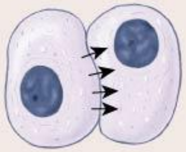
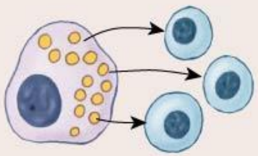
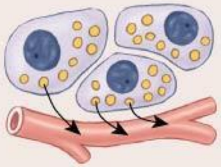
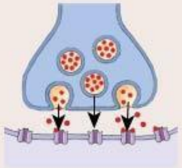
Competency 1:The Endocrine Control System

The Endocrine Control System
The student will be able to understand the endocrine system by:

1.Distinguishing the structure and functions of the major endocrine organs.
2. Differentiating hormone types and mechanisms of action.
3. Explaining hypothalamus-pituitary gland relationships.
4.Explaining the homeostatic imbalances of the endocrine system.

Table 18-1 Mechanisms of Intercellular Communication.

Table 18–1 Mechanisms of Intercellular Communication

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

The Endocrine System vs The Nervous System

Functional Anatomy

The endocrine system together with the nervous system maintain homeostasis by coordinating and regulating the activities of cells, tissues, organs, and systems throughout the body. The difference is that the effects of the nervous system synaptic communication are generally short lived and more localized, while the effects of the endocrine communication are generally long lasting and more wide spread.

Endocrine cells and tissues produce about 30 different hormones (chemical messengers). The endocrine system controls and coordinates many body processes.

Endocrine cells release hormones or paracrines into the extracellular fluid. Unlike exocrine cells, endocrine organs are scattered throughout the body.

Figure 18-1 Organs and Tissues of the Endocrine System (Part 1 of 2).

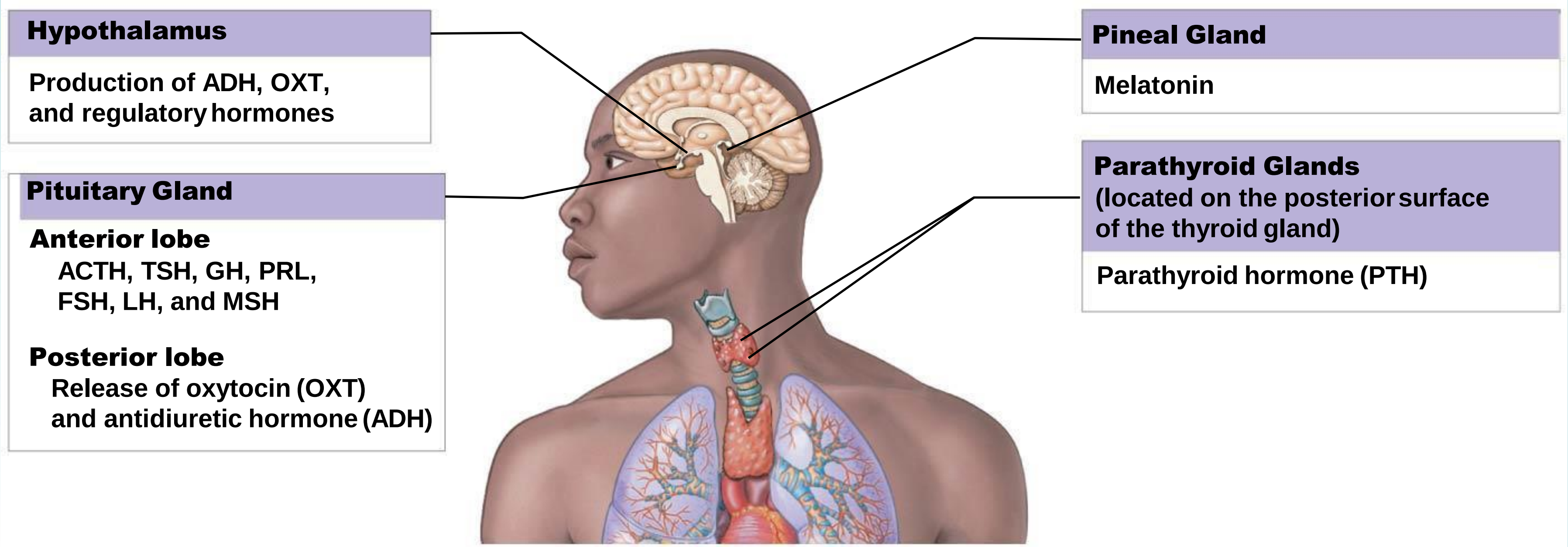


Figure 18-1 Organs and Tissues of the Endocrine System (Part 2 of 2).

Thyroid Gland

Thyroxine (T_4)
Triiodothyronine (T_3)
Calcitonin (CT)

Adrenal Gland

Medulla
Epinephrine (E)
Norepinephrine (NE)

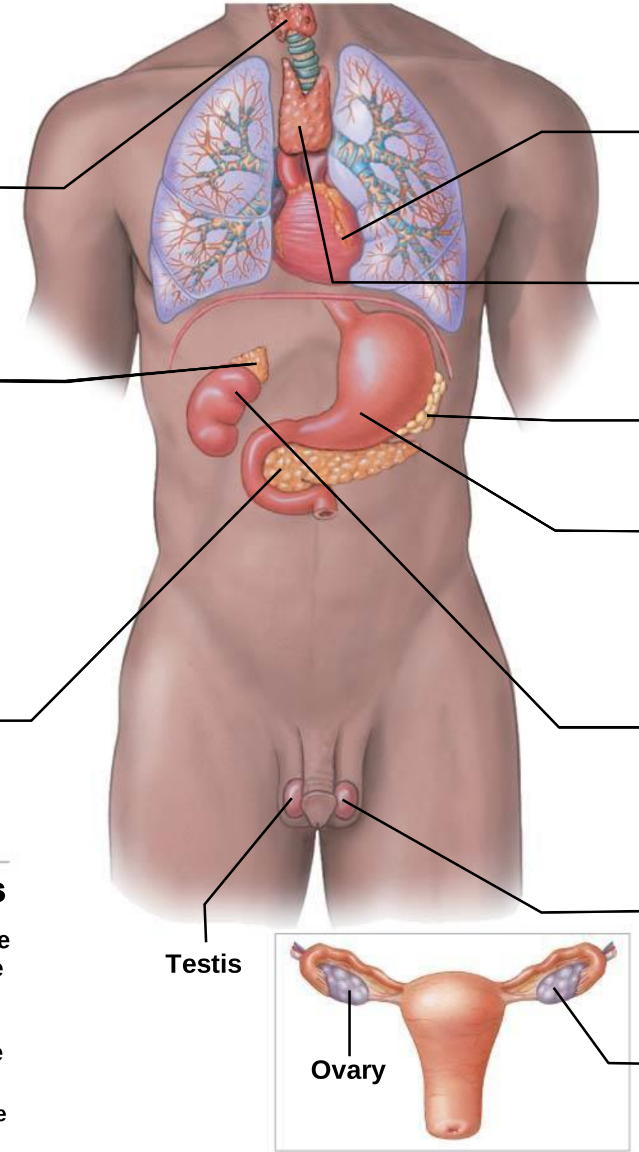
Cortex
Cortisol, corticosterone, aldosterone, androgens

Pancreatic Islets

Insulin, glucagon

KEY TO PITUITARY HORMONES

ACTH	Adrenocorticotropic hormone
TSH	Thyroid-stimulating hormone
GH	Growth hormone
PRL	Prolactin
FSH	Follicle-stimulating hormone
LH	Luteinizing hormone
MSH	Melanocyte-stimulating hormone



Organs with Secondary Endocrine Functions

Heart
- Atrial natriuretic peptide (ANP)
- Brain natriuretic peptide (BNP)

See Chapter 21

Thymus (Undergoes atrophy during adulthood)
- Thymosins

See Chapter 22

Adipose Tissue
- Leptin

Digestive Tract
Secretes numerous hormones involved in the coordination of system functions, glucose metabolism, and appetite

See Chapter 25

Kidneys
- Erythropoietin (EPO)
- Calcitriol

See Chapters 19 and 26

Gonads
Testes (male)
Androgens (especially testosterone), inhibin

Ovaries (female)
Estrogens, progesterone, inhibin

See Chapters 28 and 29

Hormone Classification

Hormones are chemical messengers. Most hormones are released by endocrine cells or glands into the bloodstream. They travel freely or bound to specific carrier proteins to specific target cells in other tissues. However, some hormones like factors called paracrines can be released locally into the extracellular fluid and affect cells of the nearby tissues that have the proper receptors. Hormones act by regulating the metabolic activities of body cells.

According to their structure, there are 3 classes of hormones:

1. Amino acid derivatives, 2. Peptide hormones, and 3. Lipid derivatives.

HORMONES

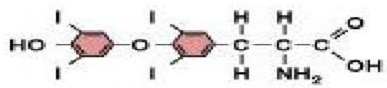
The hormones of the body can be divided into three groups on the basis of their chemical structure.

Amino Acid Derivatives

Amino acid derivatives are small molecules that are structurally related to amino acids, the building blocks of proteins.

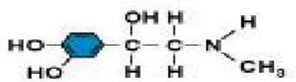
Derivatives of Tyrosine

Thyroid Hormones



Thyroxine (T_4)

Catecholamines

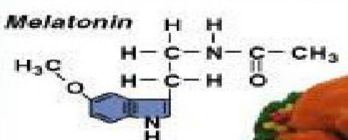


Epinephrine

Sources of tyrosine include meat, dairy, and fish.

Derivative of Tryptophan

Melatonin



Turkey is a well known source of tryptophan. Other sources include chocolate, oats, bananas, dried dates, milk, cottage cheese, and peanuts.

Peptide Hormones

Peptide hormones are chains of amino acids. Most peptide hormones are synthesized as **prohormones**—inactive molecules that are converted to active hormones before or after they are secreted.

Glycoproteins

These proteins are more than 200 amino acids long and have carbohydrate side chains. The glycoproteins include *thyroid-stimulating hormone* (TSH), *luteinizing hormone* (LH), and *follicle-stimulating hormone* (FSH) from the anterior lobe of the pituitary gland, as well as several hormones produced in other organs.

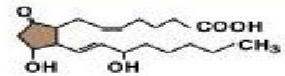
Short Polypeptides/Small Proteins

This group of peptide hormones is large and diverse. It includes hormones that range from **short chain polypeptides**, such as *antidiuretic hormone* (ADH) and *oxytocin* (OXT) (each 9 amino acids long), to **small proteins**, such as *growth hormone* (GH; 191 amino acids) and *prolactin* (PRL; 198 amino acids). This group includes all the hormones secreted by the hypothalamus, heart, thymus, digestive tract, pancreas, and posterior lobe of the pituitary gland, as well as several hormones produced in other organs.

Lipid Derivatives

There are two classes of lipid derivatives: **eicosanoids**, derived from arachidonic acid, a 20-carbon fatty acid; and **steroid hormones**, derived from cholesterol.

Eicosanoids

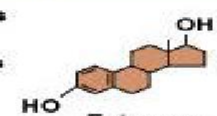


Prostaglandin E

Eicosanoids (ī-kō-sa-noydz) are important paracrine factors that coordinate cellular activities and affect enzymatic processes (such as blood clotting) in extracellular fluids. Some eicosanoids, such as **leukotrienes** (loo-kō-TRĪ-ēns), have secondary roles as hormones. A second group of eicosanoids—**prostaglandins**—are involved primarily in coordinating local cellular activities. In some tissues, prostaglandins are converted to **thromboxanes** (throm-BOX-ānz) and **prostacyclins** (pros-ta-SĪ-klinz), which also have strong paracrine effects.

Aspirin suppresses the production of prostaglandins.

Steroid Hormones



Estrogen

Steroid hormones are released by the reproductive organs (androgens by the testes in males, estrogens and progestins by the ovaries in females), by the cortex of the adrenal glands (corticosteroids), and by the kidneys (calcitriol). Because circulating steroid hormones are bound to specific transport proteins in the plasma, they remain in circulation longer than do secreted peptide hormones.

Classes of Hormones

1. **Amino Acid Derivatives:** Also known as biogenic amines. They are small molecules structurally related to amino acids. They include: 1- the derivatives of the amino acid tyrosine which include epinephrine, norepinephrine (catecholamines) and the thyroid hormones Thyroxine and Triiodothyronine; and 2- the derivatives of the amino acid tryptophan which include Dopamine, serotonin, and melatonin.

2. **Peptide Hormones:** These are formed by chains of amino acids join by peptide bonds. Most of these hormones are released as prohormones, which are inactive molecules to be activated by specific chemical before or after secreted. There are two types of peptide hormones: glycoproteins and polypeptides which are short polypeptides of small proteins.

Glycoproteins: are polypeptide chains with more than 200 amino acids and with carbohydrate side chains. These peptide hormones include: TSH or thyroid stimulating hormone, LH or luteinizing hormone, and FSH or follicle stimulating hormone. Other hormones that belong to this category are erythropoietin released by the kidneys, and inhibin released by the gonads.

Polypeptides: some are short polypeptide chains. These include the antidiuretic hormone or ADH and oxytocin (9 amino acids each).

Others are small proteins or long polypeptide chains such as insulin (51 aa) growth hormone or GH (191 aa) and prolactin or PRL (198 aa). This group also includes all of the hormones produced by the hypothalamus, heart (ANP), thymus, digestive tract, pancreas, parathyroid glands, and calcitonin from the thyroid gland.

This group also includes some hormones secreted by the anterior pituitary gland such as ACTH or adrenocorticotropic hormone, and MSH or melanocyte stimulating hormone.

3. Lipid Derivatives: These include: eicosanoids derived from the fatty acid arachidonic acid and steroid hormones derived form cholesterol.

Eicosanoids: are derived from the fatty acid arachidonic acid, and they are small molecules that have a five-carbon ring at one end. They are paracrines that help to coordinate cellular activities and enzymatic reactions that take place in the extracellular fluid. Some important eicosanoids include: 1- **prostaglandins** are produced by most body tissues and are involved in coordinating local cellular activities. Prostraglandins can be converted to thromboxanes and prostacyclins. They help regulate blood pressure, increase uterine contractions during child birth, and enhance blood clotting and the inflammatory response.

2- Leukotrienes which are secreted by active white blood cells and help coordinate tissue response to injury and defense.

Steroids hormones: they are synthesized from cholesterol.

They are carried by specific transport proteins in the plasma, therefore and they remain in circulation longer than peptide hormones.

These include: 1- the gonadal hormones released by the male testes such as androgens (testosterone) and the female ovaries such as estrogens, and progesterone; 2- the corticosteroids produced by the adrenal cortex; and 3- the hormone calcitriol produced by the kidneys.

Transport and Inactivation of Hormones

Hormones can circulate freely or bound to special carrier proteins

Free hormones stay functional for less than an hour because:

1 They diffuse out of the blood stream and bind to receptors in the cell of the target tissues.

2 They are broken down and absorbed in the liver or kidneys.

3 They are broken down by enzymes in the plasma or interstitial fluid.

Thyroid and Steroid hormones stay in circulation longer than other hormones because 1- most (99%) of them are bound to special transport proteins in the blood, 2- there is an equilibrium between free and bound forms, and 3- the bloodstream contains a substantial reserve of bound hormones.

