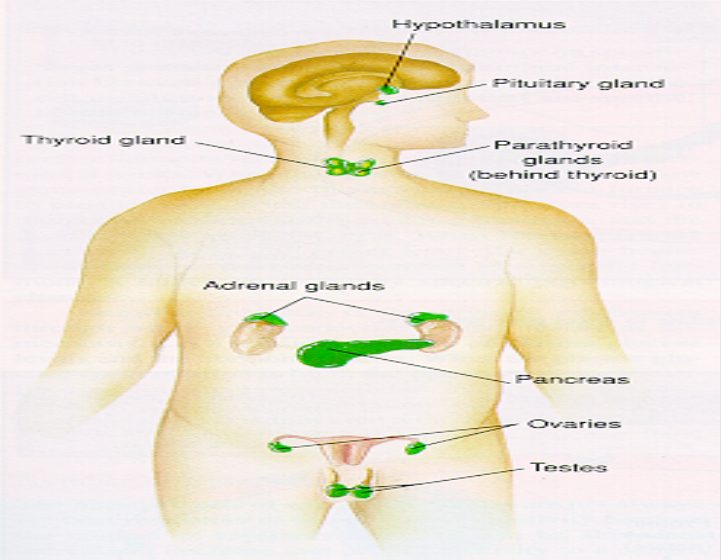
Introduction to Exercise Physiology -The Endocrine System



Learning Outcomes

- To understand the function of the endocrine system
- To be able to explain the process by which hormones act within cells
- To know some of the key hormones and glands that produce functional outcomes within the bodily system

Exocrine or Endocrine

- Exocrine – release products (enzymes) into ducts

  e.g. Sweat, tears, digestive juices

- Endocrine – directly to bloodstream; NO DUCTS

  e.g. Hormones

Mechanisms of the Endocrine System

1. Controls the processes involved in movement and physiological equilibrium.
2. Includes all tissues or glands that secrete hormones into the blood.
3. Secretion of most hormones is regulated by a negative feedback system.
4. The number of receptors for a specific hormone can be altered to meet the body's demand.

Endocrine Glands

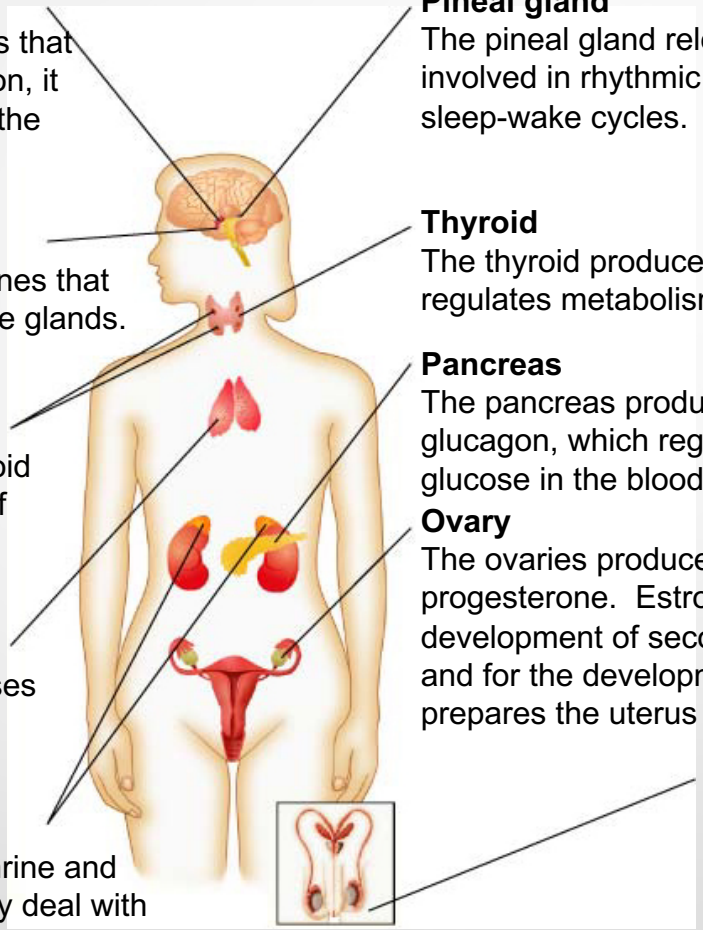
Hypothalamus
The hypothalamus makes hormones that control the pituitary gland. In addition, it makes hormones that are stored in the pituitary gland.

Pituitary gland
The pituitary gland produces hormones that regulate many of the other endocrine glands.

Parathyroid glands
These four glands release parathyroid hormone, which regulate the level of calcium in the blood.

Thymus
During childhood, the thymus releases thymosin, which stimulates Tcell development.

Adrenal glands
The adrenal glands release epinephrine and nonepinephrine, which help the body deal with stress.



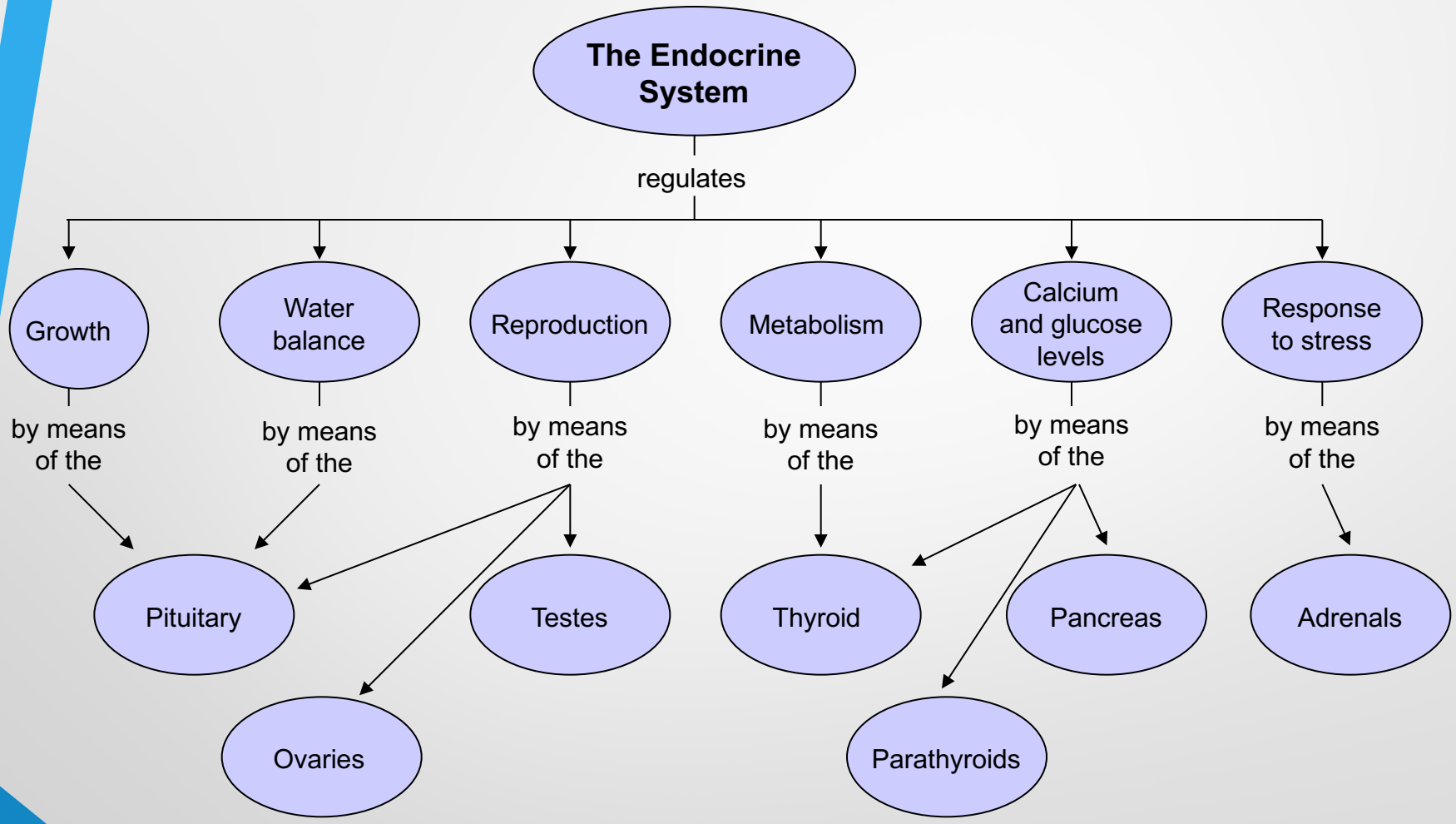
Pineal gland
The pineal gland releases melatonin, which is involved in rhythmic activities, such as daily sleep-wake cycles.

