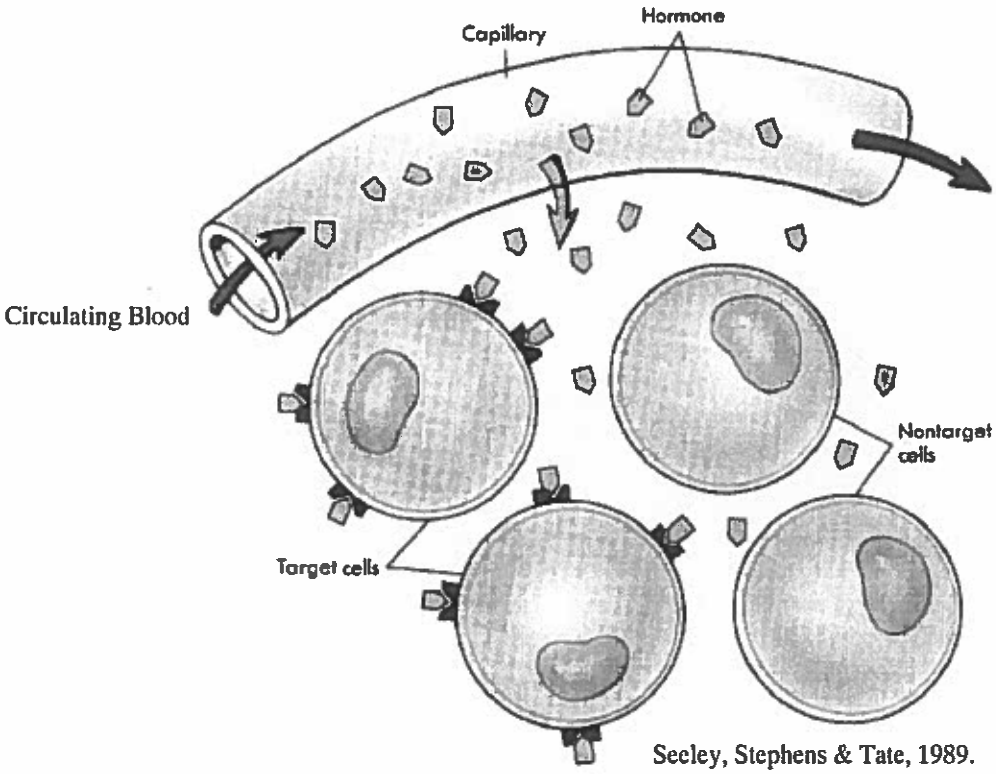
- Most hormones are not secreted at a constant rate → most endocrine glands increase or decrease their secretory activity over time.
- Most hormone secretion is controlled by **negative-feedback mechanisms** that function to maintain **homeostasis** (maintain hormone levels within normal concentration ranges).



- Hormone secretion from endocrine glands is regulated by one or more of 3 mechanisms:
    1. A non-hormone substance.
        - Involves the action of a substance other than a hormone on the endocrine gland.
        - Example: the concentration of glucose in the blood affects the rate of insulin secretion.
    2. Stimulation by the nervous system.
        - Neurons synapse with the cells that produce the hormone and when action potentials result, the neurons release a neurotransmitter that causes the endocrine cell to increase hormone secretion (or in some cases the neurotransmitter may be inhibitory).
        - Example: Epinephrine is released from the adrenal medulla in response to sympathetic stimulation (stressful stimuli).
    3. A hormone from another endocrine tissue.
        - Involves the control of the secretory activity of one endocrine gland by a hormone secreted by another endocrine gland.
        - Example: Thyroid releasing hormone (TRH) released from the hypothalamus, stimulates the release of thyroid stimulating hormone (TSH) from the anterior pituitary, which stimulates the release of thyroid hormones from the thyroid gland. The thyroid hormones will eventually inhibit TRH and TSH secretion.

Interaction of Hormones & Target Tissues

- Hormones bind to **receptors** in their target tissues and alter the rate at which certain activities occur.
- Hormones do not cause cells to do new things, but they do affect the **rate** at which target cells perform processes they can already do:
  - ✓ may activate or inactivate enzymes that already exist in the cytoplasm of target cells,
  - ✓ may alter the rate at which specific molecules are synthesized within cells, or
  - ✓ may alter membrane permeability.
- Hormone receptors are **protein molecules** that exist in specific three-dimensional shapes.
  - ➔ Unique shape and chemical composition allow receptors to be highly specific
- The presence or absence of specific receptor molecules in cells determines which cells will or will not respond to each hormone →i.e. determines which cells are the **target cells** for a specific hormone.



Seeley, Stephens & Tate, 1989.

Classes of Hormone Receptors

1. Membrane-bound receptors

➔ Bind to **water-soluble** or large molecular weight hormones (molecules that <u>can't</u> diffuse across phospholipid bilayer).

- protein hormones – ex. epinephrine, norepinephine and thyroid hormones.

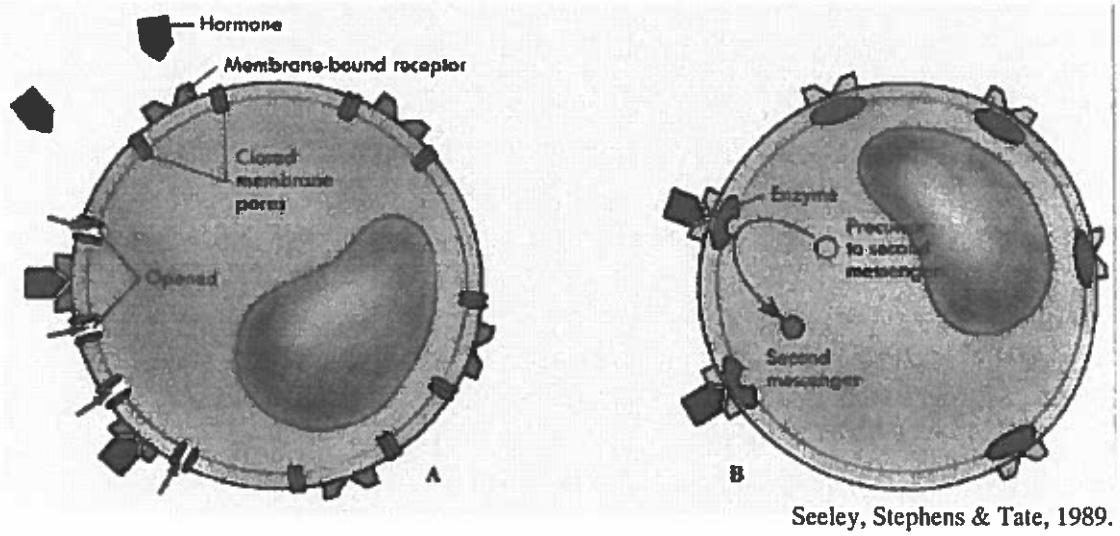
2. Intracellular receptors

➔ Bind to **lipid-soluble** hormones (molecules that can diffuse across phospholipid bilayer of cell membrane and enter the cytoplasm).

- steroid hormones – ex. male and female sex hormones and cortisol.

Membrane-Bound Receptors & the Second Messenger Model

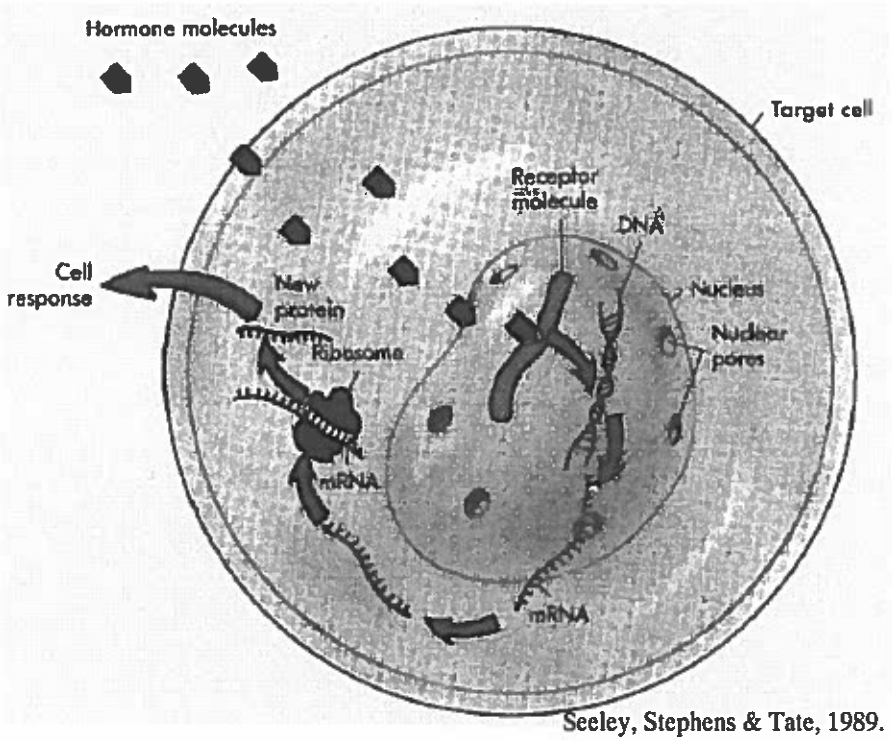
- Membrane-bound receptors are proteins located within the cell membrane.
- **Water-soluble (protein)** hormones in the **interstitial fluid** (fluid in between the cells) bind to the hormone receptor, and the combination of the hormone and receptor initiates a **response** in the target cells:
  - A. may cause a structural change in the cell membrane, resulting in a change in the membrane's **permeability**.
  - B. may lead to the activation of an enzyme within the membrane.
    - The activated enzyme catalyzes a reaction that produces a **second messenger** such as **cAMP** (the hormone is considered the first messenger).
    - The second messenger then alters the actions of enzymes, producing the response of the target cells to the hormone.
    - Second messenger mechanisms are rapid acting because they act on already existing enzymes.



Seeley, Stephens & Tate, 1989.