Mechanism of Hormone Action

The binding of a hormone may modify the cellular processes of a cell by: 1- changing the genetic activity, 2- changing the rate of proteins synthesis, and 3- changing the membrane permeability. These actions can change the types, activities, or quantities of enzymes and structural proteins of their target cells. They may stimulate or inhibit the production of enzymes or structural proteins by turning on or off the proper genes. They may activate or deactivate and enzyme by changing its shape. Also, they may increase or decrease the rate of protein or enzymatic synthesis by altering the rate of transcription and translation.

Hormone Receptors

1. They are proteins to which a particular hormone binds strongly.
2. They can respond to several different hormones.
3. Different tissues can have different combinations of receptors.
4. The sensitivity of a cell to a particular hormone depends on presence or absence of receptors in the plasma membrane or inside the cell.

The hormone receptors are dynamic, and they can change in number.

Down-regulation

It occurs when the presence of a hormone triggers a decrease in number of hormone receptors

When the levels of the hormone are high, the cell becomes less sensitive to the hormone.

Up-regulation

It occurs when the absence of a hormone triggers an increase in the number of hormone receptors

When the levels of the hormone are low, the cell become more sensitive to the hormone.

Hormones and Cell or plasma Membrane Receptors

Catacholamines and peptide hormones are not lipid soluble, they are water soluble, so they can not cross the plasma membrane so they bind to receptors in the outer surface of the cell membrane or extracellular receptors.

Steroid and Thyroid hormones are lipid soluble and diffuse across the plasma membrane, then bind to receptors inside the cell or intracellular receptors

Hormones that bind to extracellular receptors in the plasma membrane can not have a direct effect on the cellular activities of the target tissues. They need to use intracellular intermediaries or second messenger to produce their action.

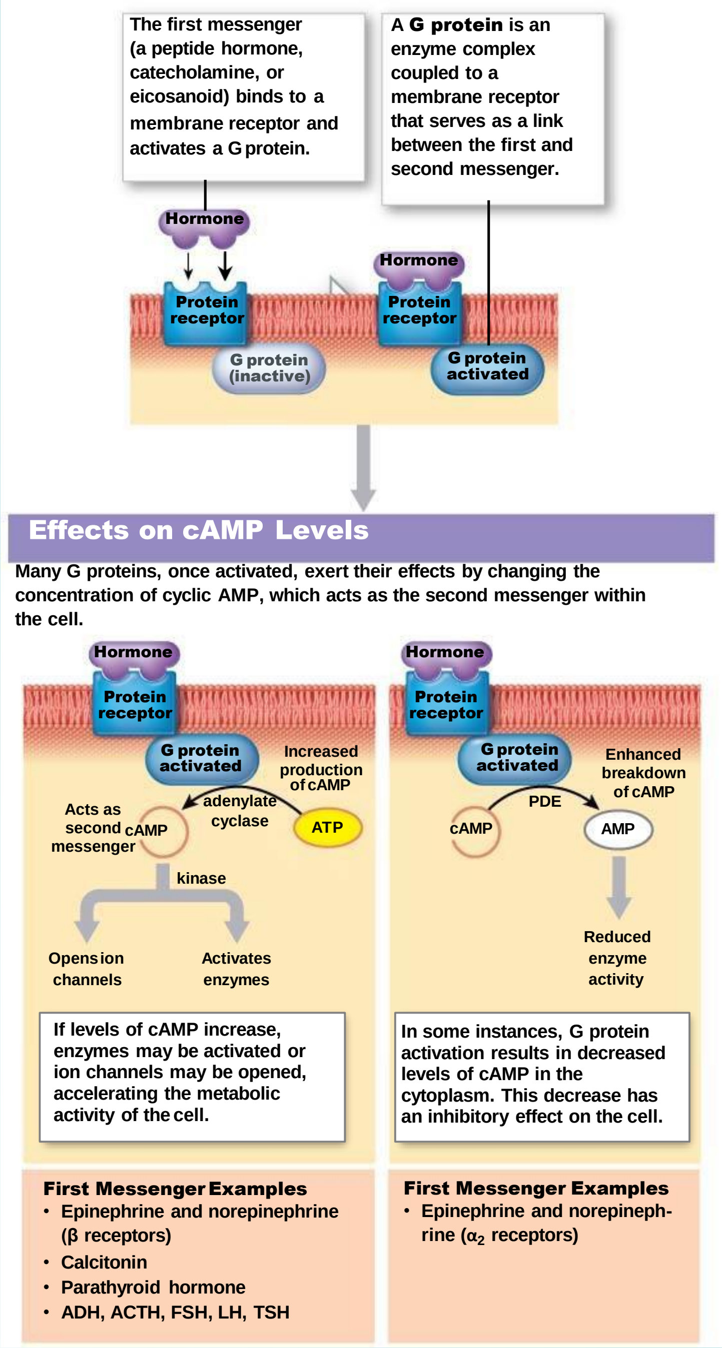
The hormone acts as a first messenger as it binds to the extracellular receptor, this promotes the release of a second-messenger in the cell. The second messenger, in turn activates, inhibits, or serves as a cofactor of an enzyme. These actions may result in change in the metabolic reaction rates. Examples of second messenger include cAMP, cGMP, and Ca^{2+}

The process of amplification takes place when a small number of hormone molecules bind to extracellular receptors, and thousand of second messengers may appear. This magnifies the effect of the hormone on the target cell.

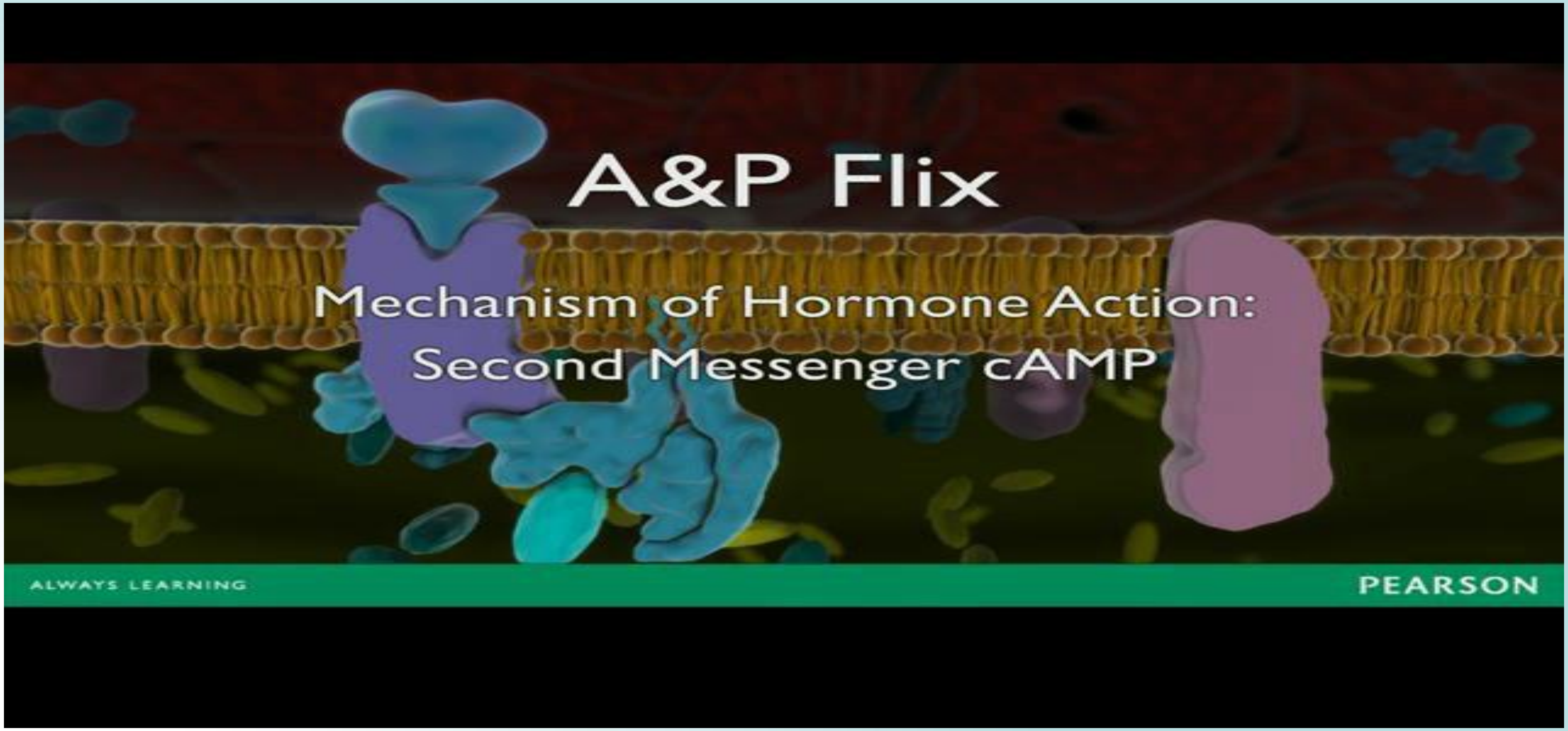
The first and the second messengers are linked by a **G-protein** which is an enzyme complex coupled to a membrane receptor. The proteins binds GTP (guanosin triphosphate).

The G protein and cAMP interaction accelerates the metabolic activity of the cell. It is an step by step process that increases the level of cAMP, but this increase is short lived because an enzyme converts cAMP to AMP.

Figure 18-3 G Proteins and Second Messengers (Part 1 of2).

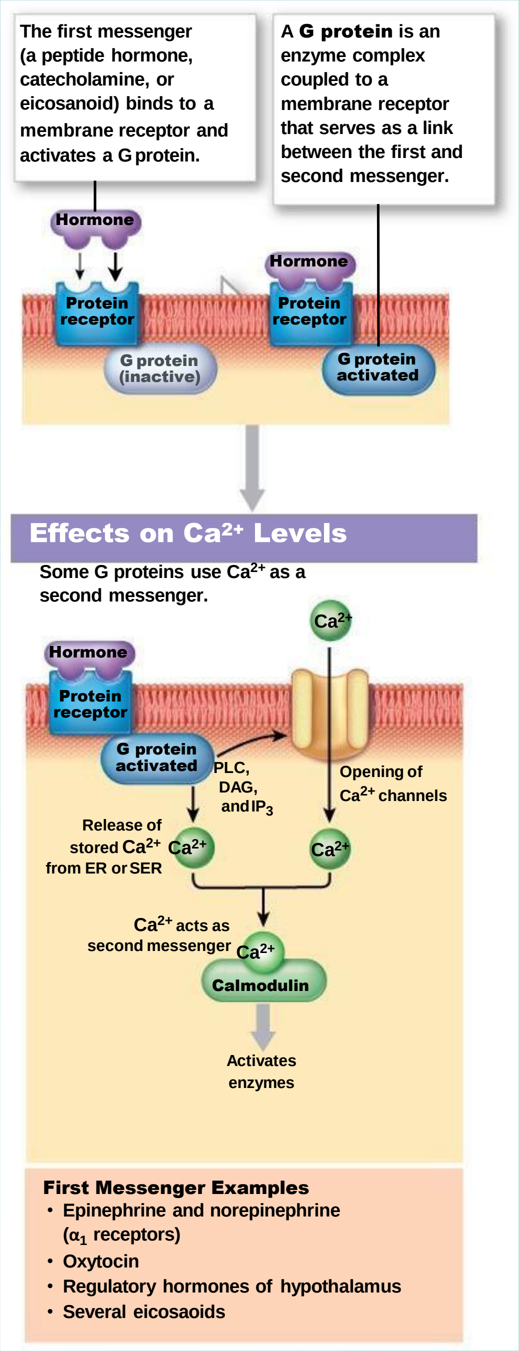


A&P Flix Animation: Mechanism of Hormone Action: Second Messenger cAMP



Activated G proteins act with calcium ions by triggering opening of calcium ion channels in the membrane and causing release of calcium ions from intracellular stores. The calcium ions can activate calmodulin which increases cellular changes.

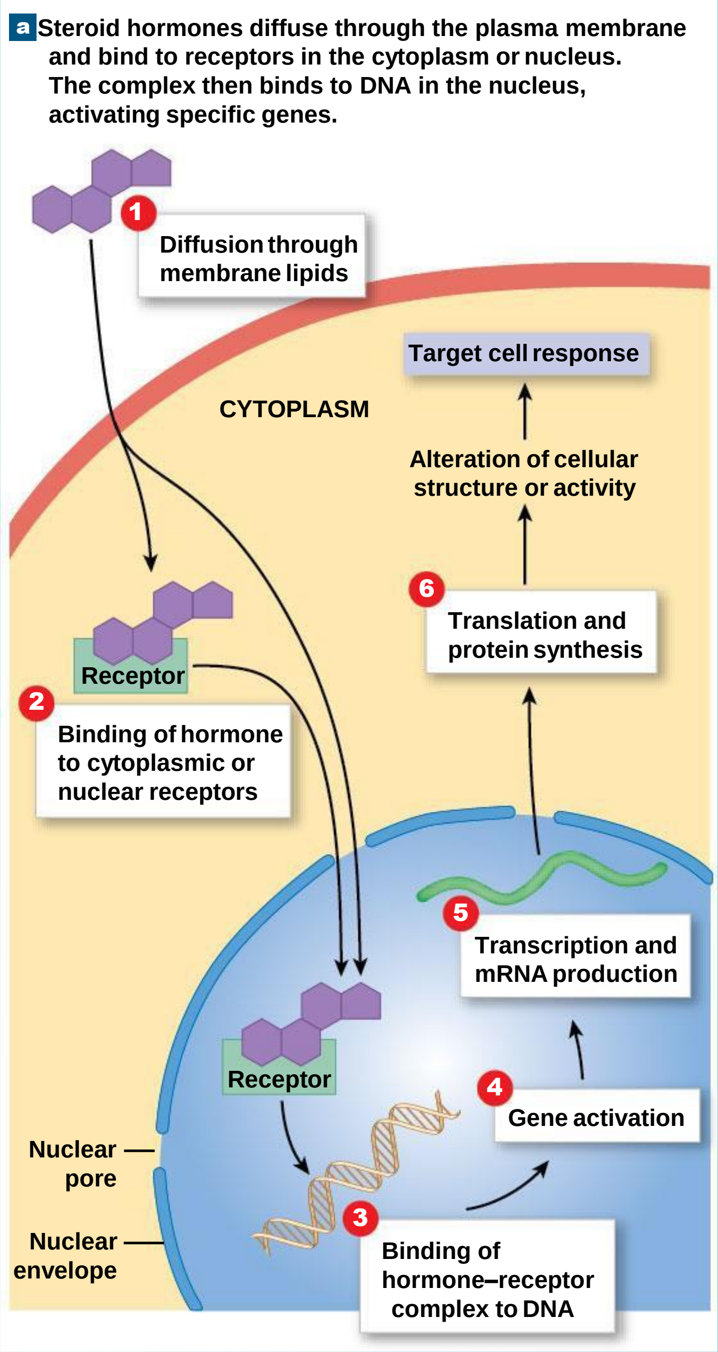
Figure 18-3 G Proteins and Second Messengers (Part 2 of 2).