Thyroid
The thyroid produces thyroxine, which regulates metabolism.

Pancreas
The pancreas produces insulin and glucagon, which regulate the level of glucose in the blood.

Ovary
The ovaries produce estrogen and progesterone. Estrogen is required for the development of secondary sex characteristics and for the development of eggs. Progesterone prepares the uterus for a fertilized egg.

Testis
The testes produce testosterone, which is responsible for sperm production and the development of male secondary sex characteristics


The Endocrine System
regulates
Growth
Water balance
Reproduction
Metabolism
Calcium and glucose levels
Response to stress
by means of the
by means of the
by means of the
by means of the
by means of the
by means of the
Pituitary
Testes
Ovaries
Thyroid
Pancreas
Parathyroids
Adrenals

Endocrine System

- Glands – release products to bloodstream directly.
- Hormones – products deliver messages to body.
- Target cells – have specific receptors for specific hormones.

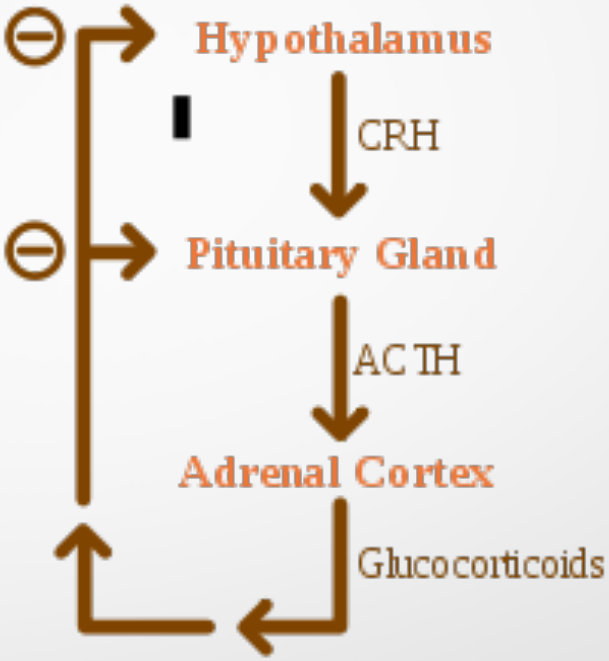
Comparison of Features of the Endocrine System and Nervous System		
FEATURE	ENDOCRINE SYSTEM	NERVOUS SYSTEM
Overall Function	Regulation of effectors to maintain homeostasis	Regulation of effectors to maintain homeostasis
Control by regulatory feedback loops	Yes (endocrine reflexes)	Yes (nervous reflexes)
Effector tissues	Endocrine effectors: virtually all tissues	Nervous effectors: muscle and glandular tissue only
Effector cells	Target cells (throughout the body)	Postsynaptic cells (in muscle and glandular tissue only)
Chemical Messenger	Hormone	Neurotransmitter
Cells that secrete the chemical messenger	Glandular epithelial cells or neurosecretory cells (modified neurons)	Neurons
Distance traveled (and method of travel) by chemical messenger	Long (by way of circulating blood)	Short (across a microscopic synapse)
Location of receptor in effector cell	On the plasma membrane or within the cell	On the plasma membrane
Characteristics of regulatory effects	Slow to appear, long lasting	Appear rapidly, short lived

Hormone Actions

- "Lock and Key" approach: describes the interaction between the hormone and its specific receptor.
  - Receptors for nonsteroid hormones are located on the cell membrane
  - Receptors for steroid hormones are found in the cell's cytoplasm or in its nucleus

Negative Feedback

- The primary mechanism through which your endocrine system maintains homeostasis.
- Secretion of a specific hormone are regulated by specific physiological changes i.e. As the hormone's function takes effect the physiological change inhibits further secretion of that hormone.



Corticotropin-releasing hormone (CRH) which directs the anterior pituitary gland to secrete adrenocorticotropic hormone (ACTH). In turn, ACTH directs the adrenal cortex to secrete glucocorticoids, such as cortisol.