Intracellular Receptor Mechanism

- Intracellular receptors are protein molecules in the cytoplasm or nucleus of a target cell (*intra* – inside the cell).
- By the process of **diffusion**, **lipid-soluble hormones** (steroid hormones) cross the cell membrane into the cytoplasm.
- The hormones bind with the receptor molecules (either in cytoplasm or nucleus), and the receptor-hormone complex activates **DNA** (in the nucleus) to produce **mRNA** (messenger RNA).
- The mRNA leaves the nucleus, passes into the cytoplasm of the cell, and binds to **ribosomes**, where it directs the **synthesis** of specific proteins.
- The protein synthesized on the ribosomes produces the cell's response to the hormone.
- Intracellular receptor mechanisms are slow acting because time is required to produce the protein.



Seeley, Stephens & Tate, 1989.

Endocrine Glands

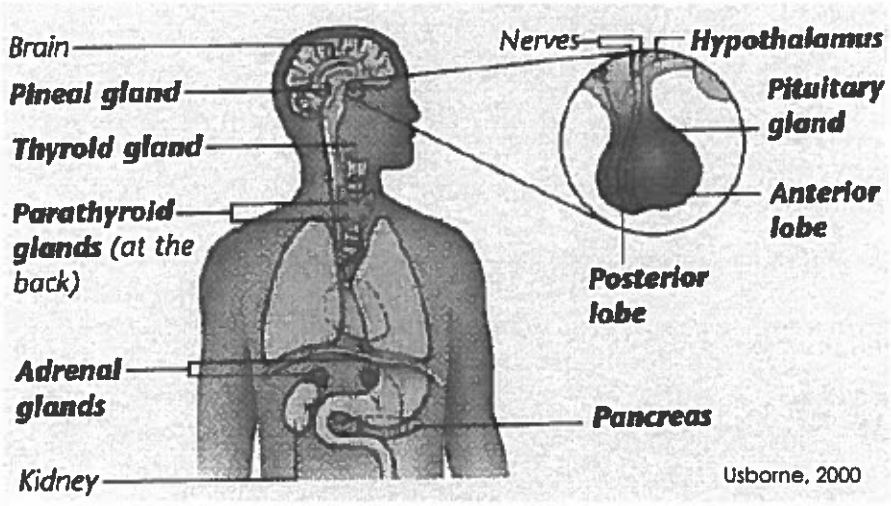
- **Glands** are special organs (groups of cells) which produce and secrete a variety of substances vital for life.
- There are two types of human glands:

1. Exocrine Glands
   - ➔ Glands which secrete substances through tubes, or ducts, onto a surface or into a cavity.
   - ➔ Most body glands are exocrine: ex. sweat glands, digestive glands.
2. Endocrine Glands
   - ➔ Glands which secrete substances called hormones directly into the blood (i.e. blood vessels in the glands)
   - ➔ The glands may be separate bodies (ex. pituitary gland, thyroid gland, adrenal glands) or cells inside organs (ex. in the sex organs).

Understanding the Role of Endocrine Glands and their Secretions

For each gland we will focus on the following:

1. The **structural** characteristics of each gland and its anatomy.
2. The **hormone(s)** secreted by each gland.
3. The **target tissues** and the **response** of target tissues to each hormone.
4. The means by which the secretion of each hormone is **regulated**.
5. The consequences and causes of **hypersecretion** and **hyposecretion** of the hormone.

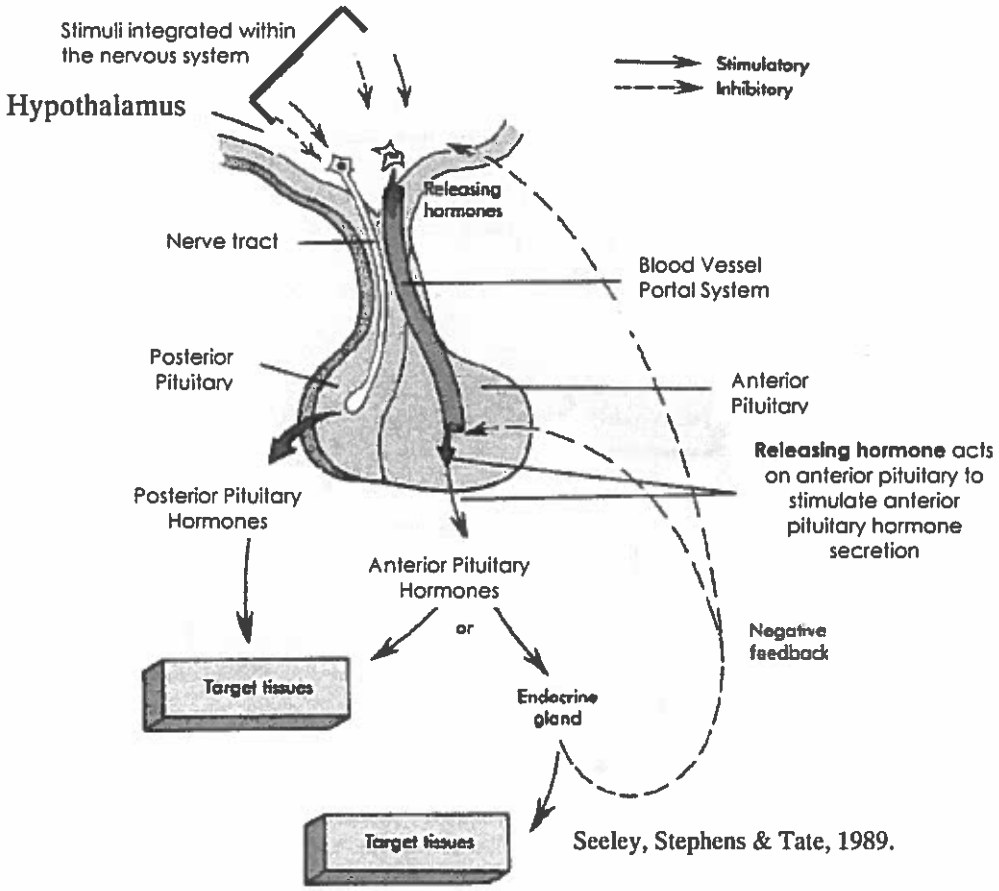


Pituitary Gland and Hypothalamus

- The hypothalamus and the pituitary are the key sites where the two major regulatory systems in the body (the nervous system and the endocrine system) interact → **Hypothalamus-pituitary complex.**
  - ➔ The hypothalamus of the brain regulates the secretory activity of the pituitary gland, and in turn, the activity of the hypothalamus is influenced by hormones, by sensory information that enters the central nervous system, and by the emotional state of the individual.

Did you know? *The term "hormonal" which is often used to describe people that are "emotional" actually has a biological basis! The strong link between the brain and the pituitary gland results in a connection between emotions and hormones!*

- Pituitary Gland is referred to as the "**MASTER GLAND**" because it not only produces its own hormones, but it also influences the hormonal production of the other glands.
- Hypothalamus is the area of brain associated with **Homeostasis.** Its major function is to relay impulses and stimuli between the brain and organs. It does this by receiving certain of the chemical transmitter substances released by the nerve cells of the brain, and in response to the trigger, releases hormones.



Seeley, Stephens & Tate, 1989.

Location and Structure of the Pituitary Gland

- Located in the base of the brain, below the hypothalamus.
- Pituitary gland is divided into two parts: **posterior pituitary** and **anterior pituitary**

Posterior Pituitary Hormones

- Connected to the hypothalamus by a stalk of nervous tissue which allows **neurohormones** (a hormone secreted by a neuron) to be sent from the hypothalamus to the posterior pituitary.
- Stores and releases two **neurohormones** which have been **produced** by the **hypothalamus**.

1. Antidiuretic Hormone (ADH)

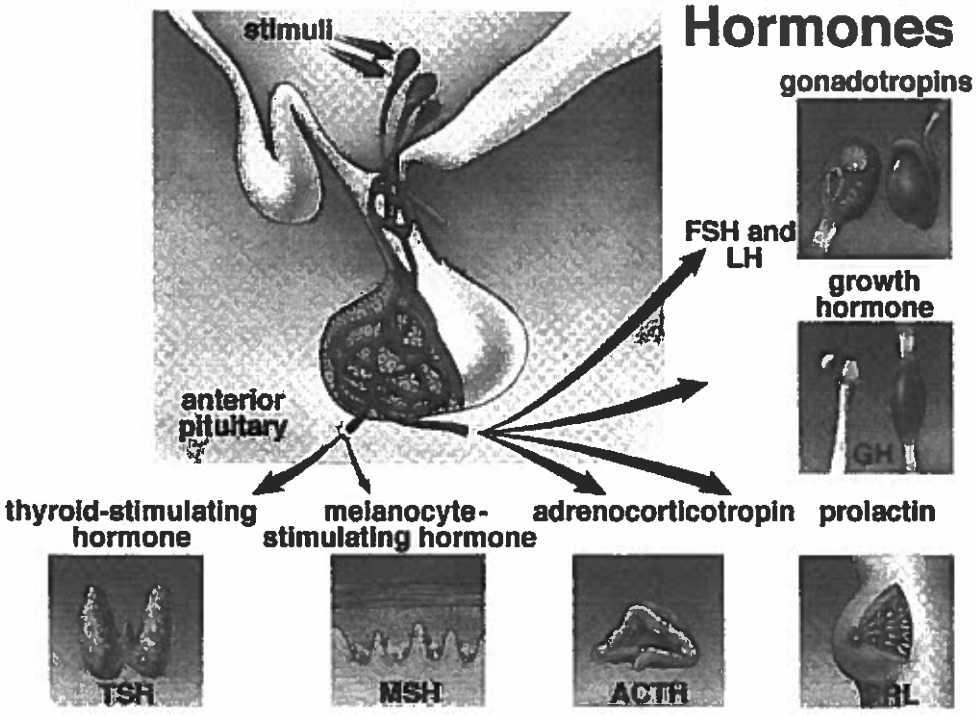
- ADH is synthesized in the hypothalamus and is transported within the stalk to the posterior pituitary for storage.
- ADH is released from the pituitary under the direct control of nerve impulses generated in the hypothalamus (when the hypothalamus receives appropriate messages about the state of the body).
- Released into blood and is carried to its target tissue – the **kidneys** – where it acts on the tubules of the kidney, affecting their ability to reabsorb water → increased water **reabsorption** (less water is lost in the urine) → restores blood volume.
    - Stimulates the distal convoluted tubule to become more permeable to water → more water is extracted out of the urine and retained in the body.
- Secretion rate for ADH changes in response to alterations in blood osmolality and blood volume. Specialized neurons, **osmoreceptors**, synapse with the ADH neurosecretory cells in the hypothalamus.
    - When blood osmolality increases, the frequency of action potentials in the osmoreceptors increases, causing an increase in action potential frequency in the neurosecretory cells. Consequently, ADH secretion increases.
    - **Baroreceptors**: A drop in BP, which normally accompanies a drop in blood volume, causes increased action potential frequency in the neurosecretory cells and increased ADH secretion.
- The inability to secrete ADH leads to the production of a large volume of dilute urine. This condition is called **diabetes insipidus** and dehydration results unless water consumption is increased dramatically.