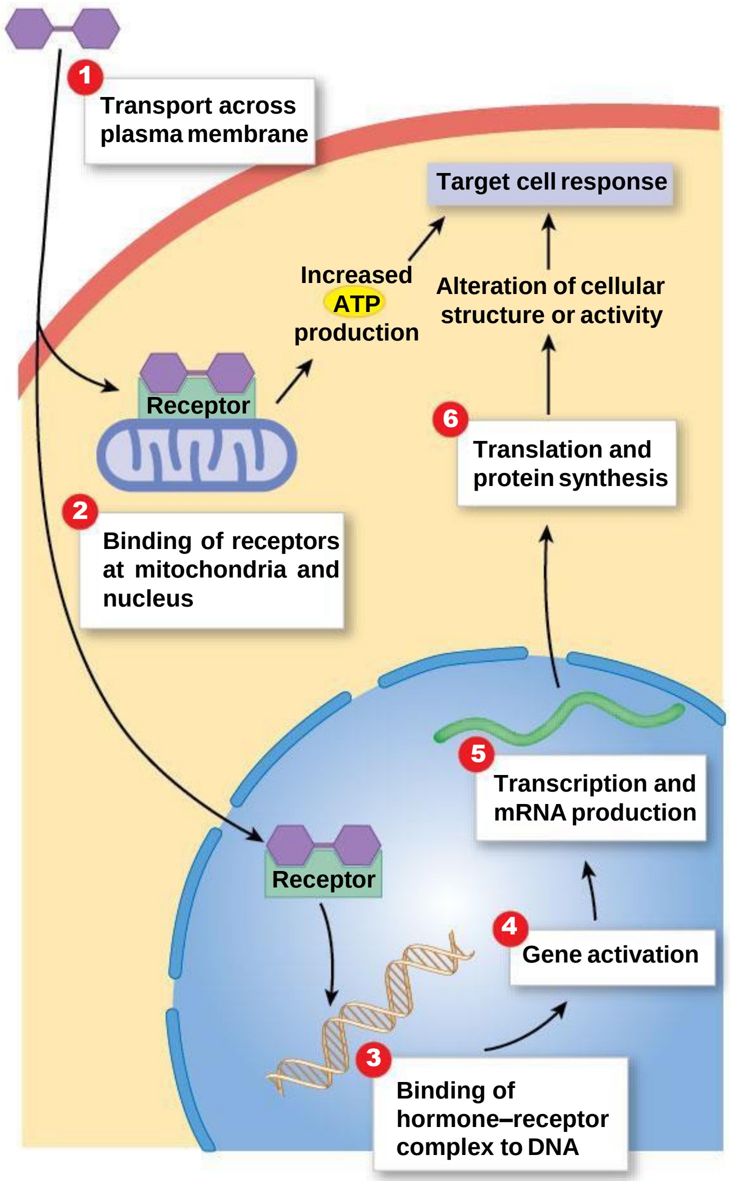
Hormones and Intracellular Receptors

Steroid hormones can alter the rate of DNA transcription in the nucleus which changes synthesis of enzymes and structural proteins. In this way the hormone directly affects the activity and structure of the target cell. Good examples of these hormones action include the steroid hormones testosterone, which increases muscle mass.

The thyroid hormones bind to receptors within the nucleus and on the mitochondria. They activate genes or change the rate of transcription increasing ATP production and metabolic rate.


a Steroid hormones diffuse through the plasma membrane and bind to receptors in the cytoplasm or nucleus. The complex then binds to DNA in the nucleus, activating specific genes.
1 Diffusion through membrane lipids
Target cell response
CYTOPLASM
Alteration of cellular structure or activity
6 Translation and protein synthesis
Receptor
2 Binding of hormone to cytoplasmic or nuclear receptors
5 Transcription and mRNA production
Receptor
4 Gene activation
Nuclear pore
Nuclear envelope
3 Binding of hormone–receptor complex to DNA

b Thyroid hormones enter the cytoplasm and bind to receptors in the nucleus to activate specific genes. They also bind to receptors on mitochondria and accelerate ATP production.



Hormone Secretion

Hormone Secretion is mainly controlled by negative feedback mechanisms. A stimulus triggers the production of the hormone that then reduces the intensity of the stimulus.

Three types of stimuli can trigger the release of a hormone: humoral, neural, and hormonal.

May involve only one hormone

Humoral Stimuli: it produces changes of chemical composition (ions or nutrients) in the extracellular fluids. For example, the parathyroid glands monitor calcium levels in the blood. Other hormones secreted in response to humoral stimuli include insulin, glucagon, aldosterone, and several hormones released by the digestive tract.

Hormonal Stimuli: may involve one or more intermediary steps where two hormones are involved. It is produced by hormones released in response to the presence or removal of other hormones. A good example of this type of stimuli are the pituitary hormones, which are released or inhibited by hypothalamic regulatory hormones, and the tropic hormones released by the anterior pituitary gland that control the activities of the thyroid gland, adrenal cortex, and reproductive organs.

Neural Stimuli: are stimuli caused by the arrival of a neurotransmitter at the neuroglandular junction. The sympathetic nervous system stimulates the adrenal medulla to release epinephrine and norepinephrin. Other hormones released by neural stimuli are oxytosin and ADH from the posterior pituitary due to stimuli of hypothalamic neurons.

The hypothalamus exerts the highest level of hormonal control

Introduction to the Endocrine System

The major processes controlled and integrated by the endocrine system are reproductive, growth, development, defense against stress, electrolyte, water, nutrient, and energy balance in the blood, and regulation of cellular metabolism. The endocrine system includes small organs or glands spread throughout the body. It also includes all the endocrine or hormone producing cells of the body such as those in the small intestine, stomach, kidney, heart, placenta, and the paracrine factors releasing cells. Endocrine glands produce hormones, which are chemical messengers released in one tissue, but transported in the blood stream to other tissues or target cells where they produce a specific response. The target tissue has receptors that bind to specific hormones, so that they can respond properly to the message delivered.

Endocrine Glands

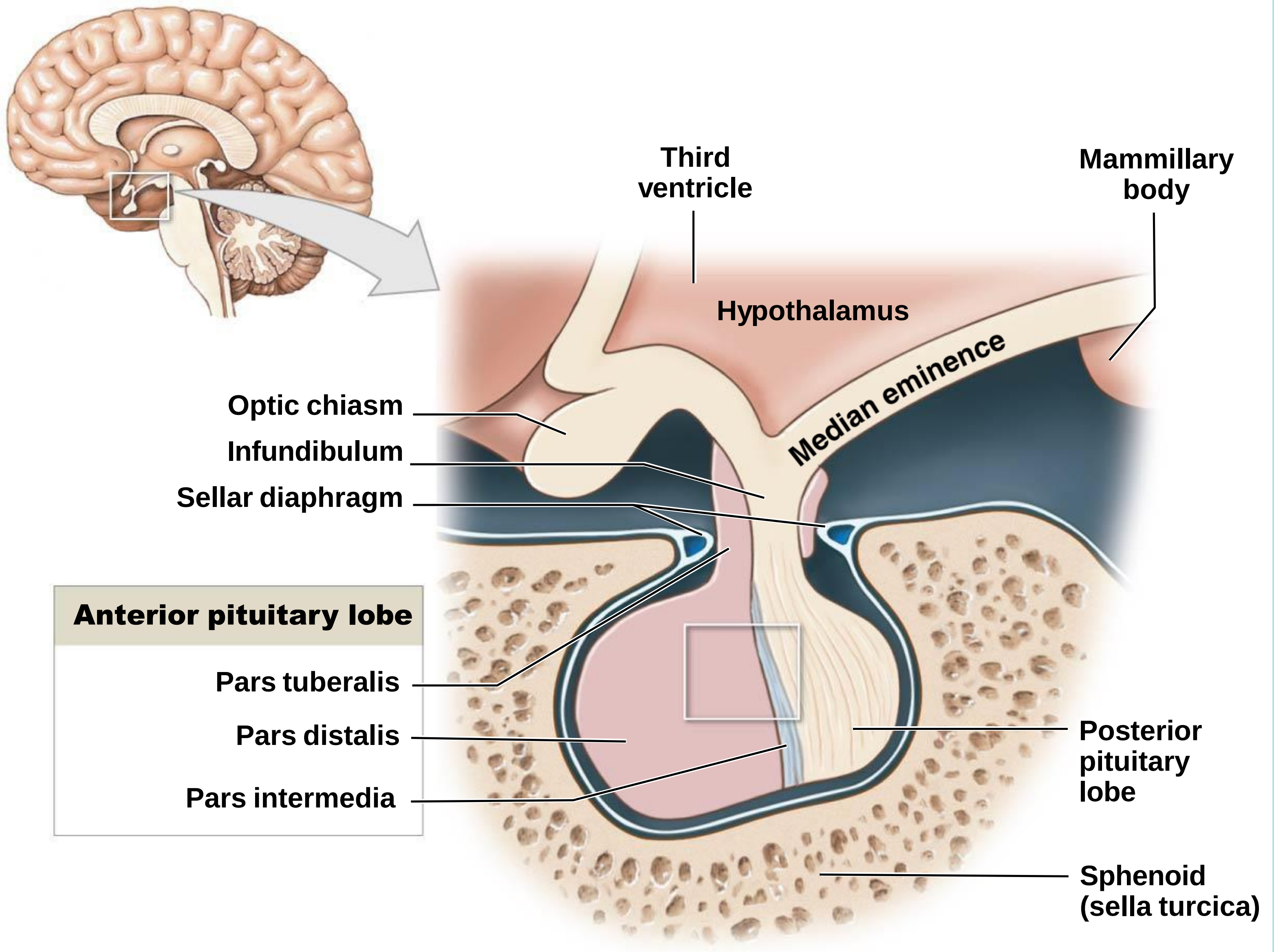
They are ductless glands formed by secretory or endocrine cells that release hormones into the extracellular fluid or body fluids. They are well vascularized and usually the cells are arranged into cords and branching networks in close contact with capillaries. They include the hypothalamus, pituitary gland, pineal gland, thyroid gland, parathyroid glands, adrenal glands, and pancreas.

Major Endocrine Organs

1. The Pituitary or Hypophysis Gland

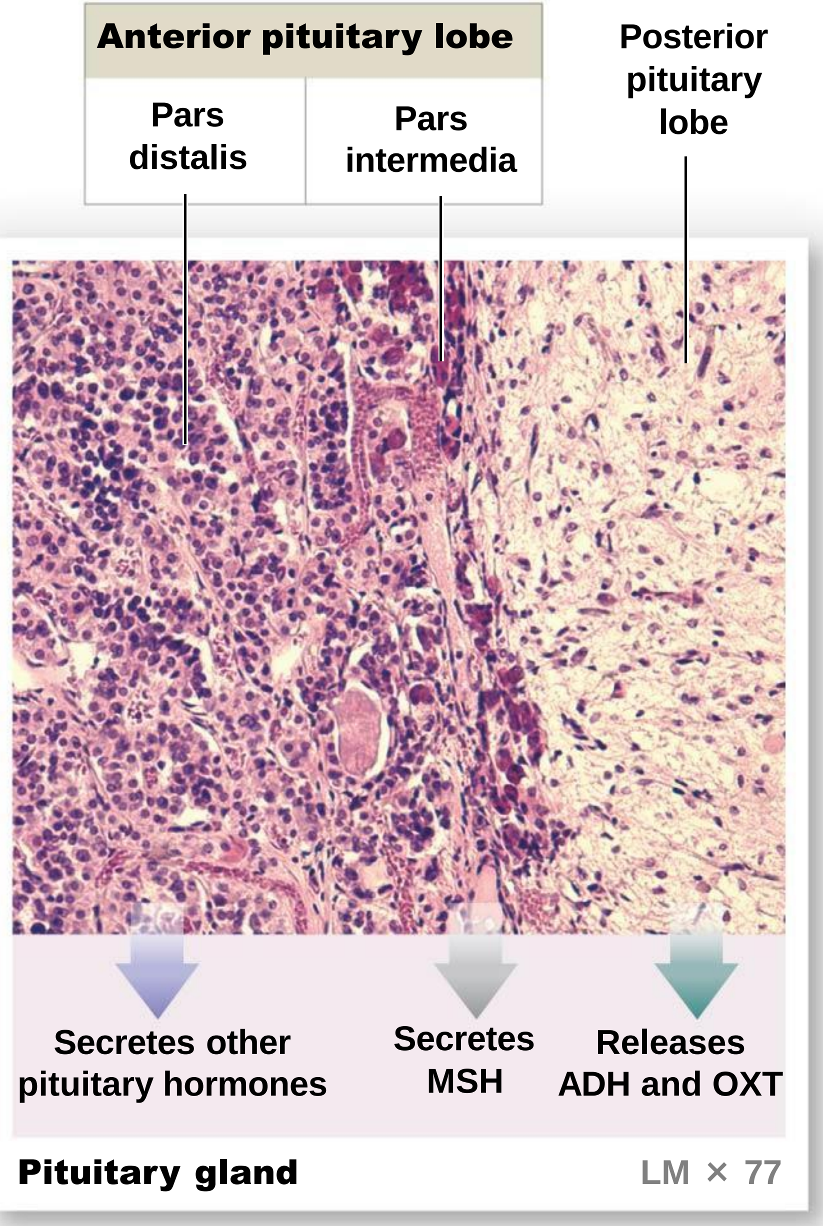
Located in the hypophyseal fossa hanging from the base of the hypothalamus of the brain by the infundibulum. It consists of a hormone producing portion, the anterior pituitary or adenohypophysis, and a neural portion, the posterior pituitary or neurohypophys, which is considered an extension of the hypothalamus. It releases nine important hormones, seven are produced and released by the anterior part, and 2 are produced by the hypothalamus, but released by the posterior part of the pituitary gland.

Figure 18-6a The Anatomy and Orientation of the Pituitary Gland.



a Relationship of the pituitary gland to the hypothalamus

Figure 18-6b The Anatomy and Orientation of the Pituitary Gland.