Chemical Classificaton of Hormones

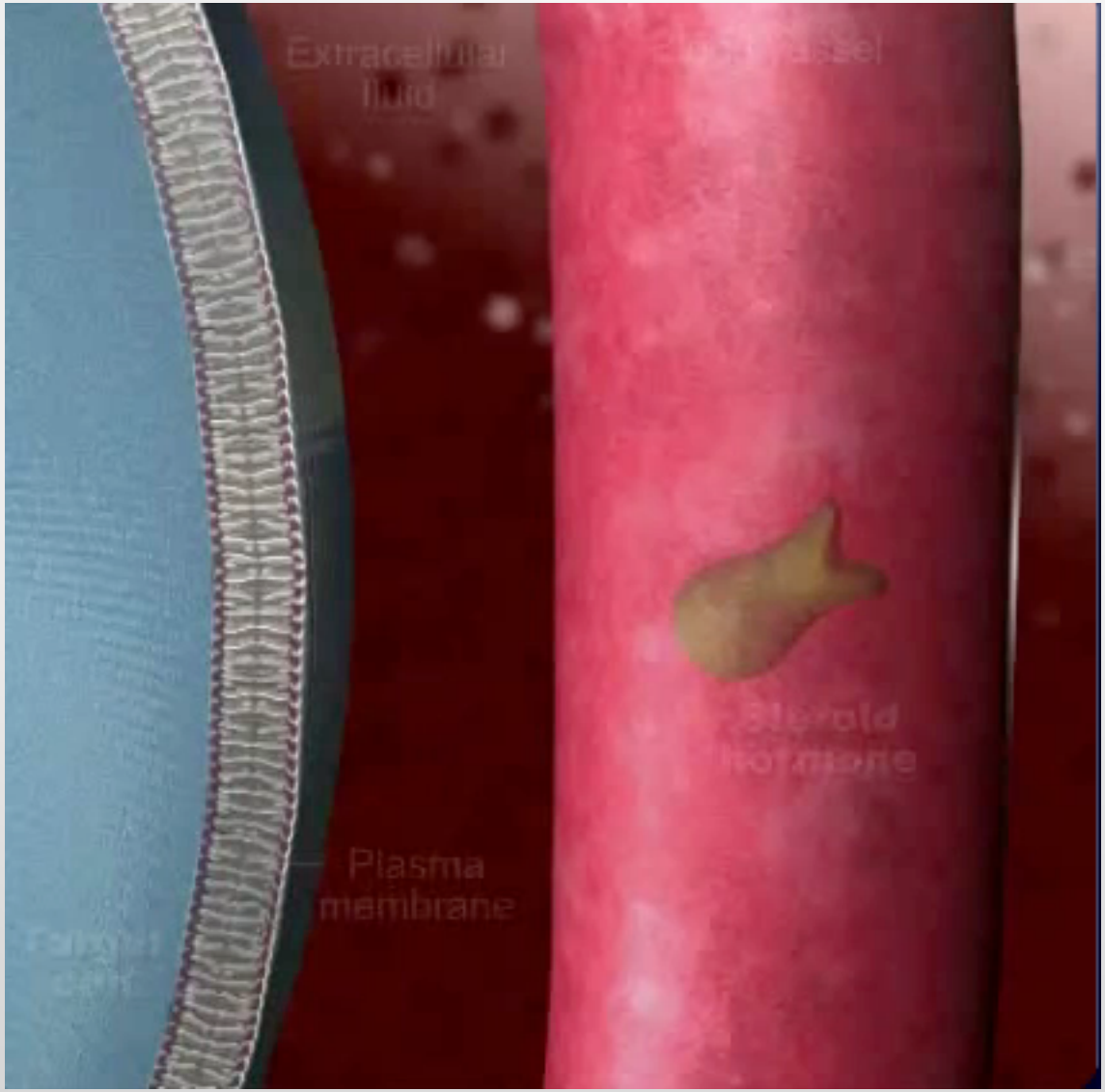
- Steroid Hormones:
  - Lipid soluble
  - Diffuse through cell membranes
  - Endocrine organs
    - Adrenal cortex
    - Ovaries
    - Testes
    - placenta

- Nonsteroid Hormones:
  - Not lipid soluble
  - Received by receptors external to the cell membrane
  - Endocrine organs
    - Thyroid gland
    - Parathyroid gland
    - Adrenal medulla
    - Pituitary gland
    - pancreas

Hormone Actions

- Steroid Hormones (Glucocorticoid, estrogen, testosterone)
  - Pass through the cell membrane by binding to specific receptors,
  - Then enters the nucleus to bind with the cells DNA which then activates certain genes (Direct gene activation).
  - mRNA is synthesized in the nucleus and enters the cytoplasm and promotes protein synthesis for:
    1. Enzymes as catalysts
    2. Tissue growth and repair
    3. Regulate enzyme function

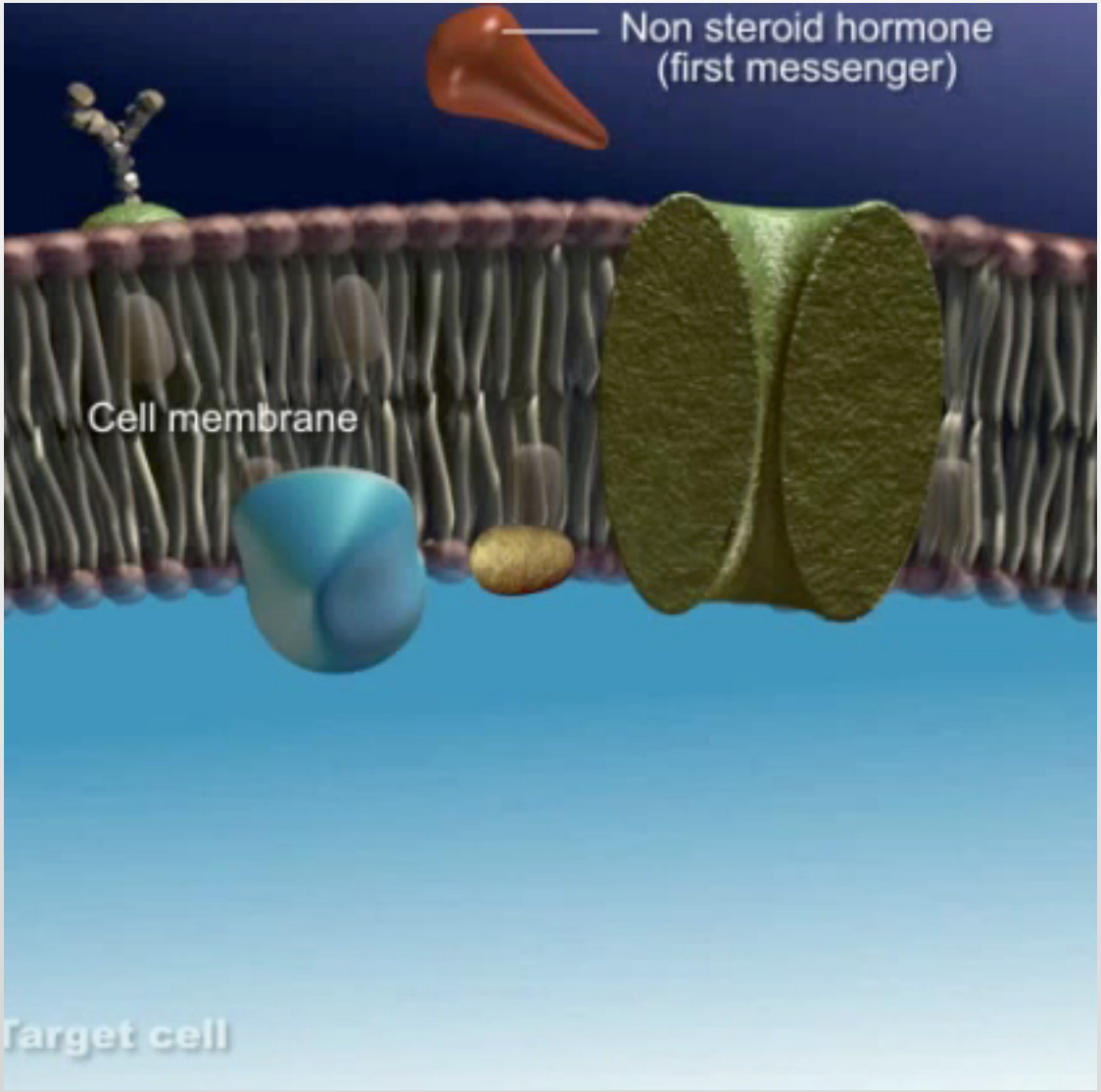
Steroid Hormone Action



Hormone Actions

- Nonsteroid Hormones
  - React with specific receptors outside the cell
  - This triggers an enzyme reaction with lead to the formation of a second messenger (cAMP).
  - cAMP can produce specific intracellular functions:
    - Activates cell enzymes
    - Change in membrane permeability
    - Promote protein synthesis
    - Change in cell metabolism
    - Stimulation of cell secretions