2. Oxytocin

- Synthesized in the hypothalamus and is transported within the stalk to the posterior pituitary for storage.
- Stimulates the smooth-muscle wall cells of the uterus and plays an important role in the expulsion of the fetus from the uterus during delivery.
- Increases milk expulsion (let down) from the mammary glands.
- Role in males is unclear.
- Stretch of the uterus or mechanical stimulation of the cervix causes oxytocin release due to a nervous reflex.

Anterior Pituitary Hormones

- Secretions of the Anterior Pituitary are influenced by neurohormones that pass from the hypothalamus through the blood vessel portal system to the anterior pituitary.
- The hypothalamus neurohormones act as **releasing hormones** that cause an increase in the secretion of anterior pituitary hormones or as **inhibiting hormones** that cause a decrease.
- Hormones released from AP are **proteins** or protein derivatives and they are transported in the circulatory system without binding to specific plasma proteins, have a half-life measured in terms of minutes, and bind to membrane-bound receptor molecules on their target cells.



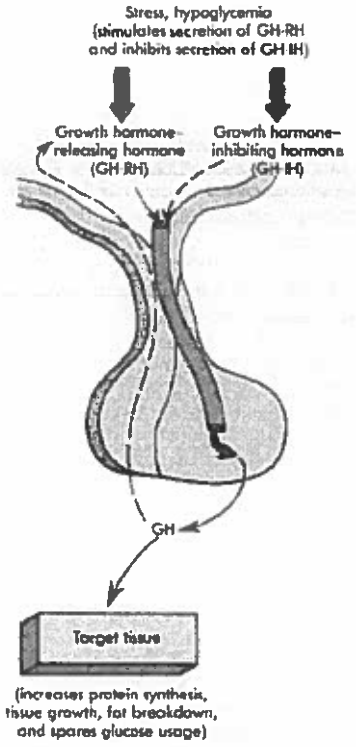
1. Growth Hormone (GH)

"You seen that weedy little rat we inoculated with the new growth hormone yesterday afternoon...?"

- aka **somatotropin**.
- Target tissue – most tissues
- Stimulates growth in **most tissues** and is one of the major regulators of metabolism.
- Increases the number of amino acids entering cells and favors their incorporation into proteins
- Increases the breakdown of lipids and the release of fatty acids from fat cells – fatty acids then used as energy sources.
- Increases glycogen synthesis and storage in tissues.
- Plays an important role in regulating blood nutrient levels following a meal and during periods of fasting.
- Peak release during deep sleep
- Heavy exercise leads to increased release of GH

REGULATION:

- Two neurohormones released from the **hypothalamus** regulate the secretion of GH:



Seeley, Stephens & Tate, 1989.

1. **Growth hormone-releasing hormone (GH-RH)**
   - Stimulates the secretion of GH
   - Secretion of GH is stimulated by low blood glucose levels and stress
   - GH inhibits the release of GH-RH
2. **Growth hormone-inhibiting hormone (GH-IH)**
   - Inhibits the secretion of GH
   - Secretion of GH is inhibited by high blood glucose levels.

DISORDERS:

These girls are sisters. The girl on the left lacked growth hormone. In this picture she was 18 cm shorter than her sister, despite being one and a half years older.

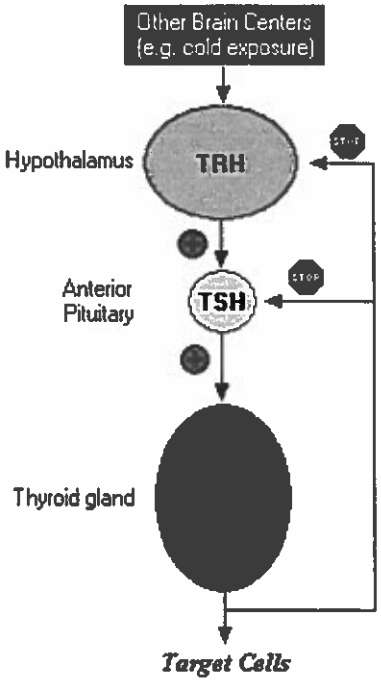
- Causes for **hypersecretion** or **hyposecretion** of GH involve tumors in the hypothalamus or the pituitary, the synthesis of structurally abnormal GH, the inability of the liver to produce somatomedins, or the lack of receptor molecules in the target cells.
- **Chronic <u>hyposecretion</u> of GH**:
  - in infants and children leads to **dwarfism** in which the stature is short due to delayed bone growth, but the bones are usually normally shaped.
  - Other symptoms due to lack of GH include mild obesity and retarded development of the adult reproductive functions.

Did you know? *The gene responsible for determining the structure of GH has been successfully transferred from human cells to bacterial cells, which produce GH that is identical to human GH. The GH produced by the bacteria is now available to treat patients who suffer from a lack of GH secretion.*

- **Chronic hypersecretion of GH**: leads to one of 2 conditions depending on whether the hypersecretion occurs before or after complete ossification of the epiphyseal plates in the skeletal system.-
  - BEFORE - **Gigantism** – prolonged growth in long bones resulting in heights of 8 feet or more!
  - AFTER - **Acromegaly** – in adults, no height increase, but does result in an increased diameter of fingers, toes, hands, and feet, the deposition of heavy bony ridges above the eyes, and prominent jaw.
  - B/c GH spares glucose usage chronic hyperglycemia results, which can lead to diabetes mellitus and the development of serve atherosclerosis.
  - Treatment of chronic hypersecretion of GH often involves surgical removal or irradiation of the GH-producing tumor.

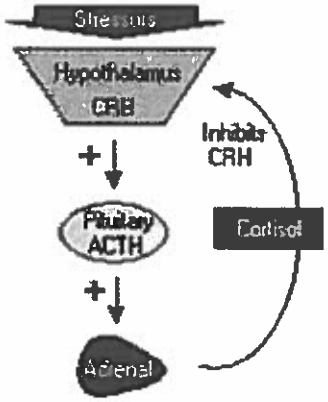
2. Thyroid-Stimulating Hormone (TSH)

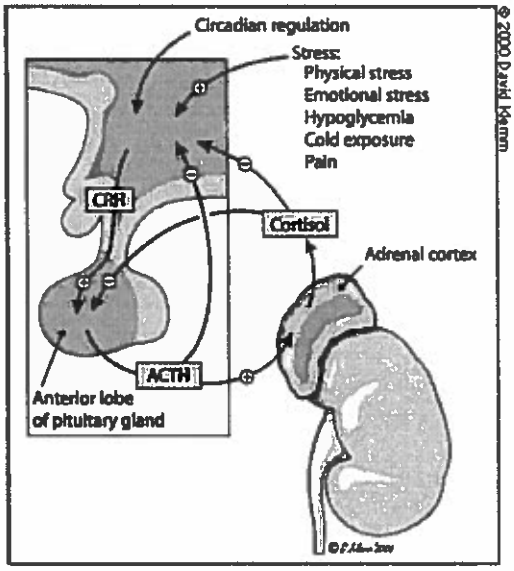
- Target tissue – thyroid gland.
- Released from the anterior pituitary into the blood and stimulates the synthesis and secretion of thyroid hormones (**thyroxine**) from the thyroid gland.



3. Adrenocorticotropic Hormone (ACTH)

- Target tissue – adrenal cortex
- Functions to increase the secretion of hormones, primarily **cortisol**, from the cortex of the adrenal glands.
- ACTH secretions increase in response to stress and exercise.



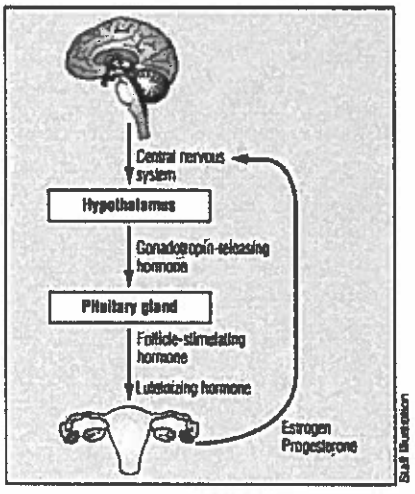


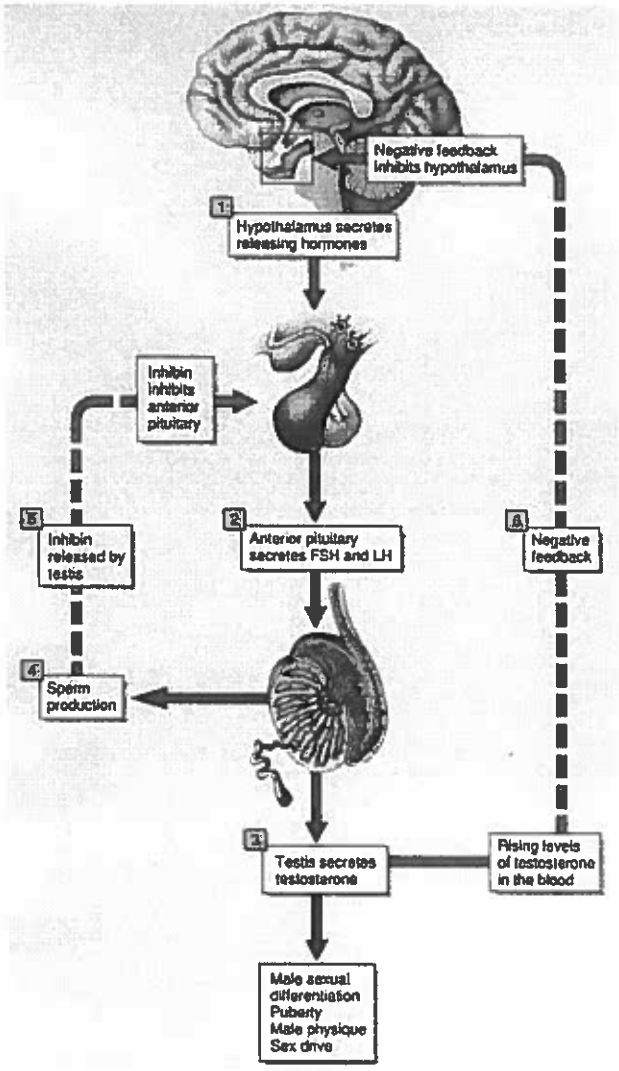
4. Melanocyte-stimulating Hormone (MSH)

- Target tissue – melanocytes in the skin
- Binds to skin melanocytes and stimulates increased melanin deposition in the skin.
- Stimulates the production of pigment-producing cells in the skin, hair and inside of the eyes.