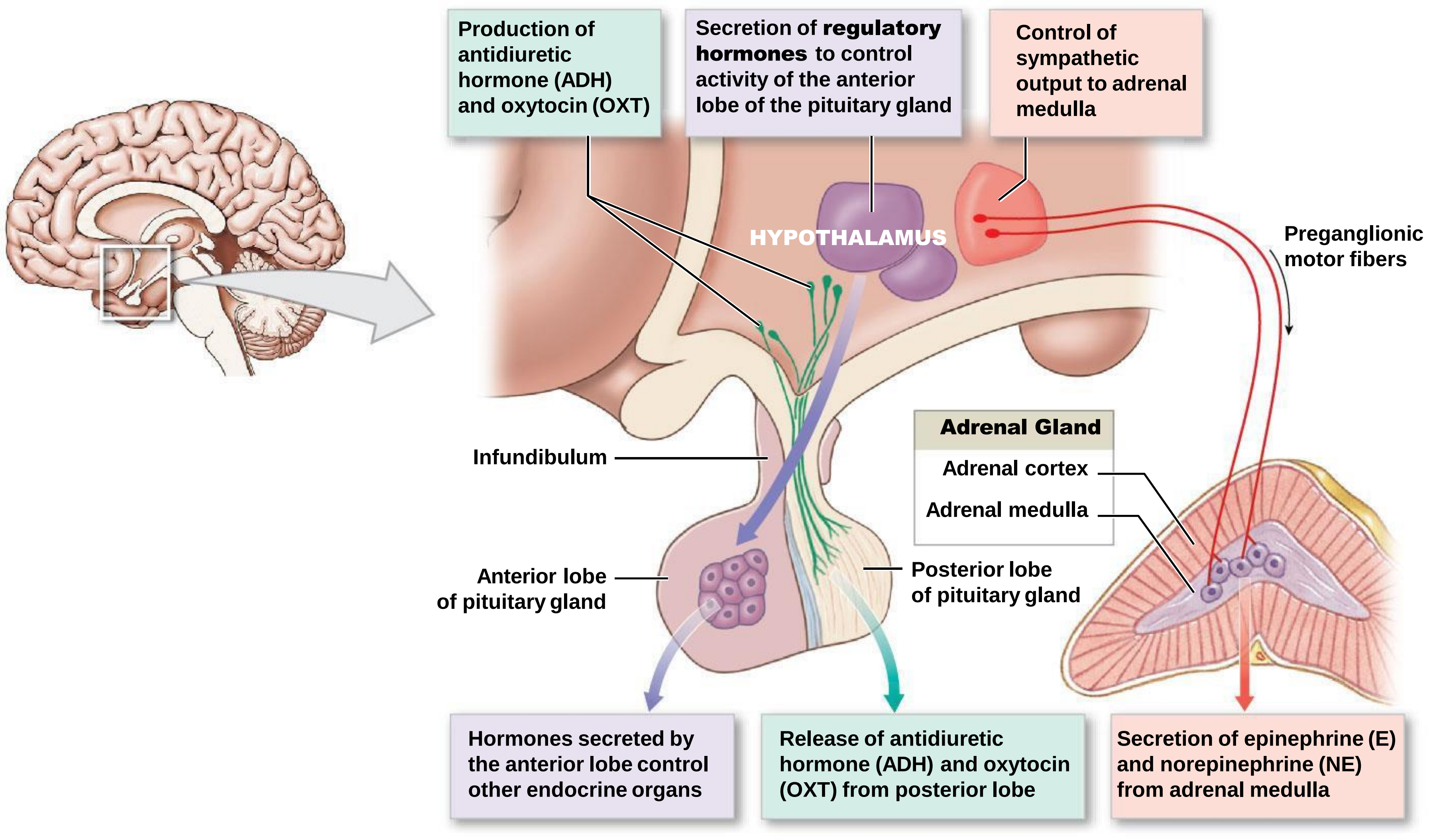


b Histology of the pituitary gland showing the anterior and posterior lobes

The hypothalamus regulates the functions of the pituitary gland and Synthesizes ADH and Oxitocin which are transported to the posterior pituitary gland for release.

The hypothalamus releases **regulatory hormones** that control the secretion of hormones by the anterior pituitary gland.

The hypothalamus contains the autonomic centers that exert direct control over the adrenal medulla.

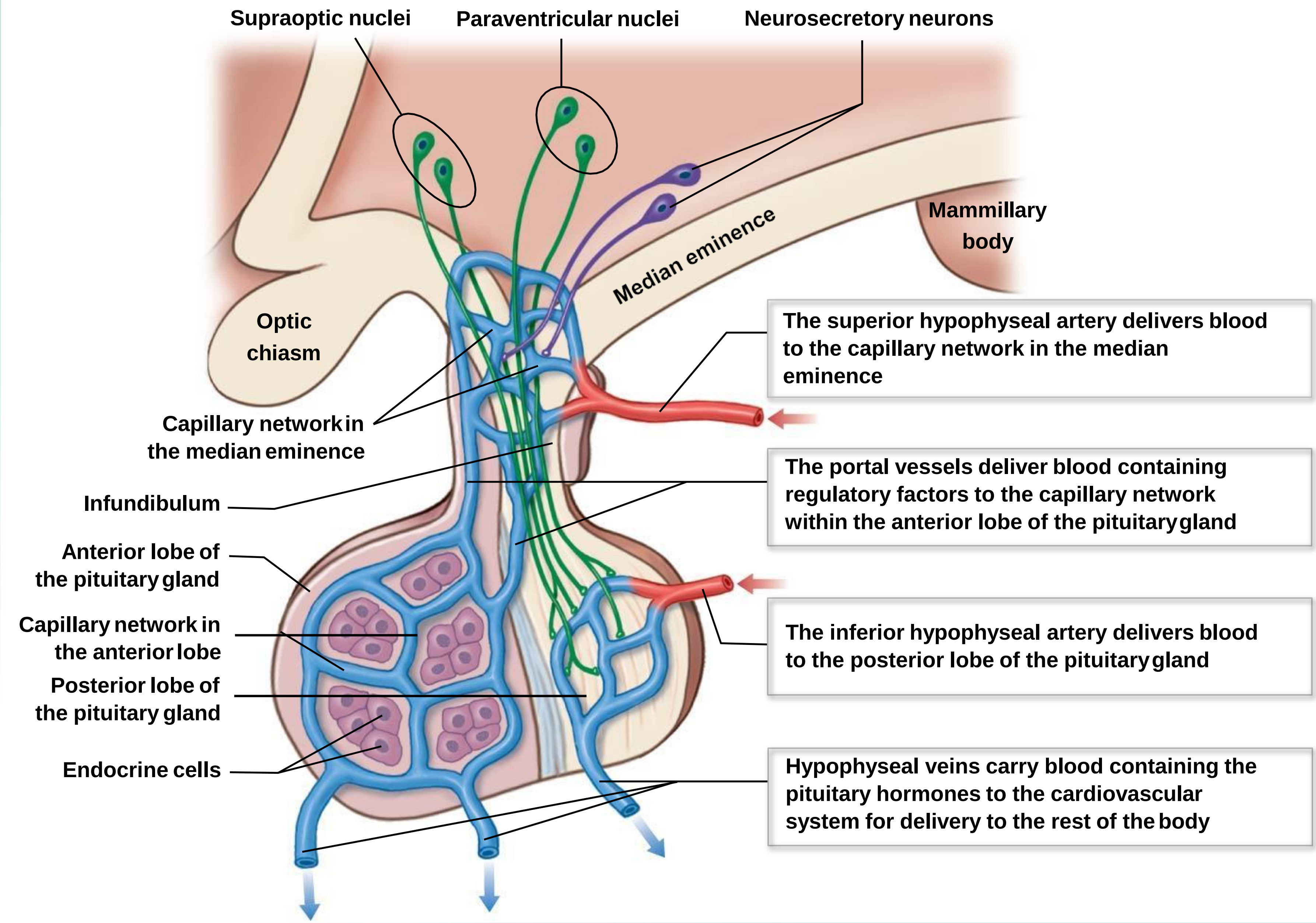


Production of antidiuretic hormone (ADH) and oxytocin (OXT)
Secretion of **regulatory hormones** to control activity of the anterior lobe of the pituitary gland
Control of sympathetic output to adrenal medulla
HYPOTHALAMUS
Preganglionic motor fibers
Adrenal Gland
Adrenal cortex
Adrenal medulla
Infundibulum
Anterior lobe of pituitary gland
Posterior lobe of pituitary gland
Hormones secreted by the anterior lobe control other endocrine organs
Release of antidiuretic hormone (ADH) and oxytocin (OXT) from posterior lobe
Secretion of epinephrine (E) and norepinephrine (NE) from adrenal medulla

a. **Anterior Lobe or Adenohypophysis:** it produces and releases five tropic hormones: Thyroid-stimulating hormone or TSH, Adrenocorticotropic hormone or ACTH, Follicle stimulating hormone or FSH, Luteinizing hormone or LH, and the melanocyte stimulating hormone or MSH all of which regulate the actions of other endocrine glands or specific cells; and the human Growth hormone (GH), and Prolactin (PRL).

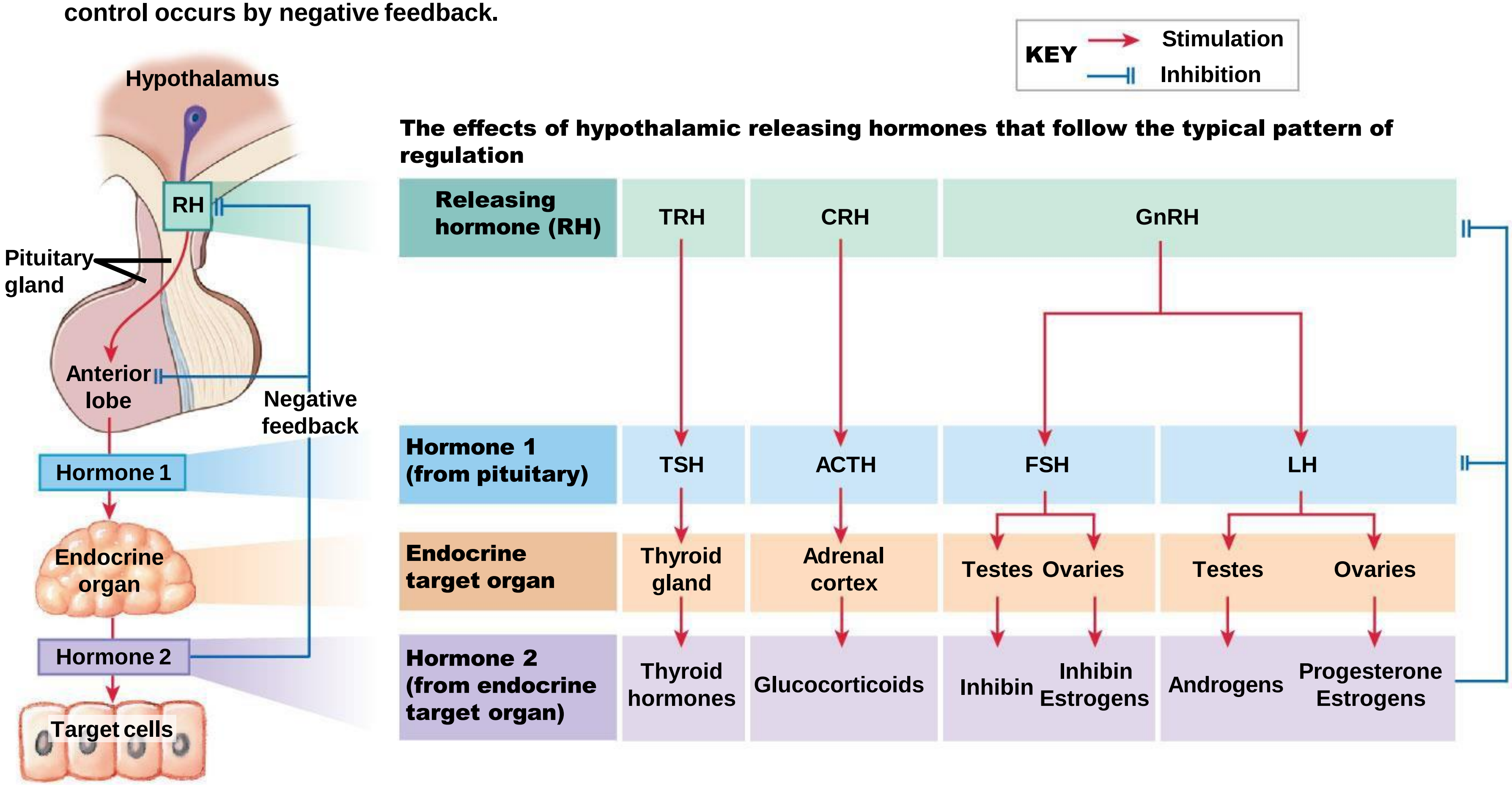
The hypothalamus controls the production of the hormones of the anterior pituitary by secreting regulatory hormones that reach the anterior pituitary through the hypophyseal portal system. The hypothalamus control of the anterior pituitary involves two classes of regulatory hormones, the releasing hormones and the inhibiting hormones.

Figure 18-7 The Hypophyseal Portal System and the Blood Supply to the Pituitary Gland.



Typical pattern of regulation when multiple endocrine organs are involved

a The hypothalamus produces a releasing hormone (RH) to stimulate hormone production by other glands. Homeostatic control occurs by negative feedback.

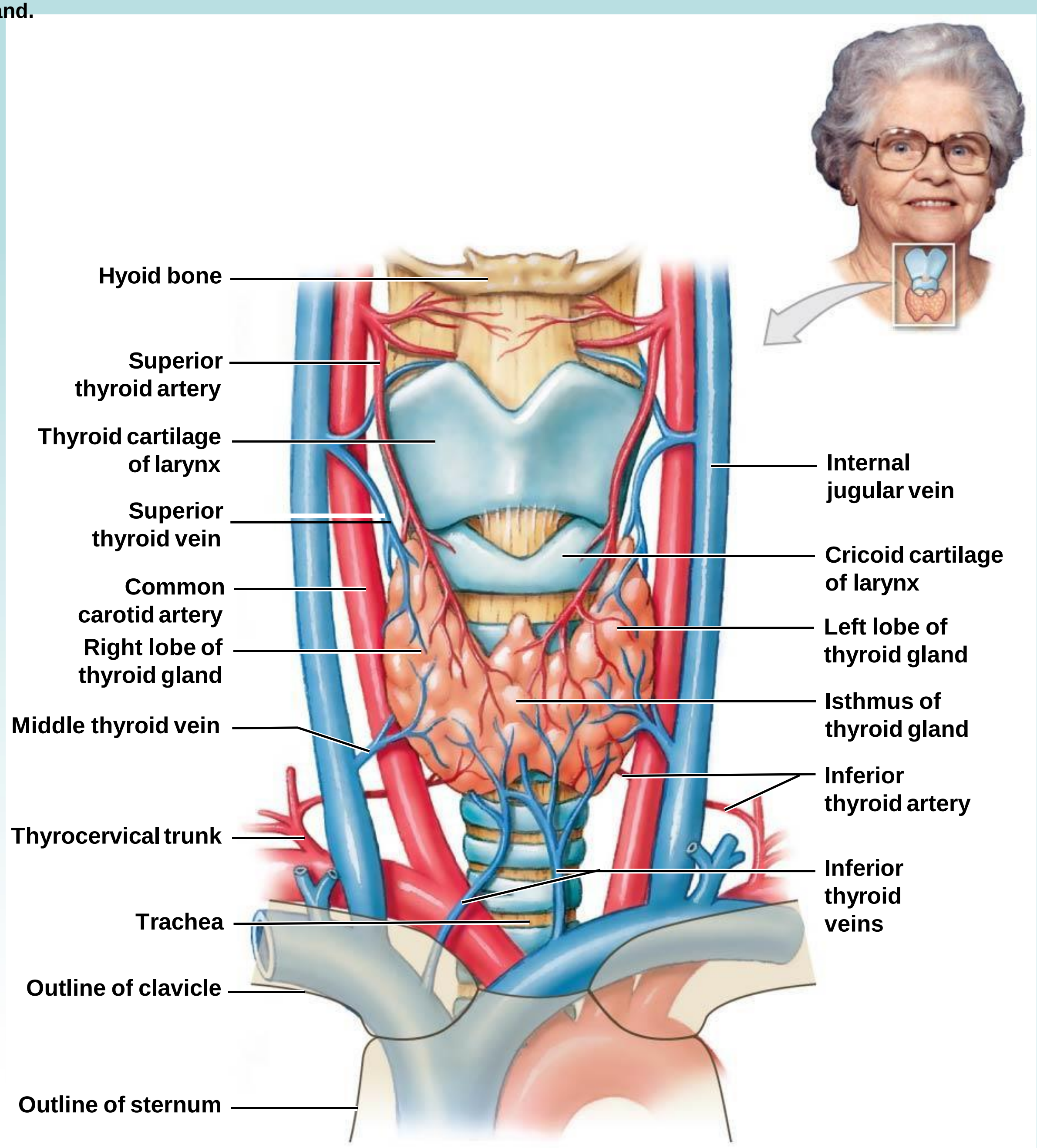


The releasing hormones stimulate the synthesis and secretion of one or more hormones. The inhibiting hormones prevent the synthesis and secretion of hormones by the anterior pituitary. The hypothalamic regulatory hormone secretion rate is controlled by negative feedback mechanisms.

b. Posterior Lobe or Neurohypophysis: stores and releases 2 hypophyseal hormones, Oxytosin and Antidiuretic hormone or ADH. The posterior lobe of the pituitary is part of the brain or an extension of the hypothalamus. Neurons of the hypothalamus produce ADH and Oxytocin and they are transported to posterior pituitary through the infundibulum by axoplasmic transport.