Non-steroid Hormone Action



TASK

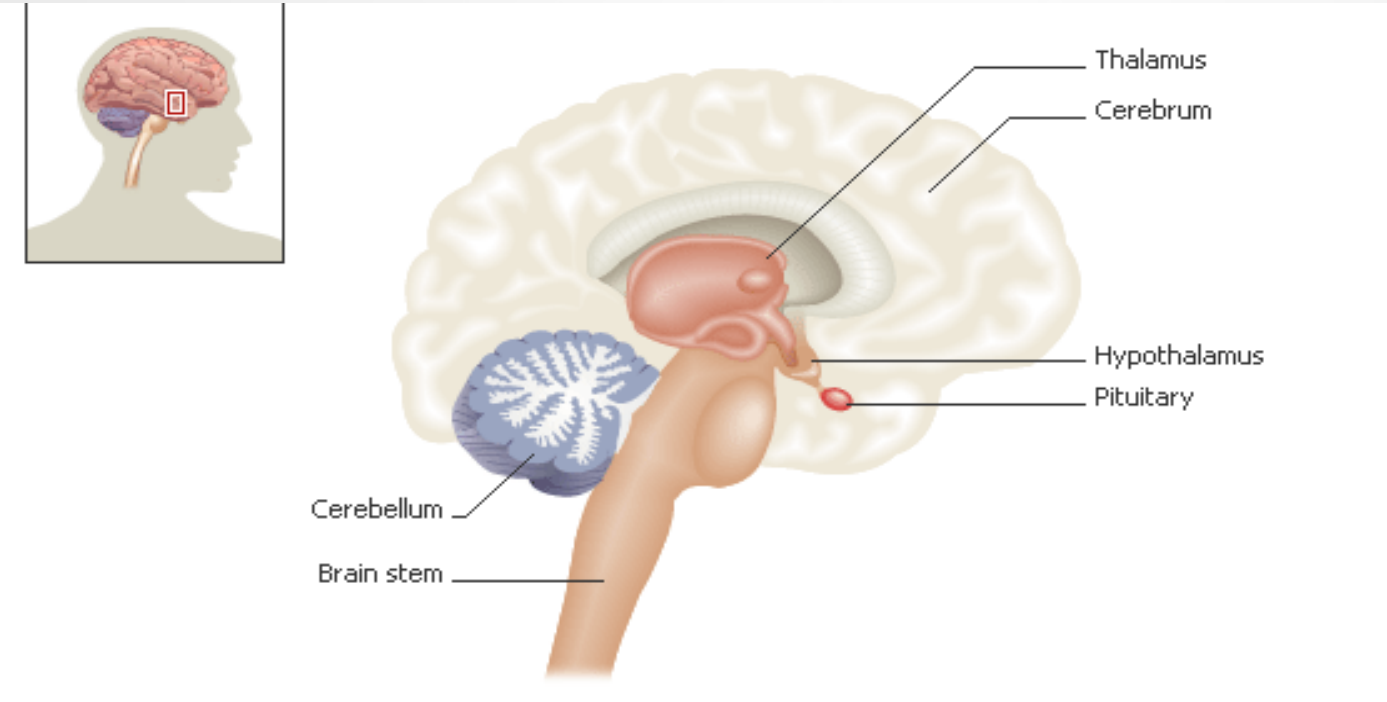
- Visually represent the process of a Non-steroid hormone in acting on a target cell
- Visually represent the process of a Steroid hormone in acting on a target cell

Number of Receptors

- Down-regulation: is the decrease of hormone receptors which decreases the sensitivity to that hormone.
- Up-regulation: is the increase in the number of receptors which causes the cell to be more sensitive to a particular hormone

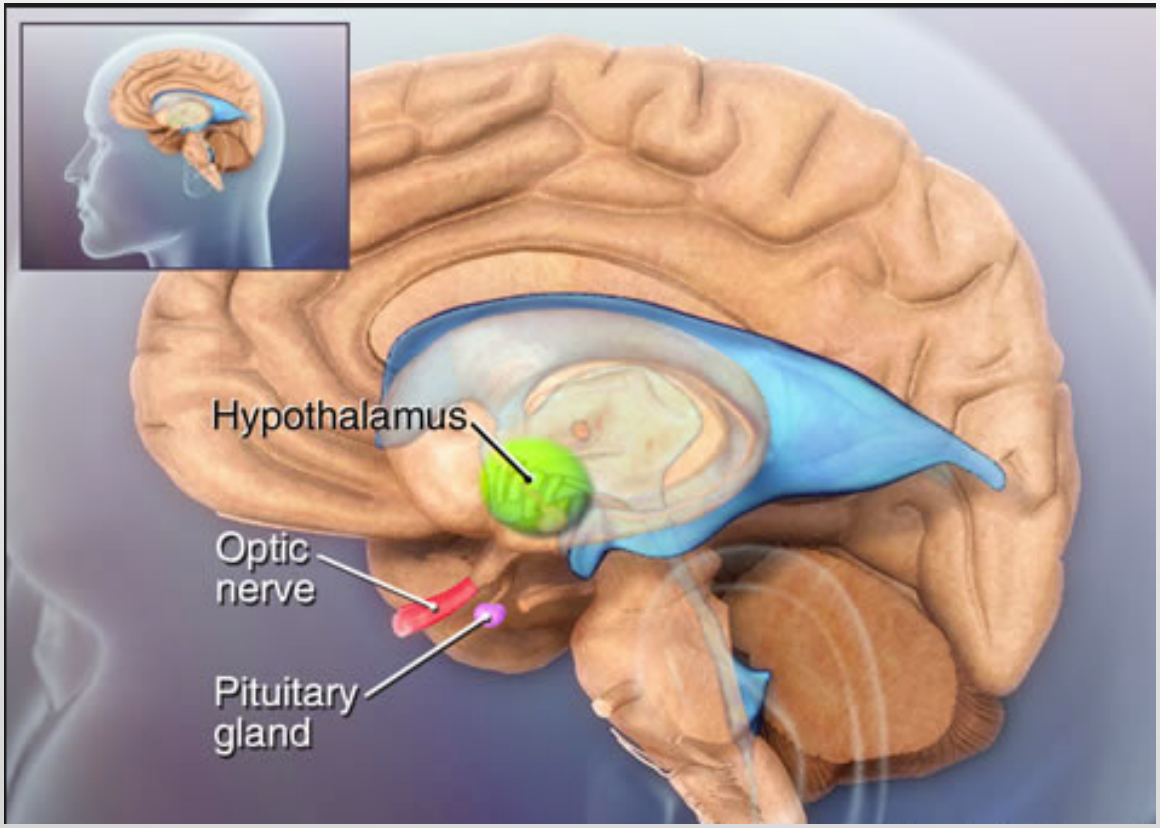
Endocrine Glands

Pituitary Gland



Hypothalamus

The endocrine and nervous systems work together to control the body and are linked by the hypothalamus.