5. Gonadotrophic Hormones

- **Trophic hormones** are released from the pituitary gland and regulate the secretion of hormones from other glands.
- Work to stimulate the development of the gonads.
- play an important role in regulating reproduction.
- Two hormones:
  - Luteinizing Hormone (LH)
    - Target tissue – ovary in females, testes in males
    - Ovulation (monthly release of the eggs in the ovaries) and progesterone production in the ovary
    - Testosterone synthesis and support for sperm production in the testes
  - Follicle-stimulating Hormone (FSH)
    - Target tissue – follicles in ovary in females and seminiferous tubes in males.
    - Follicle maturation and estrogen secretion in ovary
    - Spermatogenesis in testes.
- **LH** and **FSH** secreted into the blood bind to membrane-bound receptors and function to regulate the production of gametes (eggs and sperm) and reproductive hormones in the ovary (estrogens and progesterones) of females and in the testes (testosterone) of males.
- **LH** and **FSH** are released from the AP cells under the influence of a single hypothalamus releasing hormone – **gonadotropin-releasing hormone (GnRH).**





6. Prolactin

- Target tissue – ovary and mammary gland in females.
- Important role in milk production in the mammary gland of lactating females
- Unclear function in males.
- Prolactin-releasing hormone (PRH) and prolactin-inhibiting hormone (PIH) from the hypothalamus affect prolactin secretion.

Thyroid Gland

Location & Structure

- Found in the neck, just below the level of the larynx.
- Composed of two lobes connected by a narrow band of thyroid tissue which lie in front and at either side of the trachea as it passes down the front side of the neck.
- Thyroid **follicles** – islands of tissue containing collections of colloid, a protein substance to which thyroid hormone is bound and from which it can be released by enzymes.
- Contains **iodine** that is vital for its activity – an absence of iodine in the diet results in malfunction of the thyroid and the growth of the gland (**endemic goiter**).

Function

- To make the thyroid hormone – **thyroxine.**

Thyroxine

- Amino acid derivative – non polar and lipid soluble
- Iodine containing hormone
- Target tissues – most cells of the body
- Increased metabolic rate - increases the rate of cellular respiration so that more oxygen consumption occurs
- Essential for normal process of maturation
- **Thyroid-Stimulating Hormone (TSH)** (from anterior pituitary) must be present to maintain thyroid hormone synthesis and secretion. TSH binds to membrane-bound receptors on the cells of the thyroid follicles, and a second messenger molecule mediates the response of thyroid cells to TSH.
- Transported in combination with plasma protein (in the blood).
- **Mechanism of Action**
  - Interact with target tissues in a similar fashion as steroid hormones.
  - They are non-polar and lipid soluble, so they diffuse through cell membranes into the cytoplasm.

- Within the cell they bind to receptor molecules in the nuclei and initiate new protein synthesis.
- May also bind to and alter the function of mitochondria resulting in greater ATP production and a greater rate of heat production.
- Newly synthesized proteins with the target cells mediate the response of the cell to the thyroid hormones.
- Requires about 1 week for an observed response to occur following the administration of thyroid hormone.

❖ Effects

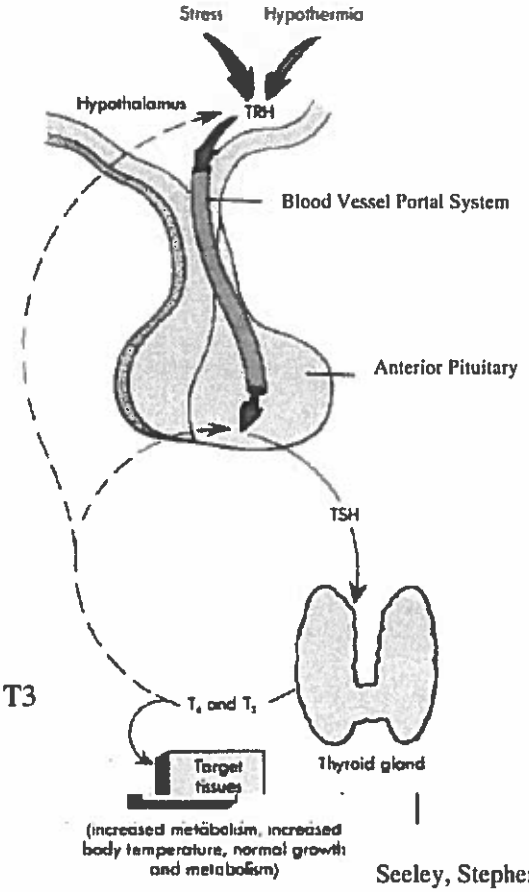
- Metabolism is primarily affected in some tissues, and growth and maturation are influenced in others.
- The normal rate of metabolism for an individual depends on an adequate supply of thyroid hormone; which increases the rate of glucose, fat and protein metabolism in many tissues, which, in turn, increases the body temperature.
- Low levels of thyroid hormones lead to the opposite effect.
- Normal growth and maturation of organs are dependent on thyroid hormones.

Effects of Hyposecretion and Hypersecretion of Thyroid Hormones

Hypothyroidism	Hyperthyroidism
Decreased metabolic rate, low body temperature, cold intolerance	Increased metabolic rate, high body temperature, heat intolerance
Weight gain, reduced appetite	Weight loss, increased appetite
Reduced activity of sweat glands, dry and cold skin	Copious sweating, warm and flushed skin
Reduced heart rate, reduced blood pressure, dilated and enlarged heart	Rapid heart rate, elevated blood pressure, abnormal electrocardiogram
Weak, flabby skeletal muscles, sluggish movements	Weak skeletal muscles that exhibit tremors, quick movements with exaggerated reflexes
Constipation	Bouts of diarrhea
Myxedema (swelling of the face and body) as a result of mucoprotein deposits	Exophthalmos (protruding of the eyes) as a result of mucoprotein and other deposits behind the eye
Apathetic, somnolent	Hyperactive, insomnia, restless, irritable, short attention span
Course hair, rough and dry skin	Soft, smooth hair and skin
Decreased iodine uptake	Increased iodine uptake
Possible goiter (enlargement of thyroid gland)	Almost always develops goiter