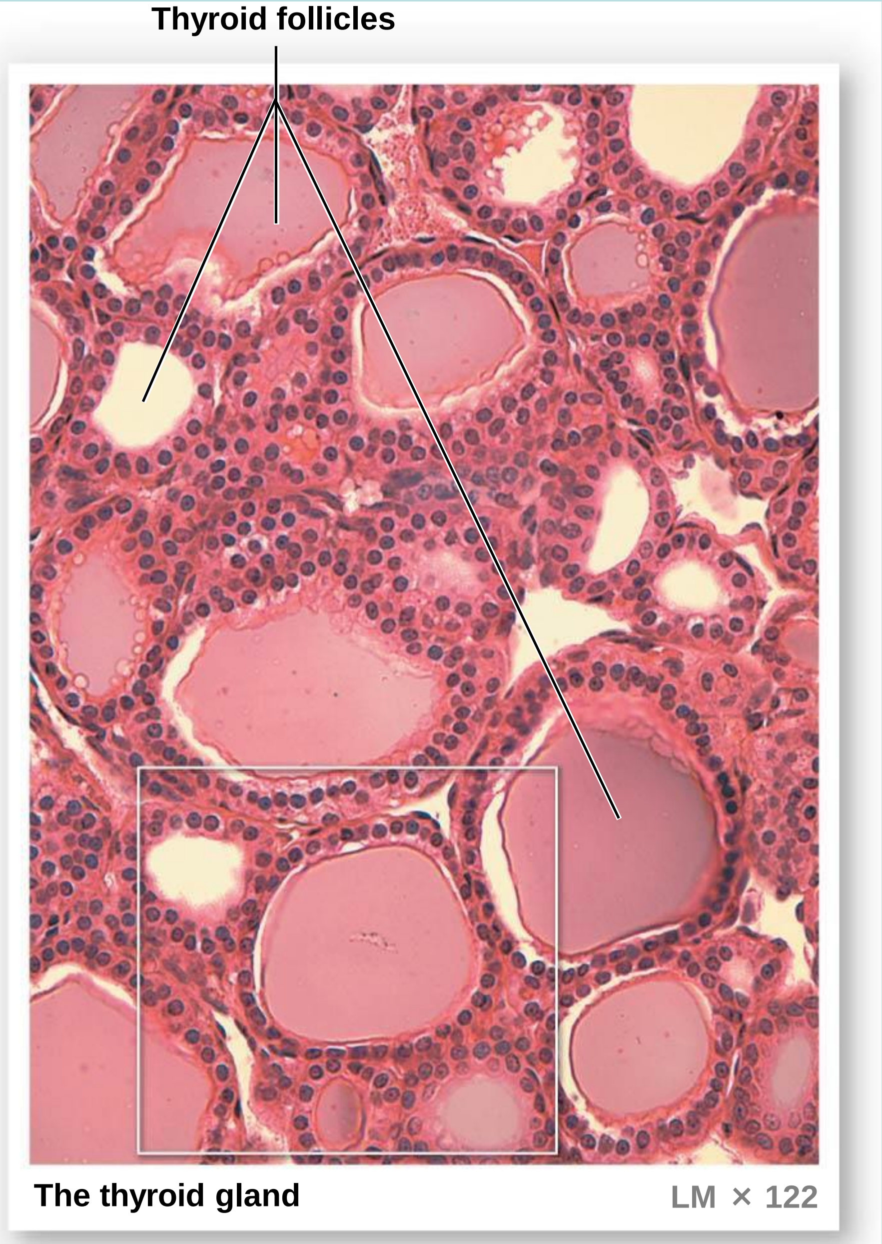
2. **The Thyroid Gland:** this red, butterfly shaped gland is located in the anterior throat, just inferior to the thyroid cartilage of the larynx. It is bilobulated and the right and left lobes lie on either side of the trachea. The lobes are connected by slender mass of tissue called the isthmus. It contains sacs or thyroid follicles that arehollow spheres lined by cuboidal epithelium and surrounded by capillares. They contain follicular cells that absorb **iodide ions** from the blood and produce Thyroglobulin, a globular protein containing the amino acid thyrosine usd to build the thyroid hormones, Thyroxine (T_4 with 4 iodide ions) and Triiodothyronine (T_3 with 3 iodide ions). The thyroid gland also has a few cells called the parafollicular or C cells that lie between follicles. These produce the hormone Calcitonin.

Figure 18-10a The Thyroid Gland.



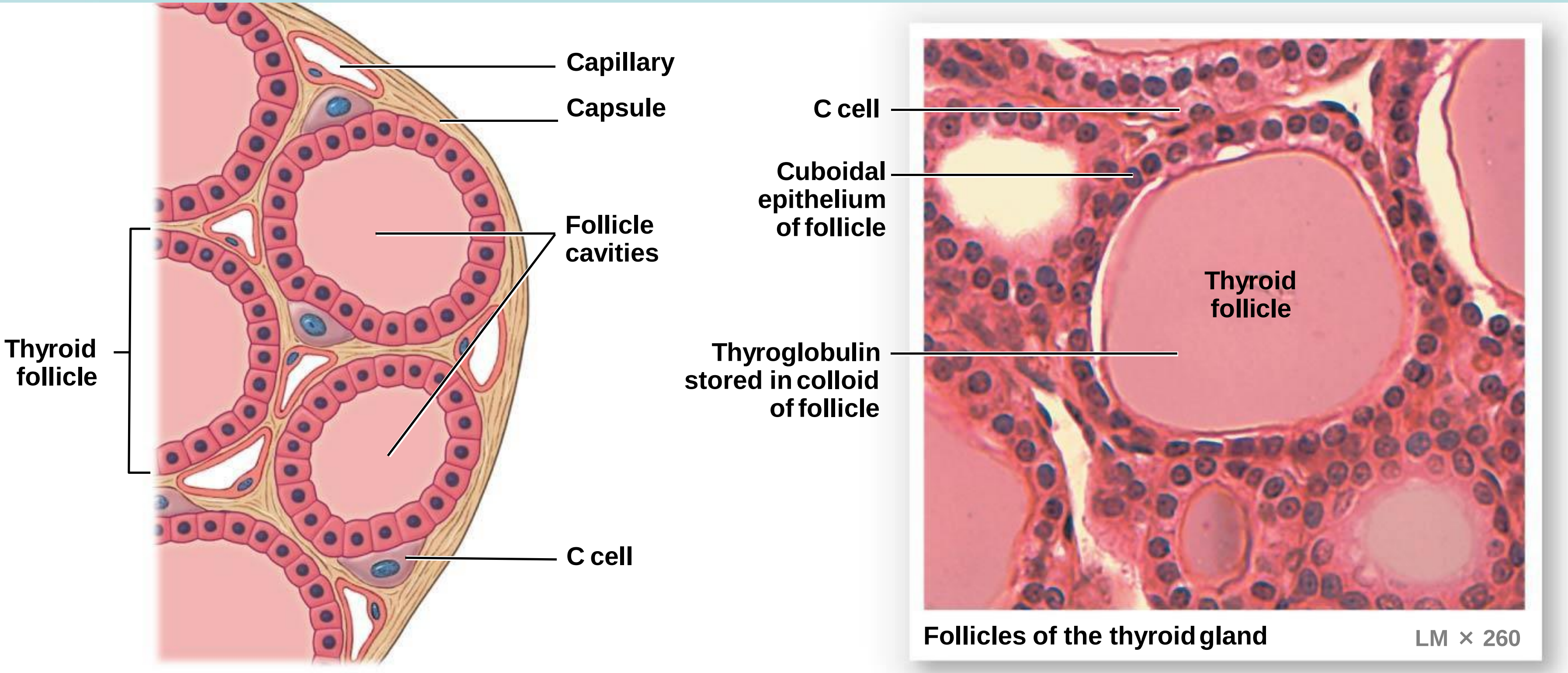
a Location and anatomy of the thyroid gland

Figure 18-10b The Thyroid Gland.



b Histological organization of the thyroid

Figure 18-10c The Thyroid Gland.

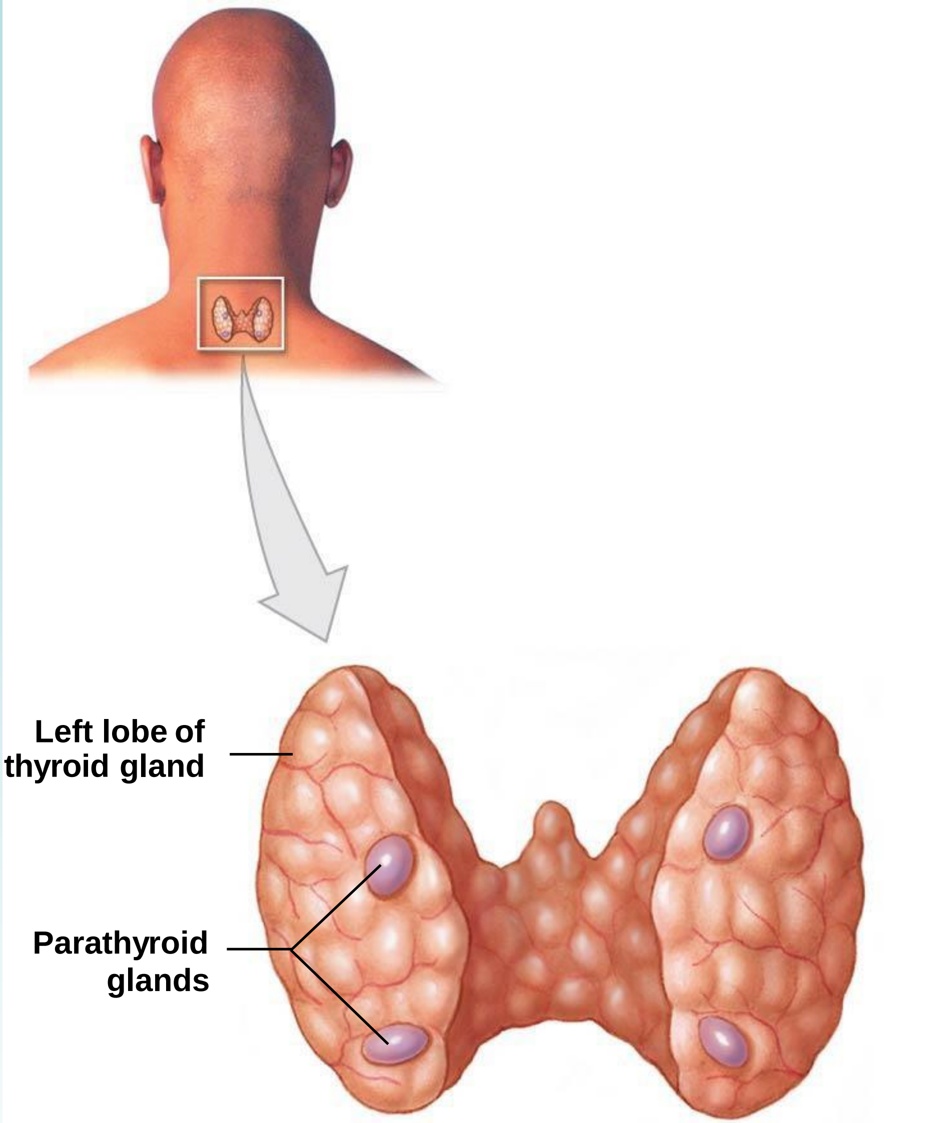


c Histological details of the thyroid gland showing thyroid follicles and both cell types in the follicular epithelium ATLAS: Plate 18c

3. The Parathyroid Glands: are two pairs of small round glands, found embedded in the posterior surface of the thyroid gland. There is one superior and one inferior on each lobe.

The parathyroid or principal cells secrete the **Parathyroid hormone (PTH)** or parathormone (PTH) when the concentration of calcium ions in the blood decreases from normal values. It raises the calcium levels in the body fluids.

Figure 18-12a The Parathyroid Glands.

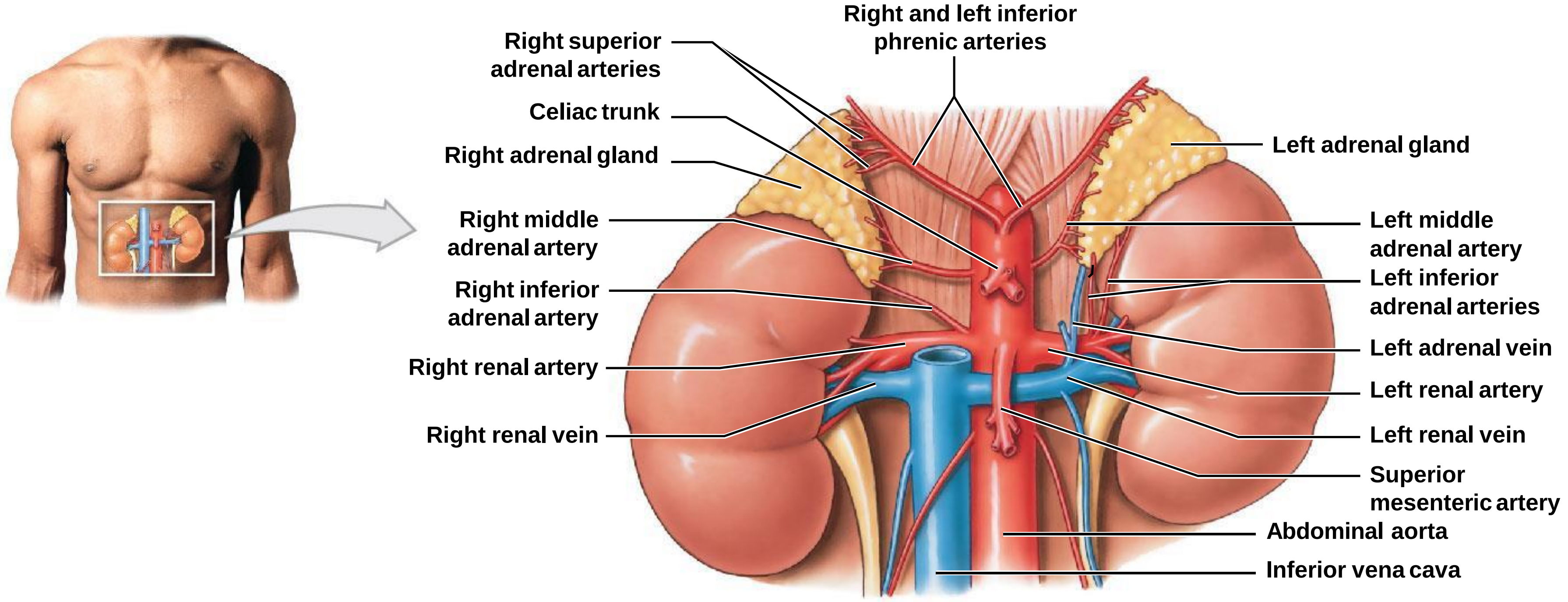


a Thyroid gland, posterior view. The location of the parathyroid glands on the posterior surface of the thyroid lobes. (The thyroid lobes are located anterior to the trachea.)