Pituitary Gland

- A marble-sized gland at the base of the brain
- Controlled by the hypothalamus or other neural mechanisms and therefore the middle man.
- **The Master Gland"**
  - Primary function is to control other glands.
  - Produces many hormones.
    - Posterior Lobe
      - Antidiuretic hormone: responsible for fluid retention
      - Oxytocin: contraction of the uterus

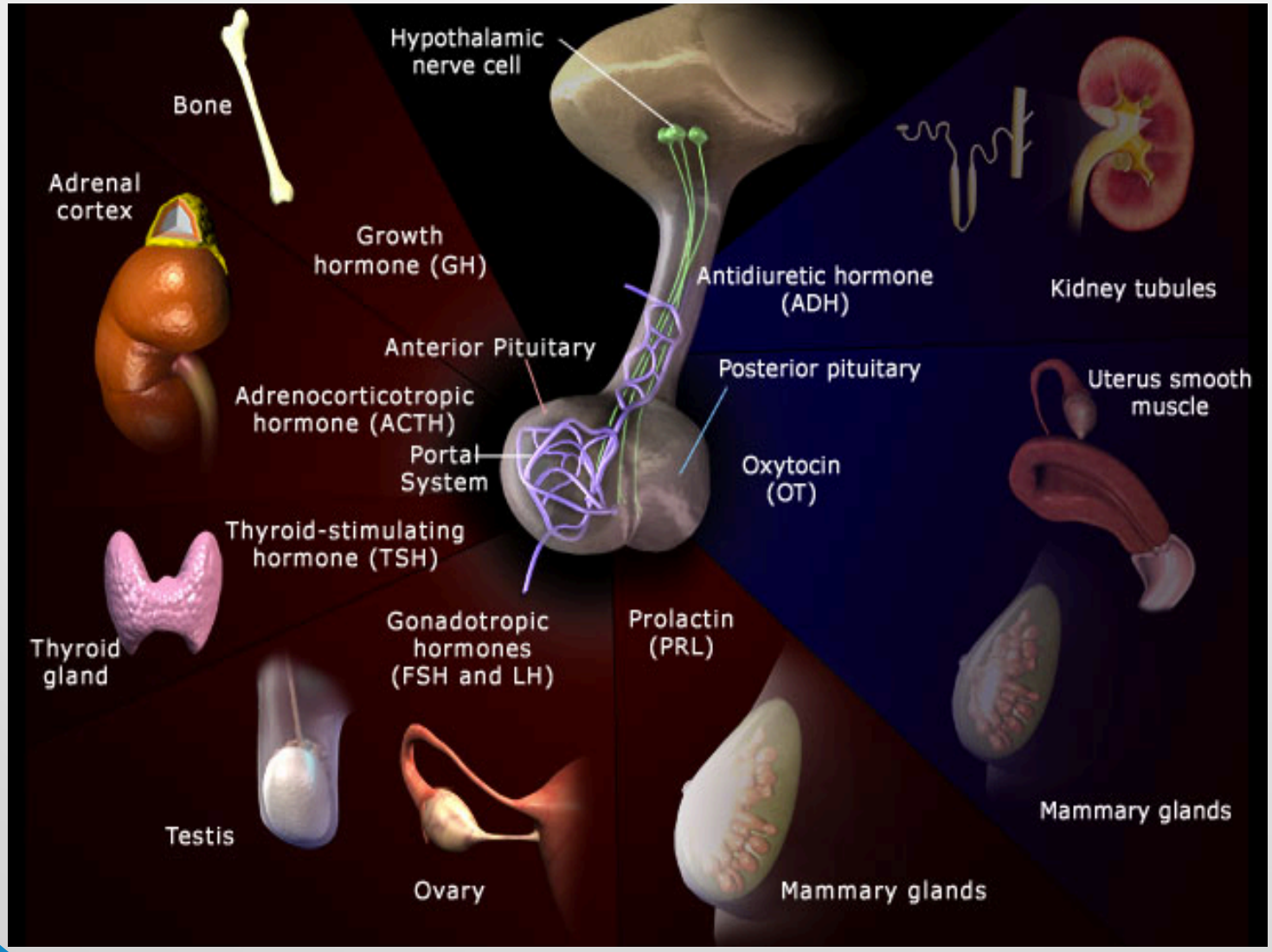
Function of Some Hormones of the Pituitary Gland

- **Oxytocin** (the natural form of pitocin)
  - stimulates gravid uterus
  - causes "let down" of milk from the breast.
- **ADH** (vasopressin) causes the kidney to retain water.
- Growth hormone (**GH**)
  - ↓ glucose usage
  - ↑ consumption of fats as an energy source
- **ACTH** stimulates the adrenal cortex to release its hormones
- **FSH & LH** stimulates maturation & release of eggs from ovary
- **TSH** stimulates the thyroid gland to release its hormones, thus ↑ metabolic rate

Pituitary Gland

- The two segments are:
  - **Anterior Pituitary:**
    - produces oxytocin and antidiuretic hormone (**ADH**)
    - produces thyroid-stimulating hormone (**TSH**)
    - growth hormone (**GH**)
    - adrenocorticotropin (**ACTH**)
    - follicle-stimulating hormone (**FSH**)
  - **Posterior Pituitary:**
    - Antidiuretic Hormone (**ADH**)
    - Oxytocin

Pituitary Gland



Anterior Pituitary Conditions

Hormone	Hyposecretion	Hypersecretion
Growth hormone (GH)	Dwarfism	Gigantism (child) Acromegaly (adult)
Prolactin (PRL)	Insufficient lactation in nursing women	Inappropriate lactation in men or non-nursing women
Luteinizing hormone (LH)	Lack of sexual development and sterility	
Follicle-stimulating hormone (FSH)	Lack of sexual development and sterility	
Thyroid-stimulating hormone (TSH)	Understimulation of the thyroid gland	Overstimulation of the thyroid