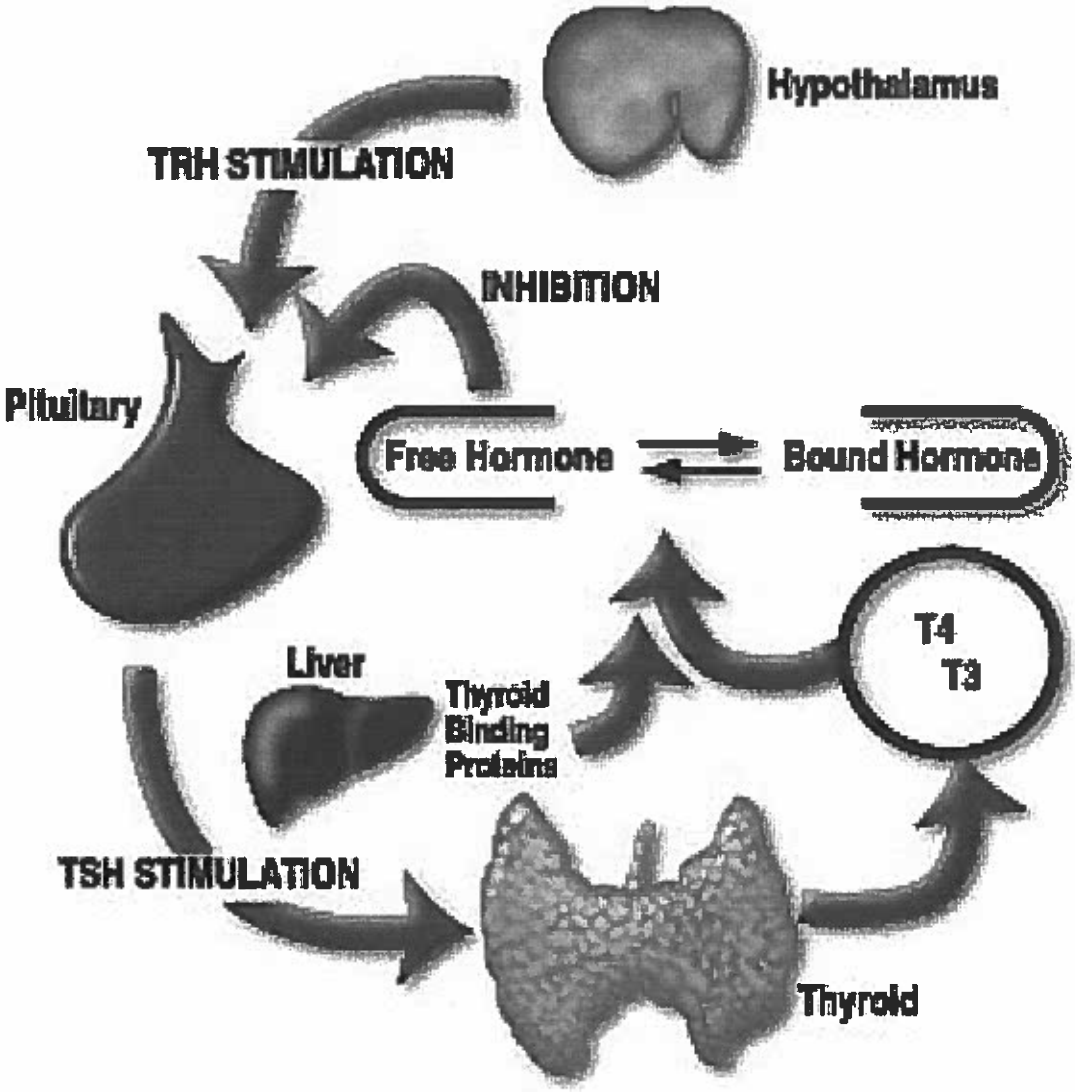
❖ Regulation

- **TSH** is the most important regulator of thyroid hormone secretion.
- Effects of increased TSH levels are increased synthesis and secretion of thyroxine, as well as increased cell size and increased cell number of the thyroid gland.
- Decreased blood levels of TSH lead to decreased thyroxine secretion and thyroid gland atrophy.
- The secretion of TSH is initiated by a hypothalamus releasing hormone called **thyrotropin-releasing hormone (TRH)**
  - TRH is released from the neurons within the hypothalamus and passes through the blood vessels portal system to the anterior pituitary, where it causes cells within the AP to secrete TSH.
  - TSH passes through the general circulation to the thyroid gland, where it causes both increased synthesis and secretion of thyroxine, which has an inhibitory effect on the secretion of both TRH from the hypothalamus and TSH from the AP.
  - Other stimuli such as stress or hypothermia (exposure to cold) act on the hypothalamus to increase TRH release.



Thyroxine = T4 and T3

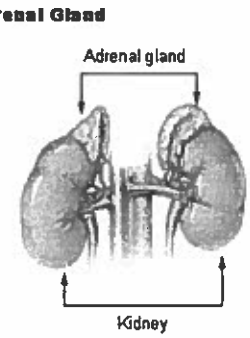
Seeley, Stephens & Tate, 1989.


Hypothalamus
TRH STIMULATION
INHIBITION
Pituitary
Free Hormone
Bound Hormone
T4
T3
Liver
Thyroid
Binding
Proteins
TSH STIMULATION
Thyroid

Abnormal Thyroid Conditions Seeley, Stephens & Tate, p. 532, 1989.

Condition	Cause	Description
Hypothyroidism	Iodine deficiency	Causes inadequate thyroid hormone synthesis, which results in elevated TSH secretion; thyroid gland enlarges (goiter) due to TSH stimulation; thyroid hormones frequently remain in the low-to-normal range.
	Goiterogenic substances	Found in certain drugs and in small amounts in certain plants such as cabbage; inhibit thyroid hormone synthesis.
	Cretinism	Caused by maternal iodine deficiency or congenital errors in thyroid hormone synthesis; results in mental retardation and a short, grotesque appearance.
	Lack of thyroid gland	Removed surgically or destroyed as a treatment for Grave's disease (hyperthyroidism)
	Pituitary insufficiency	Results from lack of TSH secretion; often associated with inadequate secretion of other AP hormones.
	Hashimoto's disease	Autoimmune disease in which thyroid function is normal or depressed.
Hyperthyroidism	Grave's disease	Characterized by goiter and exophthalmos; apparently an autoimmune disease; most patients have long-acting thyroid stimulator (LATS), a TSH-like immune globulin, in their plasma.
	Tumors – benign or cancer	Result in either normal secretion or hypersecretion of thyroid hormones.
	Thyroiditis – a viral infection	Produces painful swelling of the thyroid gland with normal or slightly increased thyroid hormone production
	Elevated TSH levels	Result from a pituitary tumor
	Thyroid storm	Sudden release of large amounts of thyroid hormones; caused by surgery, stress, infections and unknown reasons

Adrenal Glands

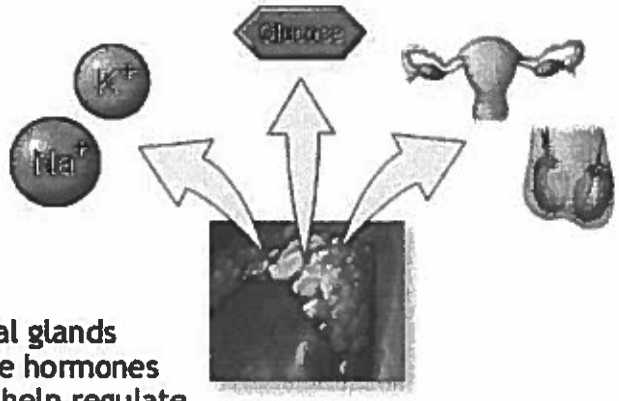


Location & Structure

- near the top of each kidney
- composed of an inner **medulla** and an outer **cortex**

Function

- release hormones that prepare the body for stress, aid in the regulation of minerals and aid in the regulation of sexual development.



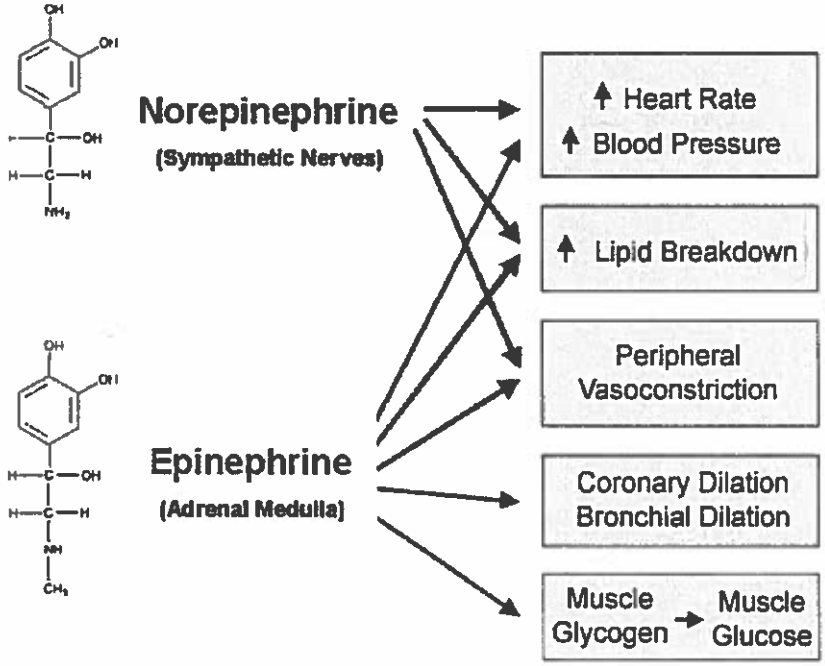
Adrenal glands secrete hormones which help regulate chemical balance, regulate metabolism and supplement other glands

Adrenal Medulla Hormones

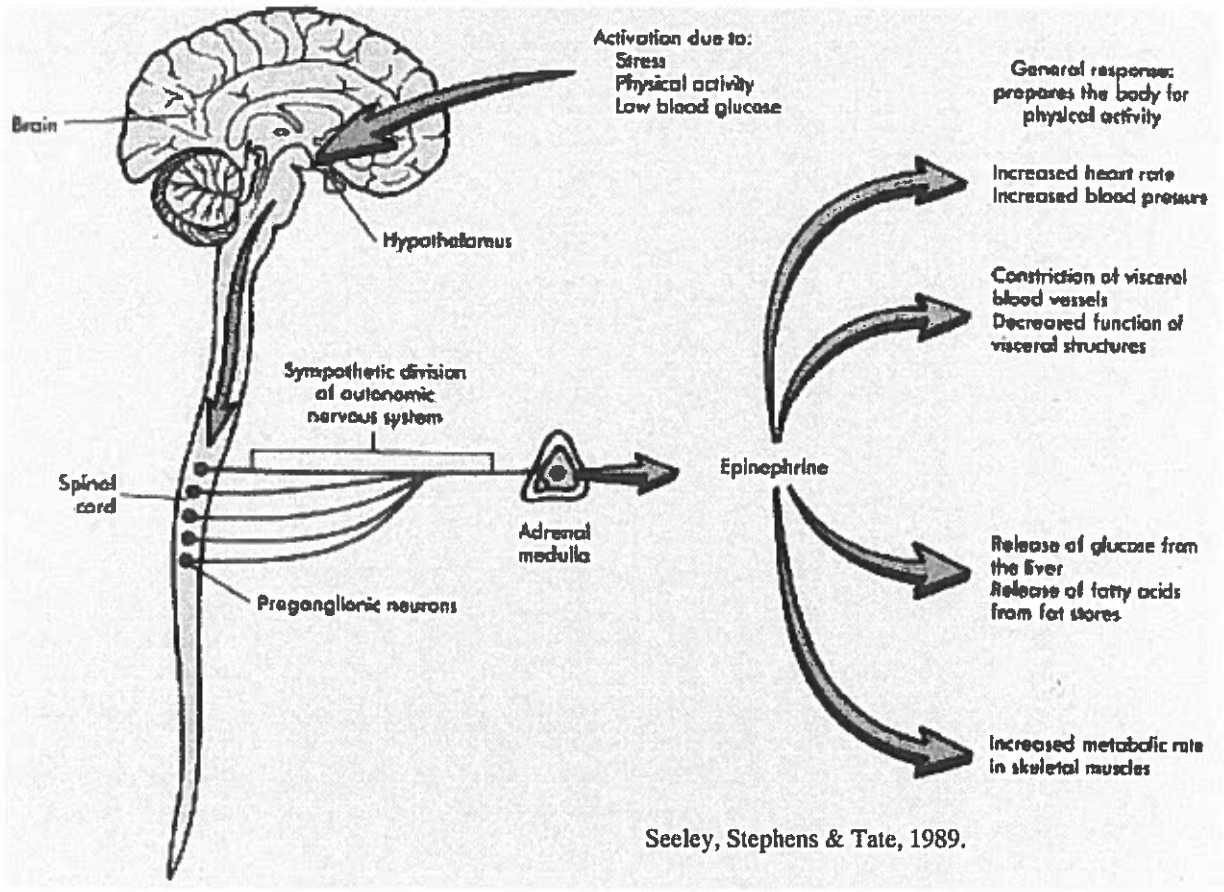
- component of the autonomic nervous system and its secretory products are neurohormones.
- Secretes two major hormones:
  1. Epinephrine (Adrenaline)
     - 80% of secretions
     - prepares body for physical activity.
     - increases blood levels of glucose, glycogen breakdown, the intracellular metabolism of glucose in skeletal muscle cells, and the breakdown of fats in adipose tissue.
     - Increases the heart rate and the force of contraction of the heart (increased cardiac output) and causes blood vessels to constrict in the skin, kidneys, gastrointestinal tract; it causes dilation of blood vessels in skeletal muscles and cardiac muscle.