4. **The Adrenal or Suprarenal Glands:** these flattened pyramidal shaped glands are found sitting on the superior border of each kidney, and are attached to them by a fibrous capsule. They are divided into two structurally and functionally distinct regions: an outer or superficial cortex adrenal, and an inner adrenal medulla.

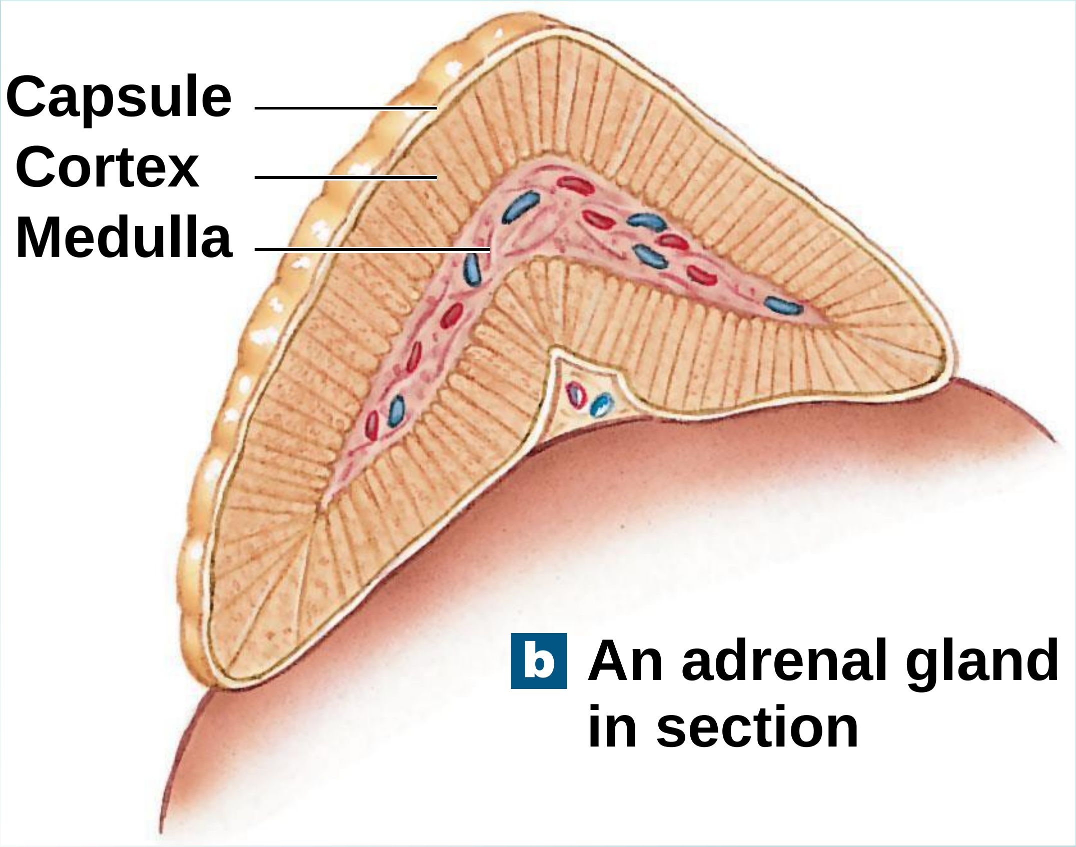
a. **The Adrenal Cortex:** it stores lipids, specially cholesterol and fatty acids and produces steroid hormones. It consist of 3 zones, the outer zone, deep to the connective tissue capsule is the **zona glomerulosa**, which produces **mineralocorticoids**, especially the hormone **aldosterone**; the middle zona or zona fasciculata secretes glucocorticoids, such as cortisol, cortisone, and corticosterone; and the inner zona or zona reticulata, which produces sex hormones called androgens.

Figure 18–14a The Adrenal Gland and Adrenal Hormones.



a A superficial view of the kidneys and adrenal glands

Figure 18–14b The Adrenal Gland and Adrenal Hormones.

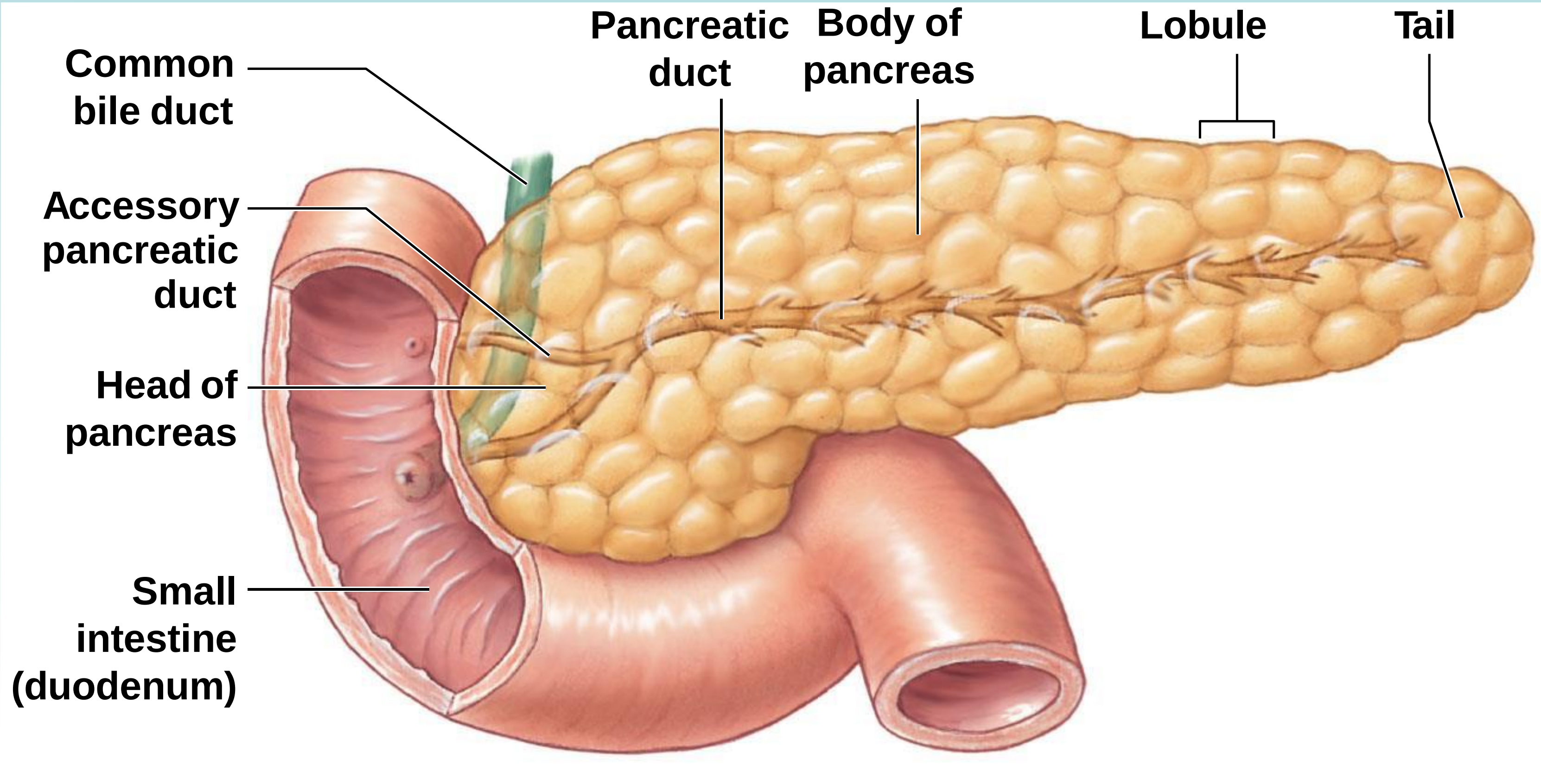


b. The Adrenal Medulla: it is the reddish brown inner area of the adrenal glands, which contain the colored chromaffin cells. These cells produce the catacholamines, epinephrine and norepinephrine in response to sympathetic system stimulation, and they are considered postganglionic fibers of the sympathetic ANS.

5. The Pancreas: it is large, tadpole shaped, slender, flattened gland located that lies in a loop between the inferior border of the stomach and the proximal portion of the small intestine. It is mostly retro peritoneal. It contains both endocrine and exocrine cells. As an exocrine gland consists of pancreatic acini and their attached ducts. They form 99% of the pancreatic volume.

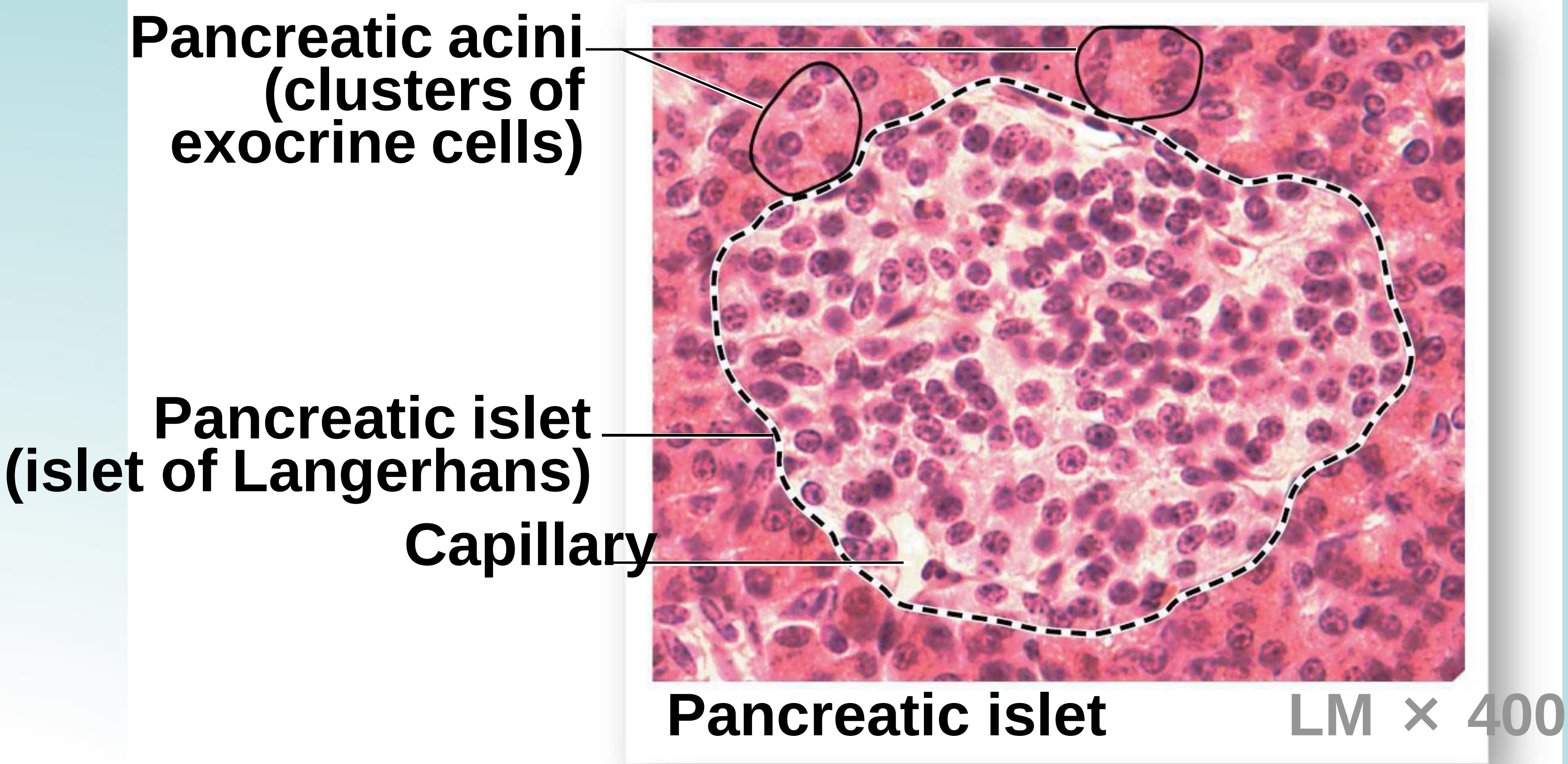
As an endocrine gland, the pancreas has structures called the pancreatic Islets or islets of Langerhans, which are clusters of cells that produce pancreatic hormones. They contain 4 different types of cells. The most abundant of them, the beta, cells secrete the hormone insulin.

Figure 18–16a Anatomy of the Pancreas.



a The gross anatomy of the pancreas

Figure 18–16b Anatomy of the Pancreas.

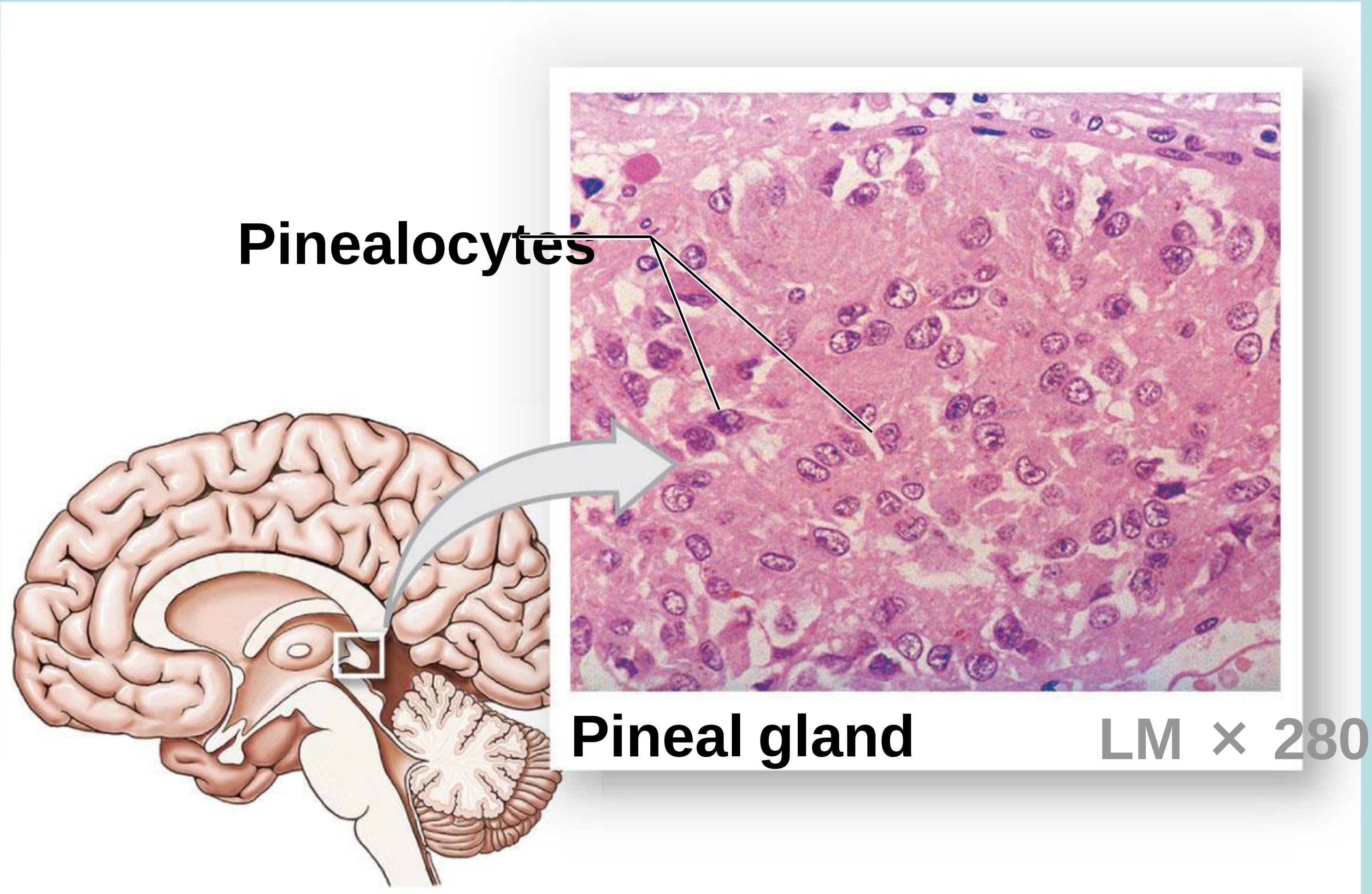


b A pancreatic islet surrounded by exocrine cells

The next in abundance are the alpha cells. These cells secrete the hormone glucagon. The delta cells, which comprise only 5% of islets of langerhans cells, secrete somatostatin. The F cells also forming only 5% of the endocrine secretory cells produce the hormone pancreatic polypeptide.