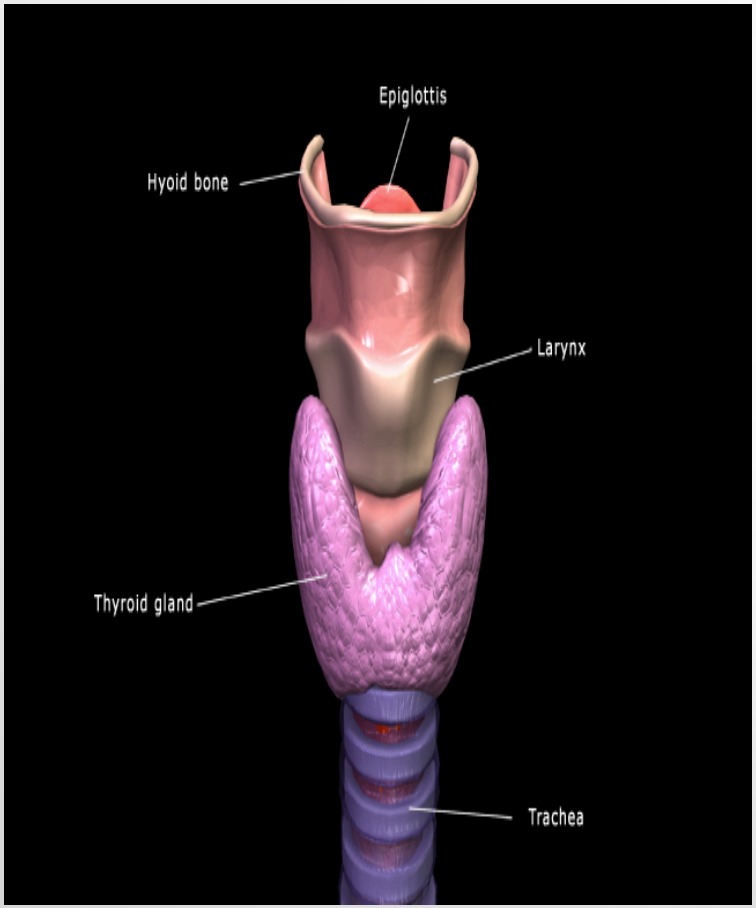
Posterior Pituitary Conditions

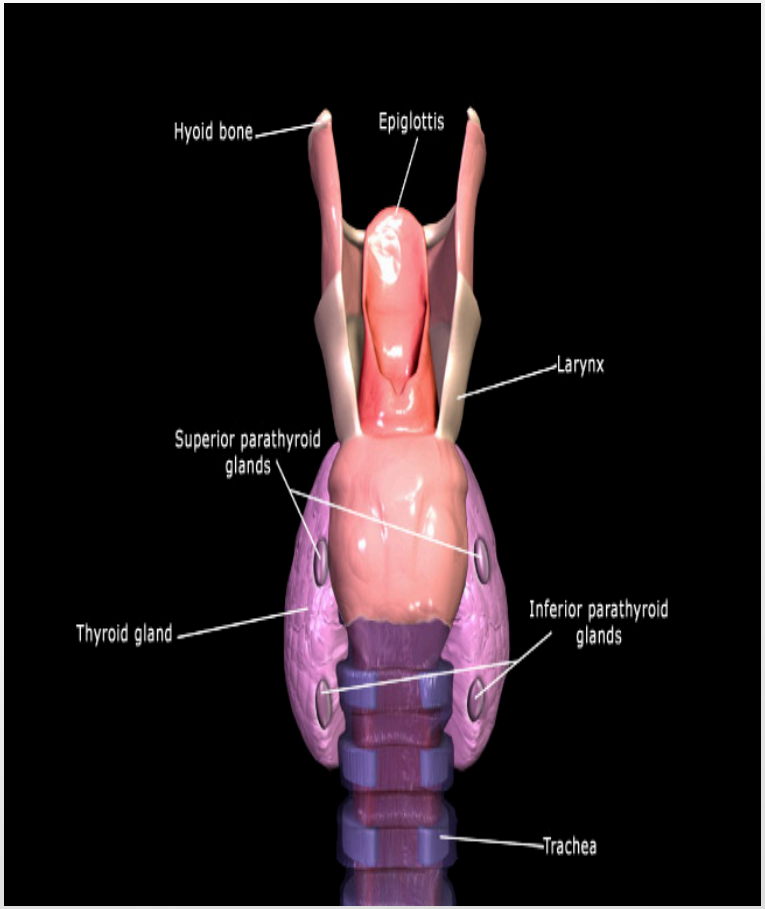
Hormone	Hyposecretion	Hypersecretion
Antidiuretic hormone (ADH)	Diabetes insipidus	Abnormal water retention
Oxytocin	Prolonged or difficult labor and delivery (uncertain)	Inappropriate ejection of milk in lactating women

Pineal Gland

- The **pineal gland** produces melatonin, derived from serotonin this hormone regulates the wake/sleep patterns and seasonal function.

Thyroid and Parathyroid





Thyroid Gland

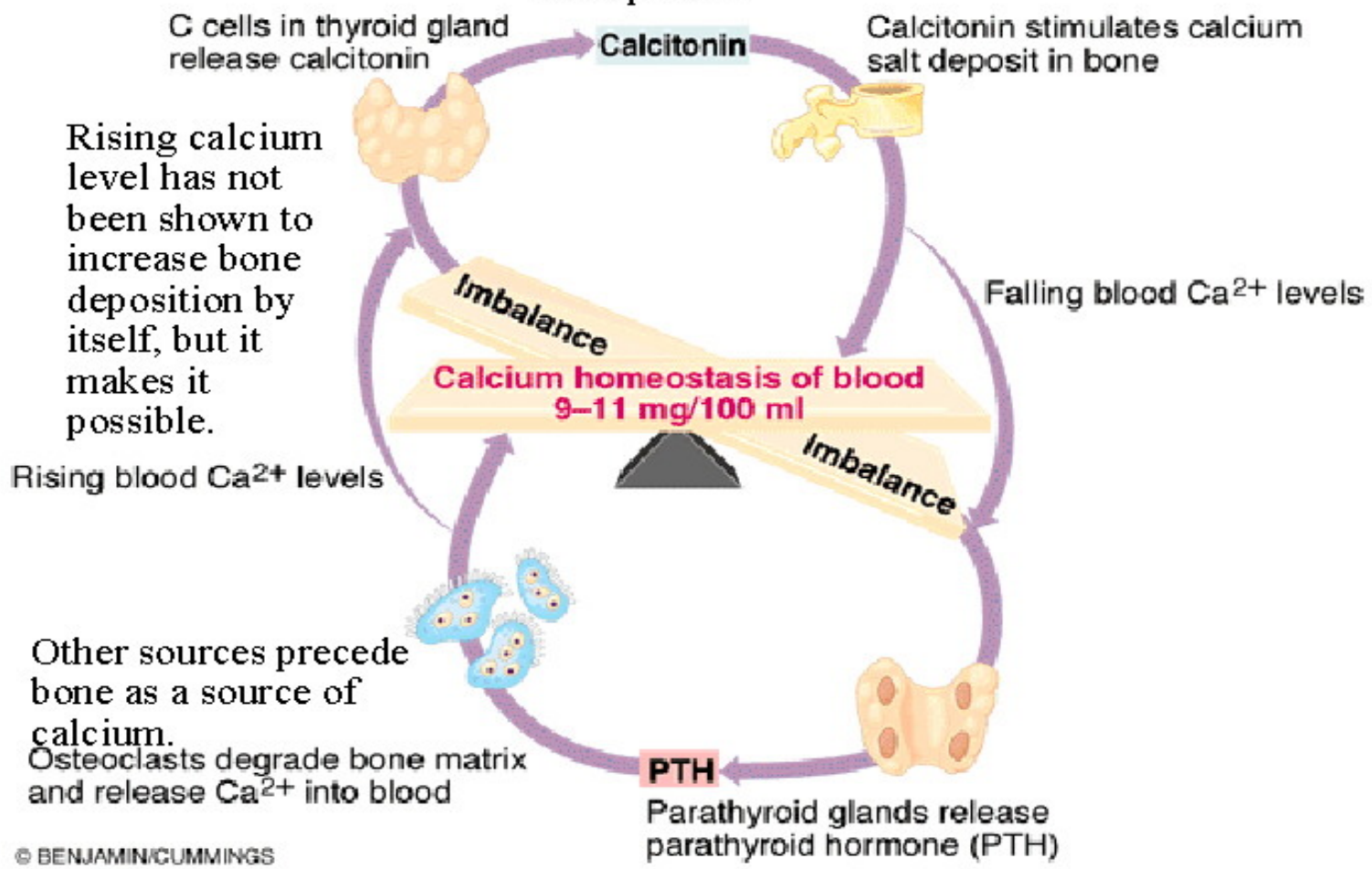
- Located along the midline of the neck
- Secretes two *nonsteroid hormones*
  - *Triiodothyronine*
  - *Thyroxine*