2. Norepinephrine (Noradrenaline)

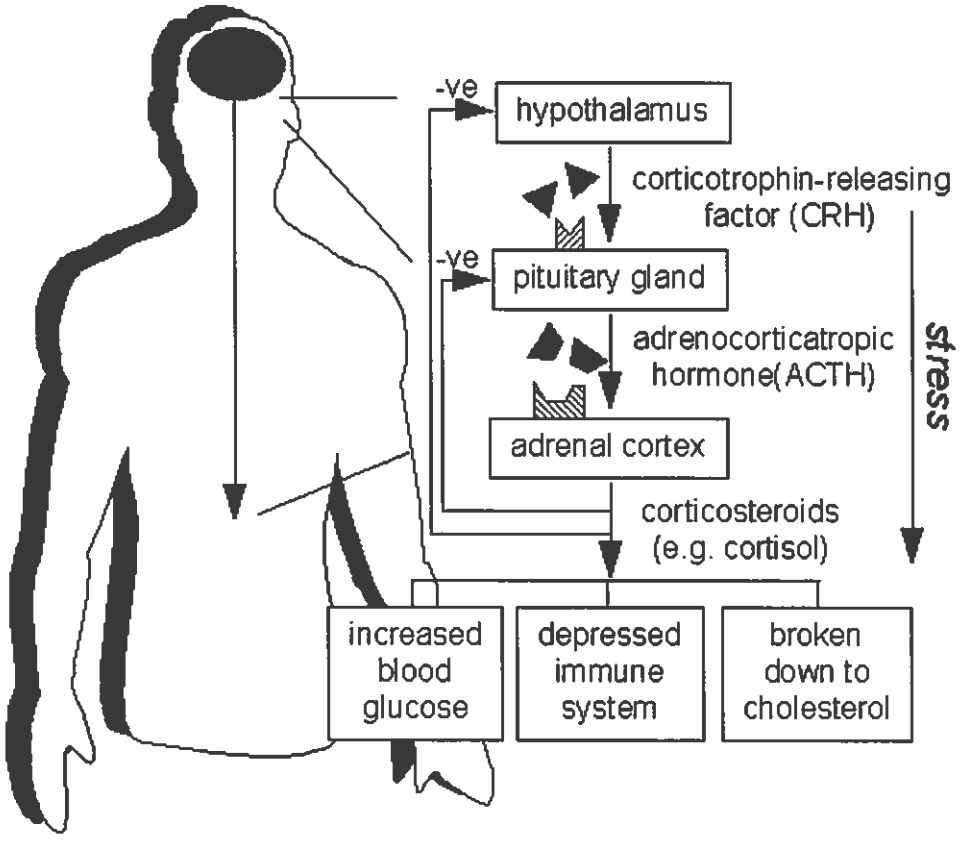
- 20% of secretions
- causes constriction of peripheral blood vessels in most areas of the body and stimulates cardiac muscle (maintains even blood pressure)



- Secretion prepares the individual for physical activity and is a major component of the **flight-or-fight response** **(General Adaptation Syndrome)**
  - ➔ Response results in reduced activity in organs not essential for physical activity and in increased blood flow and metabolic activity in organs that participate in physical activity. It also mobilizes nutrients that can be used to sustain physical exercise.
- Effects of Epinephrine and Norepinephrine are short lived b/c they are rapidly metabolized, excreted, or taken up by tissues. Half-life in the circulatory system is measured in terms of minutes.
- **REGULATION:**
  - release generally occurs in response to stimulation by sympathetic neurons since the adrenal medulla is a specialized portion of the autonomic nervous system.
  - Conditions leading to release of adrenal medulla neurohormones include emotional excitement, injury, stress, exercise and low blood glucose levels.



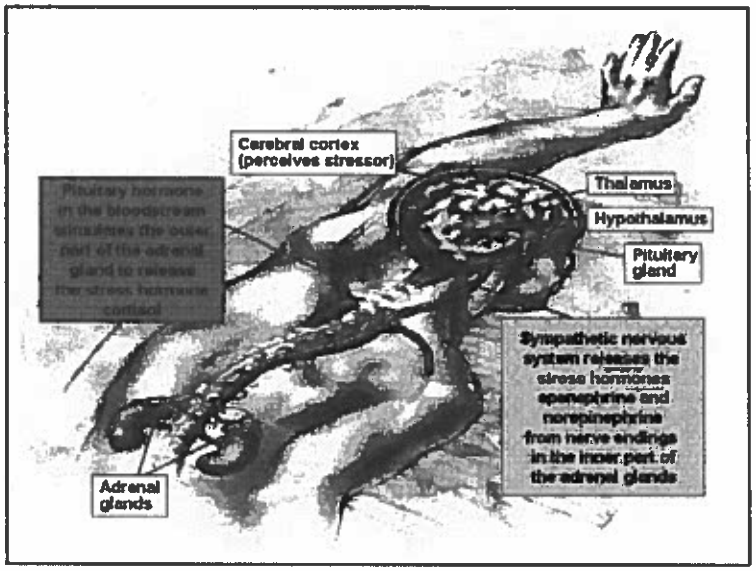
Seeley, Stephens & Tate, 1989.



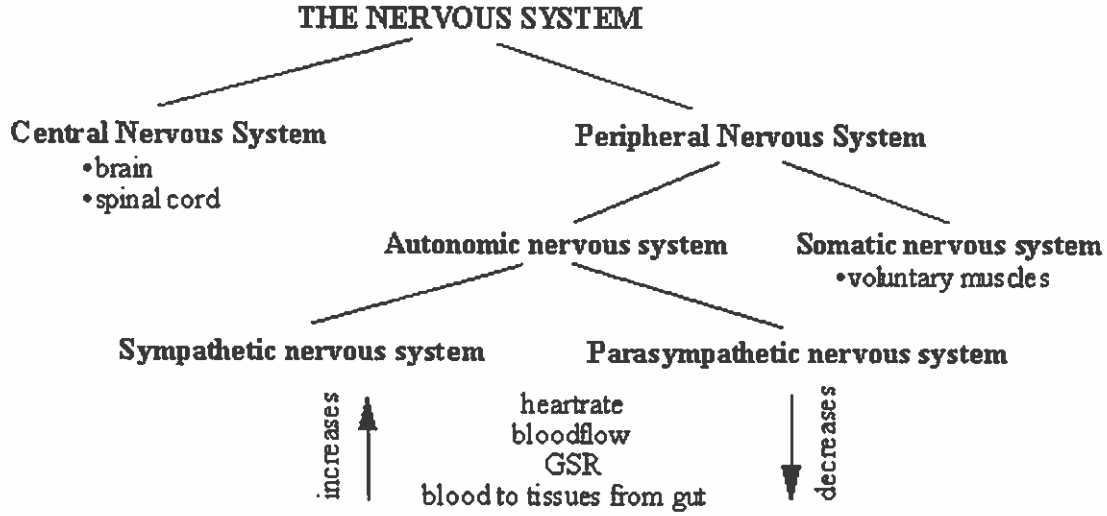
Got Gas?