6. The Pineal Gland: it is small gland located in the roof of the third ventricle of the brain, and it is part of the epithalamus. It contains cells called the pinealocytes that produce the hormone melatonin.

Figure 18–15 Anatomy of the Pineal Gland.



Hormones, their Specific Functions, and Homeostatic Imbalances

Hormones of the Anterior Pituitary or Hypophysis: The anterior pituitary gland or adenohypophysis produces 7 hormones: thyroid stimulating hormone or TSH, Adrenocorticotropic hormone or ACTH (corticotropin), follicle stimulating hormone or FSH, luteinizing hormone or LH, melanocyte stimulating hormone or MSH, growth hormone or GH (somatotropin), and prolactin or PRL. The first five hormones are called tropic, because they turn on other endocrine glands or cells to release certain products, or they support other organs. The products can be hormones, or pigments.

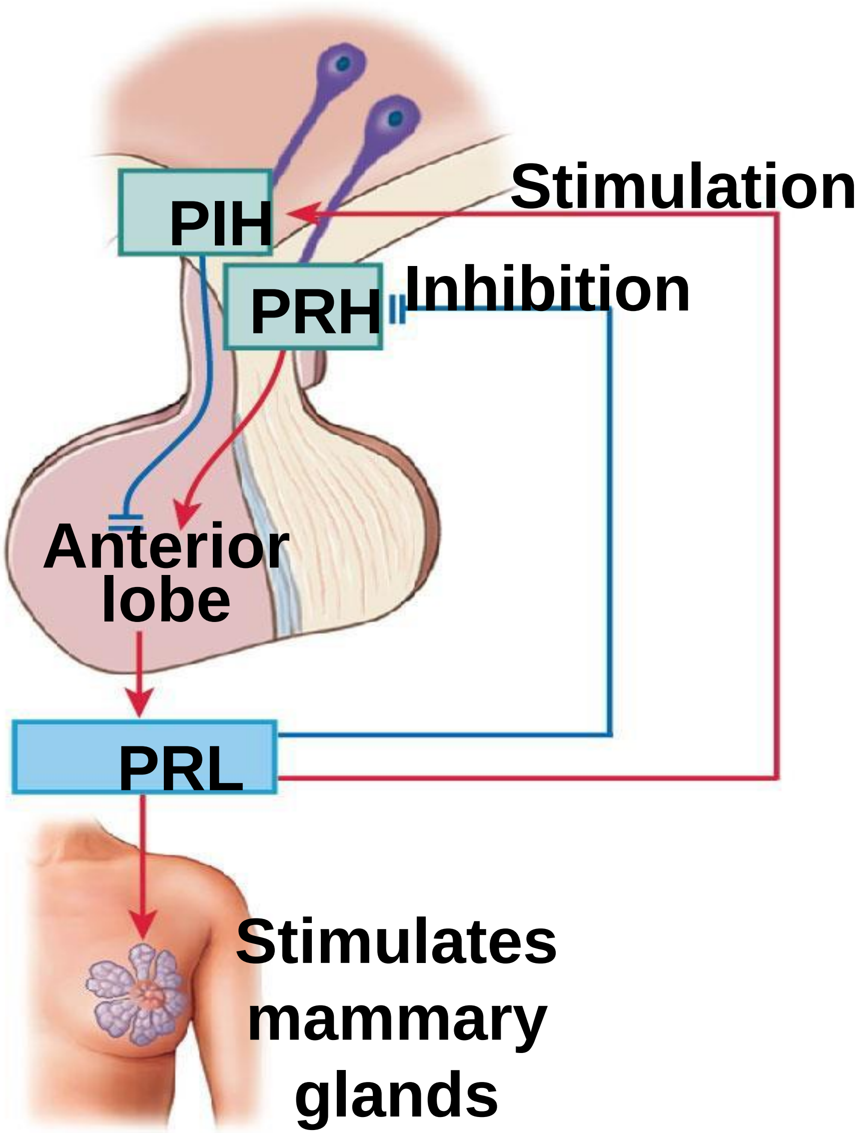
1. **Thyroid-Stimulating Hormone (TSH):** stimulates the thyroid gland, and promotes the release of normal levels of thyroid hormones. It is regulated by the TRH or thyroid regulating hormone and the negative feedback with the levels of thyroid hormones.
2. **Adrenocorticotropic Hormone (ACTH) or Corticotropin:** stimulates adrenal cortex to release steroid hormones specifically the release of glucocorticoids. It is controlled by CRH or corticotropin releasing hormone from the hypothalamus and the negative feedback with the levels of glucocorticoids.

3. **Gonadotropins:** are the follicle stimulating hormone or FSH and luteinizing hormone or LH, which regulate the activities of the gonads. FSH stimulates follicle development and estrogen secretion in females, and sperm cell production in males. LH stimulates ovulation, and progestins production in females, and androgen production in males. GnRH or gonadotropin releasing hormone, inhibin, and the negative feedback with the levels gonadal hormones regulates them. The low production of these hormones can produce hypogonadism or immature sexual organs in children, and sterile adults.
4. **Prolactin (PRL):** it stimulates milk production by the breast, and promotes mammary gland development in females. In males is believed to help regulate androgen production. It is regulated by PRH or prolactin releasing hormone and PIH or prolacting inhibiting hormone.

Variations on the typical pattern of regulation of endocrine organs by the hypothalamus and anterior pituitary lobe

b

The regulation of prolactin (PRL) production by the anterior lobe. In this case, the hypothalamus produces both a releasing hormone (PRH) and an inhibiting hormone (PIH). When one is stimulated, the other is inhibited.



5. Growth Hormone (GH): stimulates the release of somatomedins released by the liver. Somatomedins stimulate growth of skeletal muscle, cartilage, and other tissues. GH stimulates stem cells in epithelial and connective tissues to divide. It stimulates breakdown of triglycerides in addipocites which leads to the **glucose- sparing effect**. It stimulates glycogen breakdown by liver cells causing the **diabetogenic effect**.

It is regulated directly or indirectly by somatomedins, and by the antagonistic effects of GHRH and GHIH or somatostatin. There are several structural abnormalities caused by the hyper or hypo secretion of GH. Gigantism is caused by hypersecretion of GH during childhood and it is characterized by very rapid growth, with long bones and tall stature. Acromegalia is caused by hypersecretion of GH in adults. It is characterized by enlarged hands, feet, nose, lower jaw, skull, and clavicle.

It can be brought on by a pituitary tumor. Pituitary Dwarfism is caused by hyposecretion of GH during the growth years. It is characterized by short stature, small organs, and high fat reserves.

6. Melanocyte Stimulating Hormone (MSH): stimulates production of melanin by melanocytes in the skin. MSH release is inhibited by dopamine.

This hormone is non-functional in adults except in pregnant women and people with certain diseases.

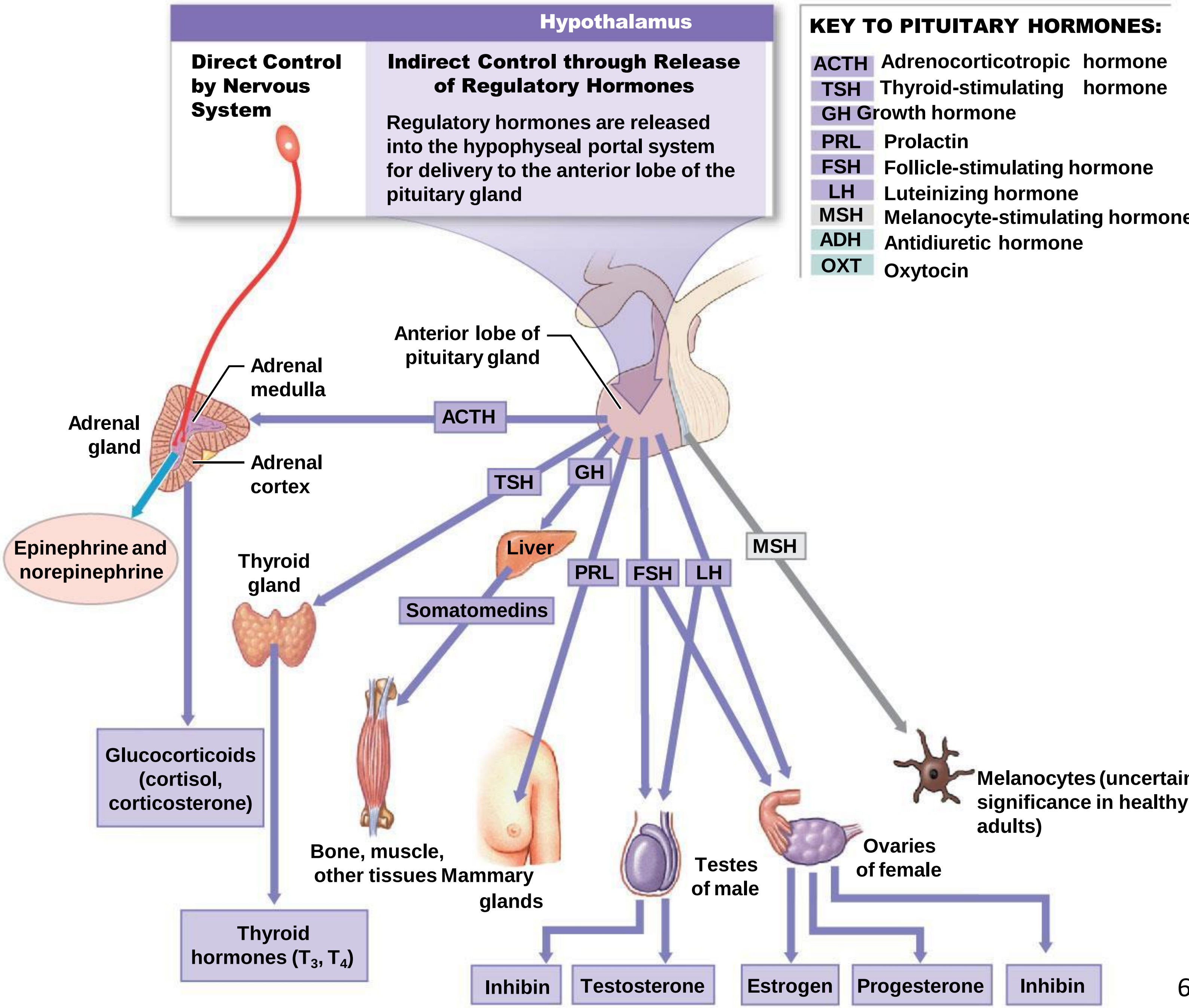

Hypothalamus
Direct Control by Nervous System
Indirect Control through Release of Regulatory Hormones
Regulatory hormones are released into the hypophyseal portal system for delivery to the anterior lobe of the pituitary gland
KEY TO PITUITARY HORMONES:
ACTH Adrenocorticotropic hormone
TSH Thyroid-stimulating hormone
GH Growth hormone
PRL Prolactin
FSH Follicle-stimulating hormone
LH Luteinizing hormone
MSH Melanocyte-stimulating hormone
ADH Antidiuretic hormone
OXT Oxytocin
Anterior lobe of pituitary gland
Adrenal medulla
Adrenal gland
Adrenal cortex
ACTH
TSH
GH
Epinephrine and norepinephrine
Thyroid gland
Liver
Somatomedins
PRL
FSH
LH
MSH
Glucocorticoids (cortisol, corticosterone)
Bone, muscle, other tissues
Mammary glands
Testes of male
Ovaries of female
Melanocytes (uncertain significance in healthy adults)
Thyroid hormones (T_3, T_4)
Inhibin
Testosterone
Estrogen
Progesterone
Inhibin

Table 18-2 The Pituitary Hormones (Part 1 of2).

Table 18–2	The Pituitary Hormones			
	Hormone	**Target**	**Hormonal Effect**	**Hypothalamic Regulatory Hormone**
ANTERIOR LOBE				
Pars distalis	**Thyroid-stimulating hormone (TSH)**	Thyroid gland	Secretion of thyroid hormones	Thyrotropin-releasing hormone (TRH)
	Adrenocorticotropic hormone (ACTH)	Adrenal cortex (zona fasciculata)	Secretion of glucocorticoids (cortisol, corticosterone)	Corticotropin-releasing hormone (CRH)
	Gonadotropins:			
	Follicle-stimulating hormone (FSH)	Follicle cells of ovaries	Secretion of estrogen, follicle development	Gonadotropin-releasing hormone (GnRH)
		Nurse cells of testes	Stimulation of sperm maturation	Gonadotropin-releasing hormone (GnRH)
	Luteinizing hormone (LH)	Follicle cells of ovaries	Ovulation, formation of corpus luteum, secretion of progesterone	Gonadotropin-releasing hormone (GnRH)
		Interstitial cells of testes	Secretion of testosterone	Gonadotropin-releasing hormone (GnRH)
	Prolactin (PRL)	Mammary glands	Production of milk	Prolactin-releasing factor (PRF)
				Prolactin-inhibiting hormone (PIH)
	Growth hormone (GH)	All cells	Growth, protein synthesis, lipid mobilization and catabolism	Growth hormone–releasing hormone (GH–RH)
				Growth hormone–inhibiting hormone (GH–IH)
Pars intermedia (not active in normal adults)	**Melanocyte-stimulating hormone (MSH)**	Melanocytes	Increased melanin synthesis in epidermis	Melanocyte-stimulating hormone–inhibiting hormone (MSH–IH)

The Neurohypophysis and the Hypothalamic Hormones

The posterior pituitary gland contains axons of hypothalamic neurons that release two hormones: ADH and Oxytocin.

1. **Antidiuretic Hormone (ADH):** stimulates the decrease of urine output by water conservation, and in high concentrations rises blood pressure by vasoconstriction. It is regulated by changes in osmotic concentration or electrolytes in the blood. The lack of its production in sufficient amounts leads to diabetes insipidus or the production of large amounts of dilute urine which can lead to dehydration.
2. **Oxytocin (OXT):** stimulates strong uterine contractions that trigger labor during childbirth. It causes milk ejection during lactation. Also seems to promote sexual arousal and nurturing behavior in females. In males is believed to produce the contraction of the smooth muscle of the duct system and prostrate gland.