- *Regulates metabolism*
  - *increases protein synthesis*
  - *promotes glycolysis, gluconeogenesis, glucose uptake*
  - *Calcitonin: calcium metabolism*

Parathyroid Gland Function

- regulate the level of calcium in the body
- produce ***parathyroid hormone -*** regulates plasma calcium (osteoclast activity) and phosphate levels.
- Increases calcium, phosphate, and magnesium absorption in intestines.
- Causes removal of calcium and magnesium from urine by kidneys.

Important for bone growth in children. It is now being given to older adults to help reverse osteoporosis

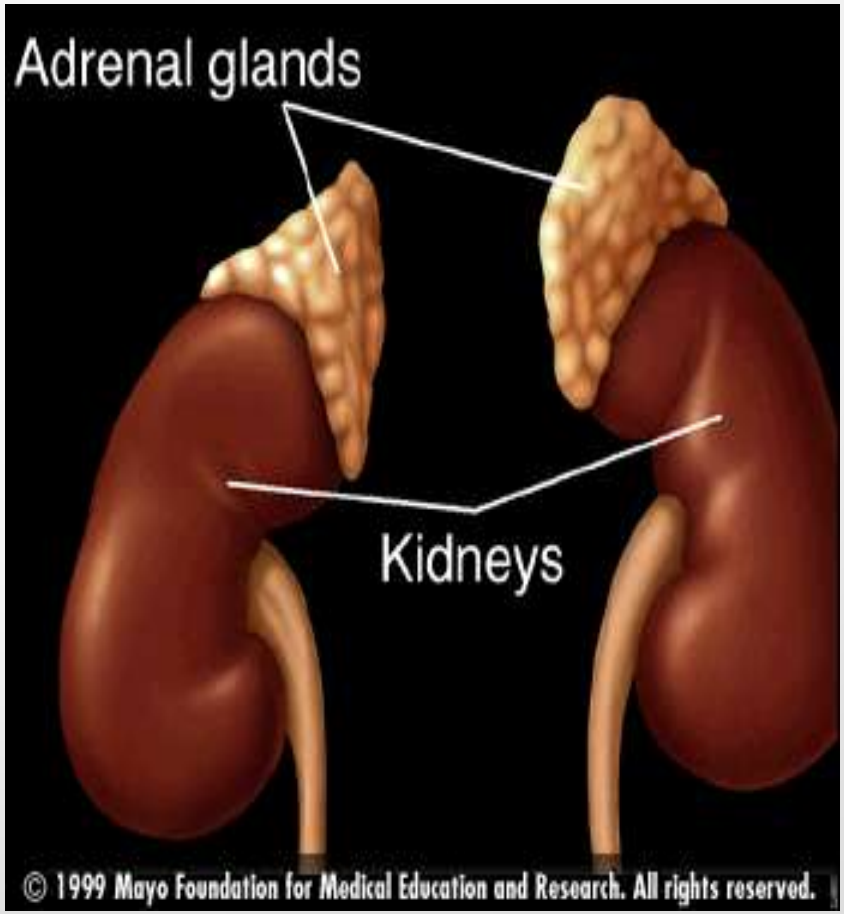


Rising calcium level has not been shown to increase bone deposition by itself, but it makes it possible.

Other sources precede bone as a source of calcium.

Adrenal Gland

- Cortex
  - Produces more than 2 dozen steroid hormones
  - corticosteriods
- Medulla
  - “fight or flight”
  - Epinephrine and norepinephrine



Adrenal Medulla

- Situated directly on top of each kidney and stimulated by the sympathetic nervous system and secretes the catecholamines
  - Epinephrine (adrenaline): elicits a fight or flight response
    - Increase H.R. and B.P.
    - Increase respiration
    - Increase metabolic rate
    - Increase glycogenolysis
    - Vasodilation
    - Norepinephrine

Adrenal Cortex

- Secretes over 30 different steroid hormones (corticosteroids)
  - Mineralocorticoids
    - Aldosterone: maintains electrolyte balance
  - Glucocorticoids
    - Cortisol:
      - Stimulates gluconeogenisis
      - Mobilization of free fatty acids
      - Glucose sparing
      - Anti-inflammatory agent

Pancreas
Endocrine and Exocrine

- In digestion pancreas secretes pancreatic amylase.
- Pancreas also secretes hormones