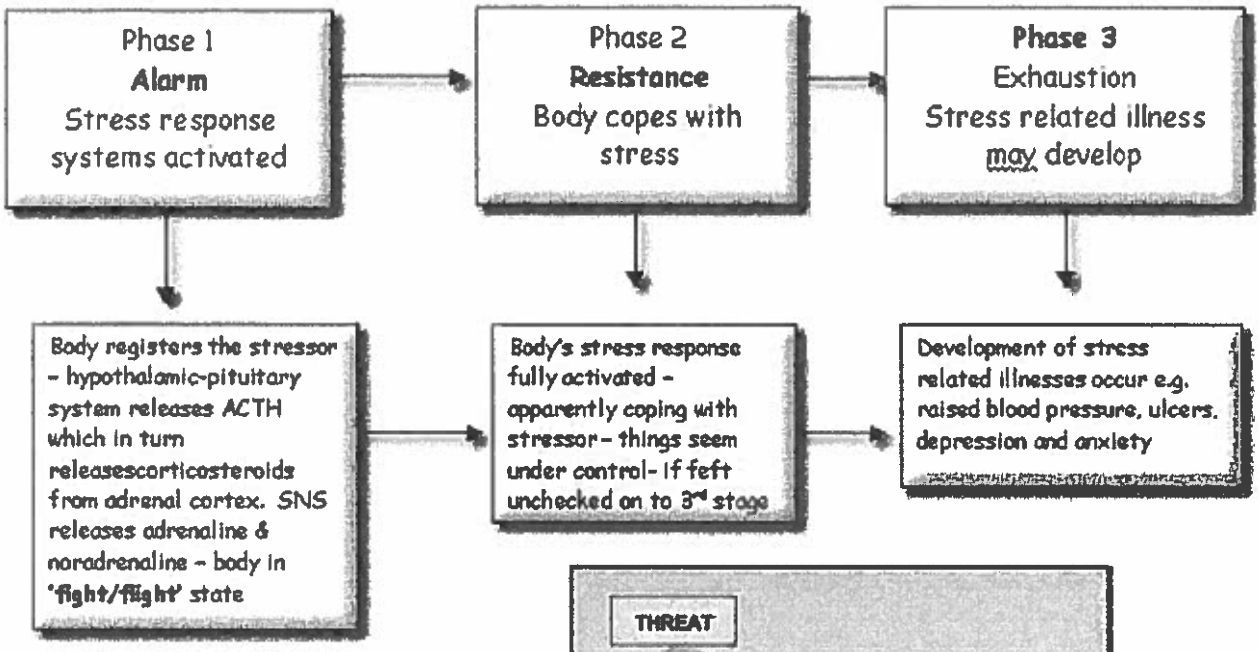
The Flight or Fight Response

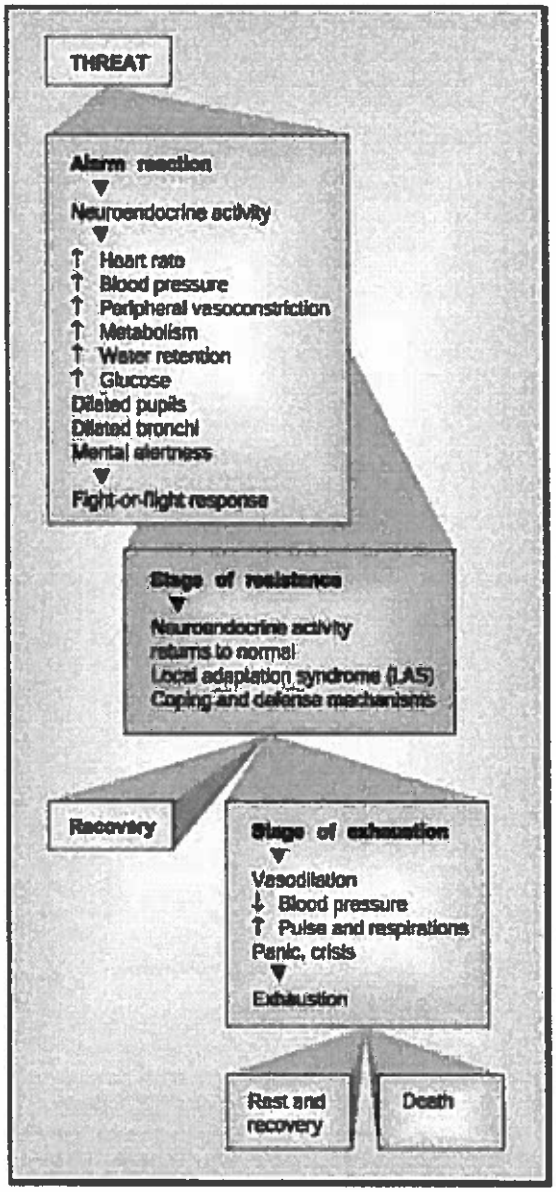
- The fight or flight response (aka **General Adaptation Syndrome**), which occurs when an individual is subjected to severe stress such as a threatening situation, may be one of avoidance such as running or one of confrontation.
- The response involves all parts of the nervous system as well as the endocrine system, and may be consciously or unconsciously mediated.



- The autonomic portion of the fight or flight response results in a general increase in sympathetic activity, including heart rate, blood pressure, sweating, muscular strength, and other responses, that prepares the individual for physical activity.
- The fight or flight response is adaptive in that it usually removes the individual from the threatening situation or prepares him for optimum physical strength.




Phase 1
Alarm
Stress response systems activated
Phase 2
Resistance
Body copes with stress
Phase 3
Exhaustion
Stress related illness may develop
Body registers the stressor – hypothalamic-pituitary system releases ACTH which in turn releasescorticosteroids from adrenal cortex. SNS releases adrenaline & noradrenaline – body in 'fight/flight' state
Body's stress response fully activated – apparently coping with stressor – things seem under control- if feft unchecked on to 3rd stage
Development of stress related illnesses occur e.g. raised blood pressure, ulcers, depression and anxiety


THREAT
Alarm reaction
Neuroendocrine activity
↑ Heart rate
↑ Blood pressure
↑ Peripheral vasoconstriction
↑ Metabolism
↑ Water retention
↑ Glucose
Dilated pupils
Dilated bronchi
Mental alertness
Fight-or-flight response
Stage of resistance
Neuroendocrine activity returns to normal
Local adaptation syndrome (LAS)
Coping and defense mechanisms
Recovery
Stage of exhaustion
Vasodilation
↓ Blood pressure
↑ Pulse and respirations
Panic, crisis
Exhaustion
Rest and recovery
Death

Adrenal Cortex Hormones

- Secretes three hormone types: **mineralocorticoids, glucocorticoids** and **androgens.**
- Steroids (lipid soluble) so they are not stored in the adrenal gland cells but diffuse from cells into the blood as they are synthesized.

Mineralocorticoids

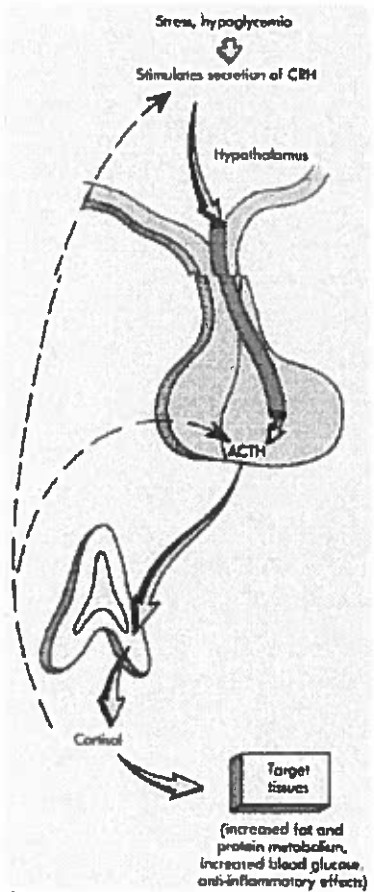
Aldosterone

- Increases the rate of sodium reabsorption by the **kidneys** resulting in increased water reabsorption by the kidneys and an increase in blood volume.
- Increases K^+ excretion into the urine by the kidneys, decreasing blood levels of K^+.

Glucocorticoids

Cortisol

- Target tissue – most tissues (liver, fat, skeletal muscle, immune tissues).
- Anti-inflammatory – decrease the intensity of the inflammatory response by decreasing both the number of white blood cells and the secretion of anti-inflammatory chemicals from tissues.



- Increase fat catabolism, decrease glucose and amino acid uptake in skeletal muscle, increase synthesis of glucose from amino acids in the liver, and increase protein degradation
- **EFFECTS** – to increase the metabolism of fats and proteins and to cause blood glucose levels and glycogen deposits in cells to increase.
- **REGULATION** – Corticotropin-releasing hormone (CRH) is released from hypothalamus neurons and passes, by way of the blood vessel portal system, to the AP, where it binds to and stimulates cells that secrete ACTH.
    - ACTH binds to membrane-bound receptors on cells of the adrenal cortex and stimulates the secretion of cortisol.
    - Cortisol, in turn, inhibits CRH and ACTH secretion.
    - Stimuli such as stress and hypoglycemia cause the release of sufficient quantities of CRH from hypothalamus neurons to override the negative-feedback effect of cortisol.
    - So under conditions of stress or food deprivation, cortisol levels increase dramatically.

Seeley, Stephens & Tate, 1989.

❖ Androgens

- Like testosterone
- Stimulate pubic and axillary hair growth and sexual drive in females.
- Responsible for the sexual development of the male fetus during its development in the womb.

Hyposecretion and Hypersecretion of Adrenal Cortex Hormones

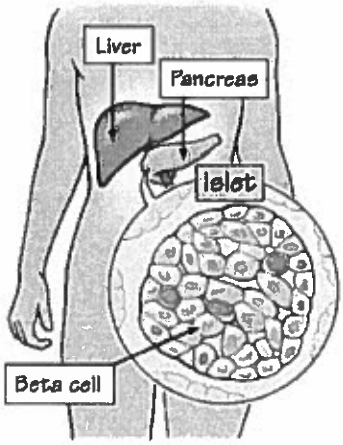
(Seeley, Stephens & Tate, p. 541, 1989)

Hyposecretion	Hypersecretion
Aldosterone	
Hyponatremia (low blood levels of sodium)	Slight hypernatremia (high blood levels of sodium)
Hyperkalemia (high blood levels of potassium)	Hypokalemia (low blood levels of potassium)
Acidosis	Alkalosis
Low blood pressure	High blood pressure
Tremors and tetany of skeletal muscles	Weakness of skeletal muscles
Polyuria	Acidic urine
Cortisol	
Hypoglycemia (low blood glucose levels)	Hyperglycemia (high blood glucose levels) – leads to diabetes mellitus
Depressed immune system	Depressed immune system
Protein and fats from diet not used resulting in weight loss	Destruction of tissue proteins causes muscle atrophy and weakness, osteoporosis, weak capillaries (easily bruised), thin skin, and impaired wound healing; fats are mobilized and redistributed, causing depletion of fat from limbs and deposition in face (moon face), neck (buffalo hump) and abdomen
Loss of appetite, nausea and vomiting	Emotional effects including euphoria and depressions
Increased skin pifmentation (due to elevated ACTH)	Thin skin
Androgens	
In women, reduction of pubic and axillary hair	In women, hirsutism (excessive facial and body hair), acne, increased sex drive, regression of breast tissue, and loss of regular menses

Pancreas – Islets of Langerhans

Location & Structure

- Long, toque shaped organ located below the stomach.
- ½ to one million islets in the pancreas



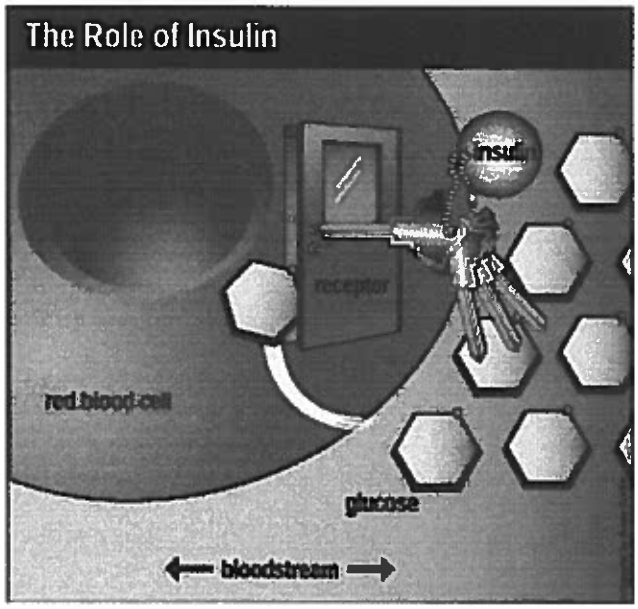
Function

- Considered both an exocrine and endocrine gland
- Exocrine portion produces pancreatic juice.
- Endocrine portion consists of **islets of Langerhans** which produce hormones which enter the circulatory system.
    - each islet is composed of **alpha cells** (20%), which secrete **glucagon**, **beta cells** (75%), which secrete **insulin**, and other cell types (5%)

Effects of Insulin and Glucagon on Their Target Tissues

Insulin

- Produced by **beta cells** of islets of Langerhans
- Protein structure – requires insulin receptors on membranes of target cells
- Target tissues – liver, adipose tissue, muscle and the satiety center (regulates appetite) in the hypothalamus.
- **Increases its target tissue's ability to take up and use glucose and amino acids.**
    - Glucose is used for energy or is stored as glycogen
    - Amino acids are used for energy or are converted to glucose or proteins.
- **Too much insulin** – target tissues accept glucose rapidly from the circulatory system; as a consequence, blood levels of glucose decline to very low levels.
- **Absence of insulin** – uptake of glucose and amino acids declines dramatically even though blood levels may be high. To take up glucose, the satiety center requires insulin. Without insulin the satiety center can't detect glucose in the extracellular fluid even though it may be present at high levels. Intense sensation of hunger develops.



- *Carbohydrates that we eat make our blood glucose (sugar) rise.*
- *To utilize the carbohydrates and lower the blood sugar, insulin opens the doors of the body's cells to glucose circulating in the blood.*
- *The glucose enters the cells and is used as the cells' fuel for energy.*
- *Insulin binds to a spot on the cell surface called a receptor.*
- *Likened to a lock and key, insulin is the key that opens up the lock (receptor) so that glucose can pass through the door into the cell.*
- *Using this analogy in type 1 diabetes, the keys have been stolen (no insulin is made by the pancreas).*
- *In type 2, the door won't open fully even with the right key (insulin resistance).*

❖ Glucagon

- Produced by **alpha cells** of islets of Langerhans
- Polypeptide structure
- Target tissue – liver (mainly), skeletal muscle and adipose tissue
- Causes the breakdown of glycogen and fats and increased glucose synthesis in the liver.

Regulation

- ❖ Secretion of insulin is under chemical, neural and hormonal control.
- ❖ **Insulin** secretion increases due to elevated blood glucose levels, an increase in some amino acids, parasympathetic stimulation, and gastrointestinal hormones. Sympathetic stimulation decreases insulin secretion.
  - Hyperglycemia (elevated blood glucose levels) directly affects the beta cells and stimulates insulin secretion.
  - Hypoglycemia (low blood glucose levels) directly inhibits insulin secretion.
  - After a meal, when glucose and amino acids levels increase in the circulatory system, insulin secretion increases.
  - During periods of fasting when blood glucose levels are low, the rate of insulin secretion declines.
- ❖ **Glucagon** secretion is stimulated by low blood glucose levels, certain amino acids, and sympathetic stimulation. High blood glucose levels inhibit glucagon secretion.

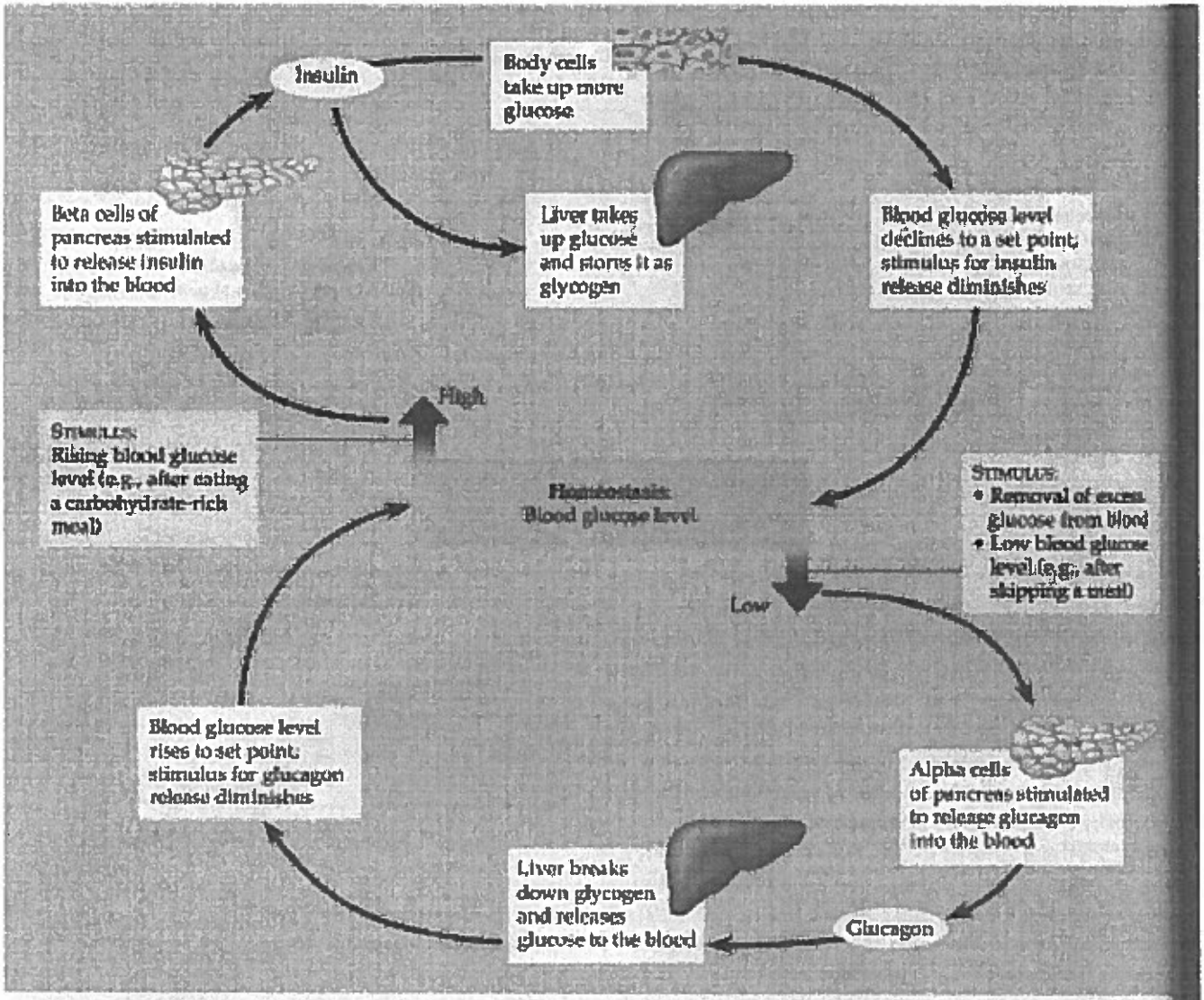


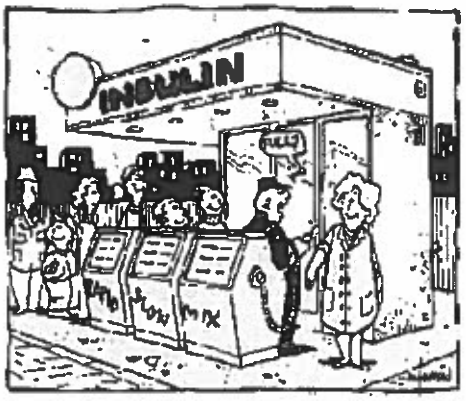
FIGURE 45.11 - Glucose homeostasis maintained by insulin and glucagon. A rise in blood glucose above the set point of about 90 mg/100 mL in humans stimulates the pancreas to secrete insulin, which triggers its target cells to take up the excess glucose from the blood. Once the excess is removed or when blood glucose concentration dips below the set point, the pancreas responds by secreting glucagon, which acts on the liver to raise the blood glucose level.

Campbell, *et. al*, 5th Edition, pg 906

Disorders

Insulin Hyposecretion

- usually caused by the degeneration of the beta cells in the islet of Langerhans.
- Diabetes Mellitus
  - Results from a lack of insulin secretion, the secretion of abnormal insulin or the inability of tissues to respond to insulin.



  - **Type I Diabetes (Juvenile-onset diabetes)**
    - Caused by a lack of insulin secretion
    - No evidence of hereditary link
    - Viral infection of islets may be involved.
  - **Type II Diabetes (Adult-onset diabetes)**
    - Caused by the inability of tissues to respond to insulin
    - Hereditary plays a role
  - Symptoms include:
    - hyperglycemia
    - excess glucose in urine
    - thirst
    - excess eating
    - dehydration
    - tissue wasting and weight loss
    - ketosis and ketones in urine
    - acidosis
    - acetone breath, obesity
    - etc.
  - Symptoms are a consequence of the abnormal metabolism of nutrients which is caused by a lack of insulin secretion or lack of insulin receptors.
  - **Treatment**:
    - Insulin injections
    - Islet of Langerhans transplants

Reproductive Organs

Testes

- **Testosterone**
  - Target tissue – most cells
  - Steroid structure
  - Aids in **spermatogenesis**; maintenance of functional reproductive organs; secondary sexual characteristics; sexual behavior.

Ovary

- **Estrogen**
  - Target tissue – most cells
  - Steroid structure
  - Uterine and mammary gland development and function' external genitalia structure; secondary sexual characteristics; sexual behavior and menstrual cycle.
- **Progesterone**
  - Target tissue – most cells
  - Steroid structure
  - Uterine and mammary gland development and function; external genitalia; secondary sexual characteristics; menstrual cycle.

Comparing the Endocrine and Nervous System

Timing

The **endocrine system** may take minutes, hours or even days to act, partly because of the time it takes for hormones to be made and carried in the blood to their target organs.

In contrast, the **nervous system** is a signaling network with branches carrying information directly to and from specific targets. Neurons are specialized for the fast transmission of impulses - as quickly as 150 m/s (over 330 mph or 540 km/h).