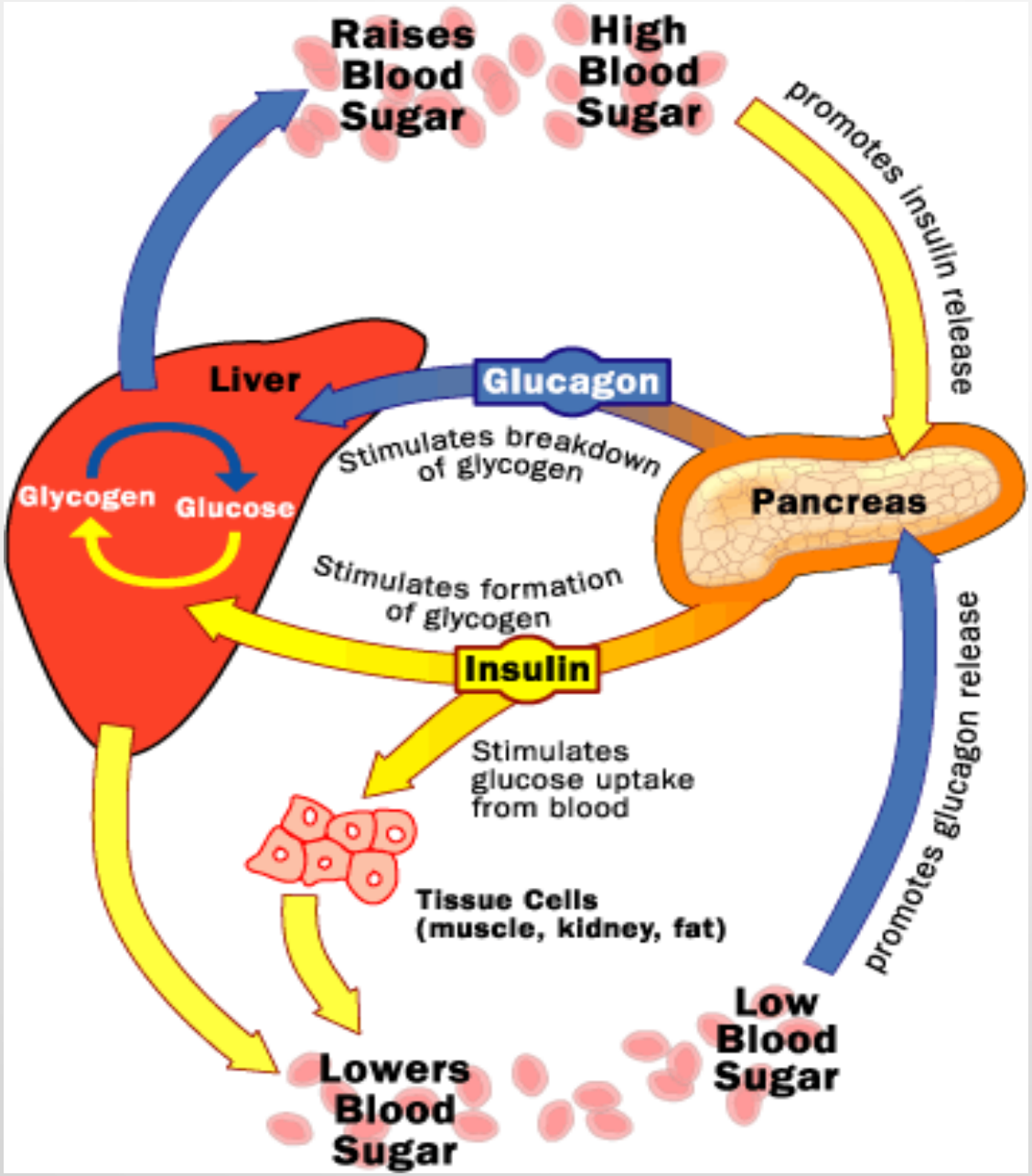
Endocrine glands

- ductless organ that releases hormones directly into the bloodstream.

Pancreas

Located slightly behind the stomach

- Insulin: reduces blood glucose
  - Facilitates glucose transport into the cells
  - Promotes glycogenesis
  - Inhibits gluconeogensis
- Glucagon: increases blood glucose
- Somatostatin


Raises Blood Sugar
High Blood Sugar
promotes insulin release
Liver
Glucagon
Glycogen
Glucose
Stimulates breakdown of glycogen
Pancreas
Stimulates formation of glycogen
Insulin
Stimulates glucose uptake from blood
Tissue Cells (muscle, kidney, fat)
promotes glucagon release
Low Blood Sugar
Lowers Blood Sugar

Gonads

- testes (testosterone) = sex characteristics
  - muscle development and maturity
- ovaries (estrogen) = sex characteristics
  - maturity and coordination

  - Gonadocorticoids
    - testosterone, estrogen, progesterone

The Endocrine Response to Exercise

Regulation of Glucose Metabolism During Exercise

- Glucagon secretion increases during exercise to promote liver glycogen breakdown (glycogenolysis)
- Epinephrine and Norepinephrine further increase glycogenolysis
- Cortisol levels also increase during exercise for protein catabolism for later gluconeogenesis.
- Growth Hormone mobilises free fatty acids
- Thyroxine promotes glucose catabolism

Regulation of Glucose Metabolism During Exercise

- As intensity of exercise increases, so does the rate of catecholamine release for glycogenolysis.
- During endurance events the rate of glucose release very closely matches the muscles need.
- When glucose levels become depleted, glucagon and cortisol levels rise significantly to enhance gluconeogenesis.

Regulation of Glucose Metabolism During Exercise

- Glucose must not only be delivered to the cells, it must also be taken up by them. That job relies on insulin.
- Exercise may enhance insulin's binding to receptors on the muscle fibre.
- Up-regulation (receptors) occurs with insulin after 4 weeks of exercise to increase its sensitivity (diabetic importance).

Regulation of Fat Metabolism During Exercise

- When low plasma glucose levels occur, the catecholamines are released to accelerate lypolysis.
- Triglycerides are reduced to free fatty acids by lipase which is activated by:
  - Cortisol
  - Epinephrine
  - Norepinephrine
  - Growth Hormone

Hormonal Effects on Fluid and Electrolyte Balance

- Reduced plasma volume leads to release of aldosterone which increases Na^+ and H_2O reabsorption by the kidneys and renal tubes.

- Antidiuretic Hormone (ADH) is released from the posterior pituitary when dehydration is sensed by osmoreceptors, and water is then reabsorbed by the kidneys.

Glucose homeostasis disorders

If hormonal disruption occurs then the consequences are significant

- Diabetes mellitus
  - Type 1 Diabetes
  - Type 2 Diabetes
  - Gestational Diabetes
  - Mature Onset Diabetes of the Young
- Hypoglycemia
  - Idiopathic hypoglycemia
  - Insulinoma
- Glucagonoma

Adrenal disorders

- Adrenal insufficiency
  - Addison's disease
  - Mineralocorticoid deficiency
- Adrenal hormone excess
  - Conn's syndrome
  - Cushing's syndrome
  - GRA/Glucocorticoid remediable aldosteronism
  - Pheochromocytoma
- Congenital adrenal hyperplasia (adrenogenital syndrome)
- Adrenocortical carcinoma

Calcium homeostasis disorders and Metabolic bone disease

- Parathyroid gland disorders
  - Primary hyperparathyroidism
  - Secondary hyperparathyroidism
  - Tertiary hyperparathyroidism
  - Hypoparathyroidism
    - Pseudohypoparathyroidism
- Osteoporosis
- Osteitis deformans (Paget's disease of bone)
- Rickets and osteomalacia

Pituitary gland disorders

- **Posterior pituitary**
  - Diabetes insipidus
- **Anterior pituitary**
  - Hypopituitarism
- **Pituitary tumours**
  - Pituitary adenomas
  - Prolactinoma (or Hyperprolactinemia)
  - Acromegaly, gigantism
  - Cushing's disease