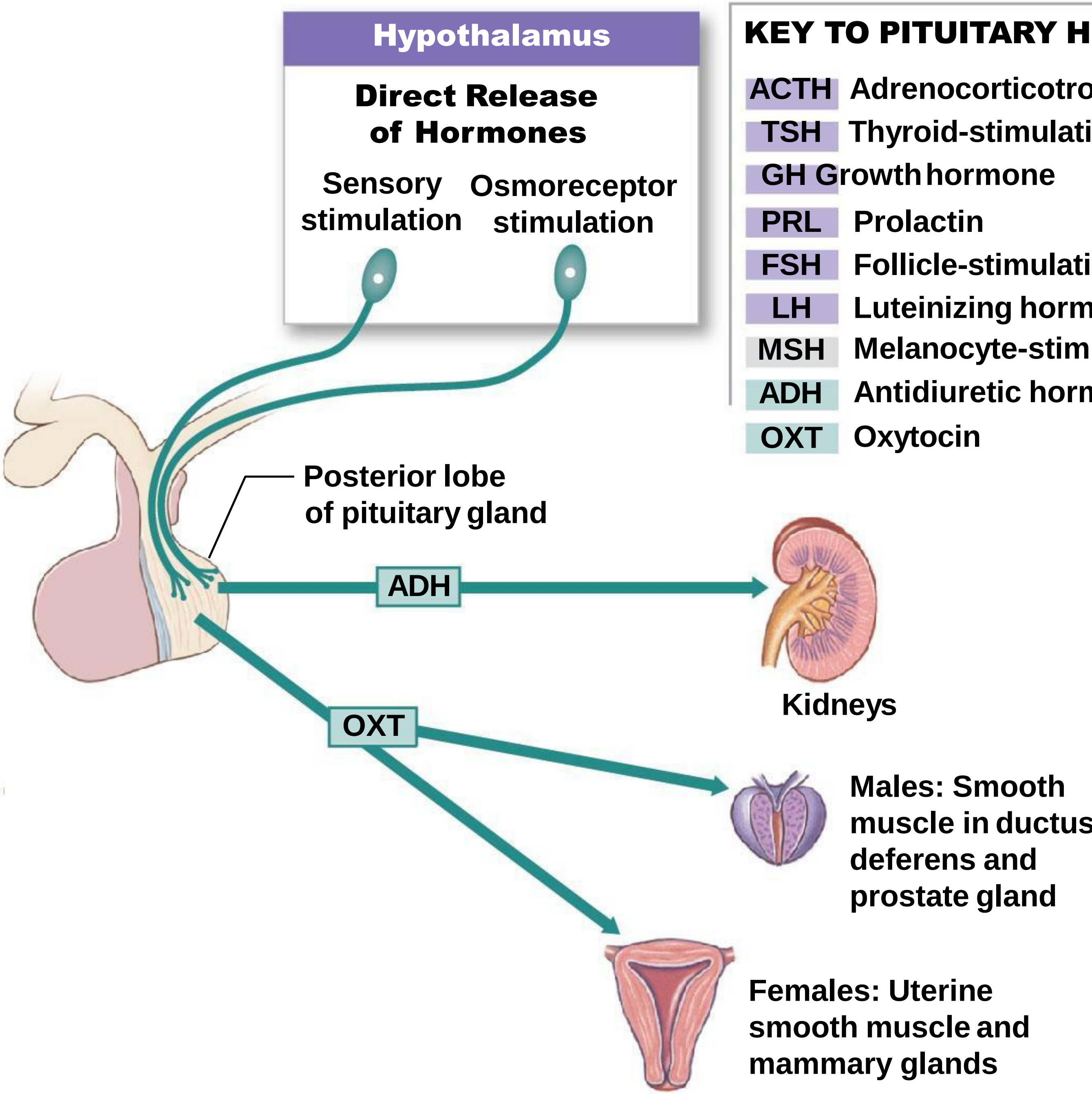
Table 18-2 The Pituitary Hormones (Part 2 of2).

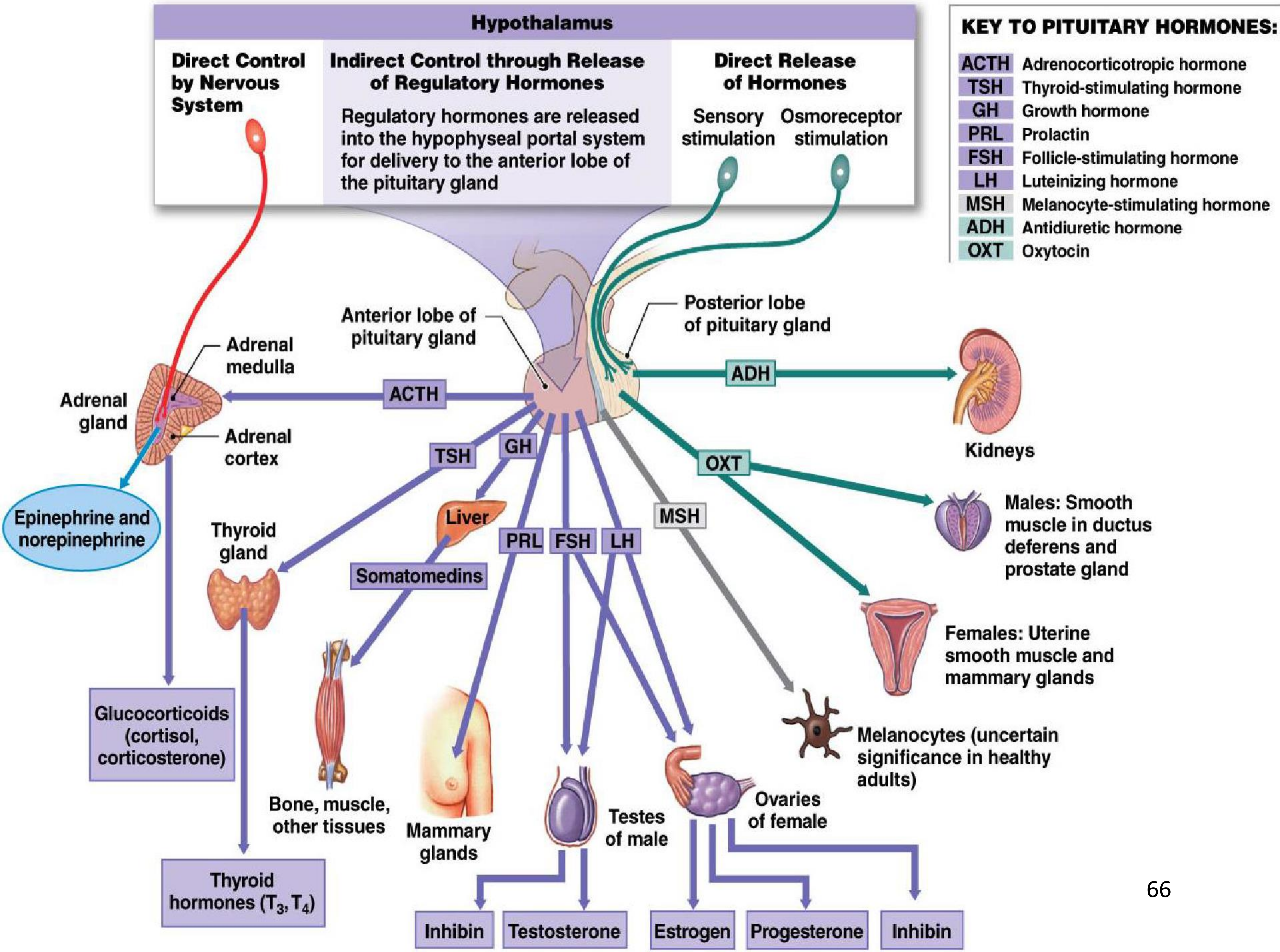
Table 18–2 The Pituitary Hormones

	Hormone	Target	Hormonal Effect	Hypothalamic Regulatory Hormone
POSTERIOR LOBE				
	Antidiuretic hormone (ADH)	Kidneys	Reabsorption of water, elevation of blood volume and pressure	None: Transported along axons from supraoptic nucleus to the posterior lobe of the pituitary gland
	Oxytocin (OXT)	Uterus, mammary glands (females)	Labor contractions, milk ejection	None: Transported along axons from paraventricular nucleus to the posterior lobe of the pituitary gland
		Ductus deferens and prostate gland (males)	Contractions of ductus deferens and prostate gland	

KEY TO PITUITARY HORMONES:

ACTH	Adrenocorticotropic hormone
TSH	Thyroid-stimulating hormone
GH	Growth hormone
PRL	Prolactin
FSH	Follicle-stimulating hormone
LH	Luteinizing hormone
MSH	Melanocyte-stimulating hormone
ADH	Antidiuretic hormone
OXT	Oxytocin

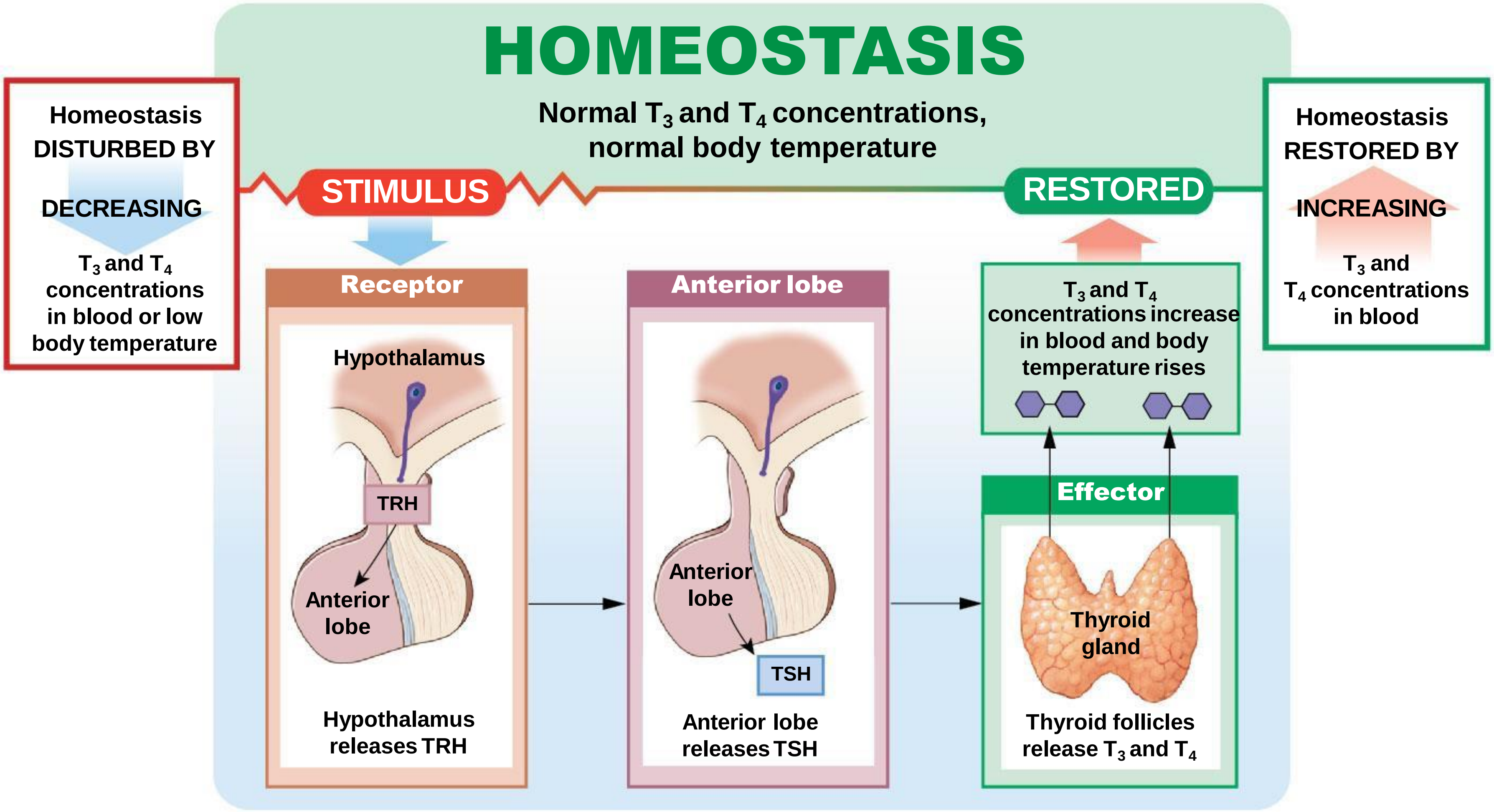




Hypothalamus
Direct Control by Nervous System
Indirect Control through Release of Regulatory Hormones
Regulatory hormones are released into the hypophyseal portal system for delivery to the anterior lobe of the pituitary gland
Direct Release of Hormones
Sensory stimulation
Osmoreceptor stimulation
KEY TO PITUITARY HORMONES:
ACTH Adrenocorticotropic hormone
TSH Thyroid-stimulating hormone
GH Growth hormone
PRL Prolactin
FSH Follicle-stimulating hormone
LH Luteinizing hormone
MSH Melanocyte-stimulating hormone
ADH Antidiuretic hormone
OXT Oxytocin
Anterior lobe of pituitary gland
Posterior lobe of pituitary gland
Adrenal medulla
Adrenal gland
Adrenal cortex
ACTH
ADH
Kidneys
TSH
GH
OXT
Epinephrine and norepinephrine
Thyroid gland
Liver
PRL
FSH
LH
MSH
Males: Smooth muscle in ductus deferens and prostate gland
Somatomedins
Females: Uterine smooth muscle and mammary glands
Glucocorticoids (cortisol, corticosterone)
Melanocytes (uncertain significance in healthy adults)
Bone, muscle, other tissues
Mammary glands
Testes of male
Ovaries of female
Thyroid hormones (T_3, T_4)
Inhibin
Testosterone
Estrogen
Progesterone
Inhibin

Thyroid Hormones

There are two hormones, T4 or thyroxine, which is the inactive form and T3 or triiodothyronine, which is the active form. They affect almost every cell in the body. They have a **calorigenic** effect which increases energy and oxygen consumption, and heat generation to help to maintain body temperature. They increase cellular metabolism. In children, they are essential to normal development of skeletal, muscular, and nervous systems. intracellular metabolism by increasing protein synthesis and lipid breakdown. These hormones also enhance the effects of sympathetic stimulation by increasing heart rate, blood pressure, nervousness, and sweating. They stimulate RBC formation, and speed up bone turnover. The levels of TSH regulate the release of these hormones. Its absence stops synthesis and secretion of thyroid hormones.



b The regulation of thyroid secretion.

Table 18–3 Effects of Thyroid Hormones on Peripheral Tissues

1. Elevates rates of oxygen consumption and energy consumption; in children, may cause a rise in body temperature
2. Increases heart rate and force of contraction; generally results in a rise in blood pressure
3. Increases sensitivity to sympathetic stimulation
4. Maintains normal sensitivity of respiratory centers to changes in oxygen and carbon dioxide concentrations
5. Stimulates red blood cell formation and thus enhances oxygen delivery
6. Stimulates activity in other endocrine tissues
7. Accelerates turnover of minerals in bone

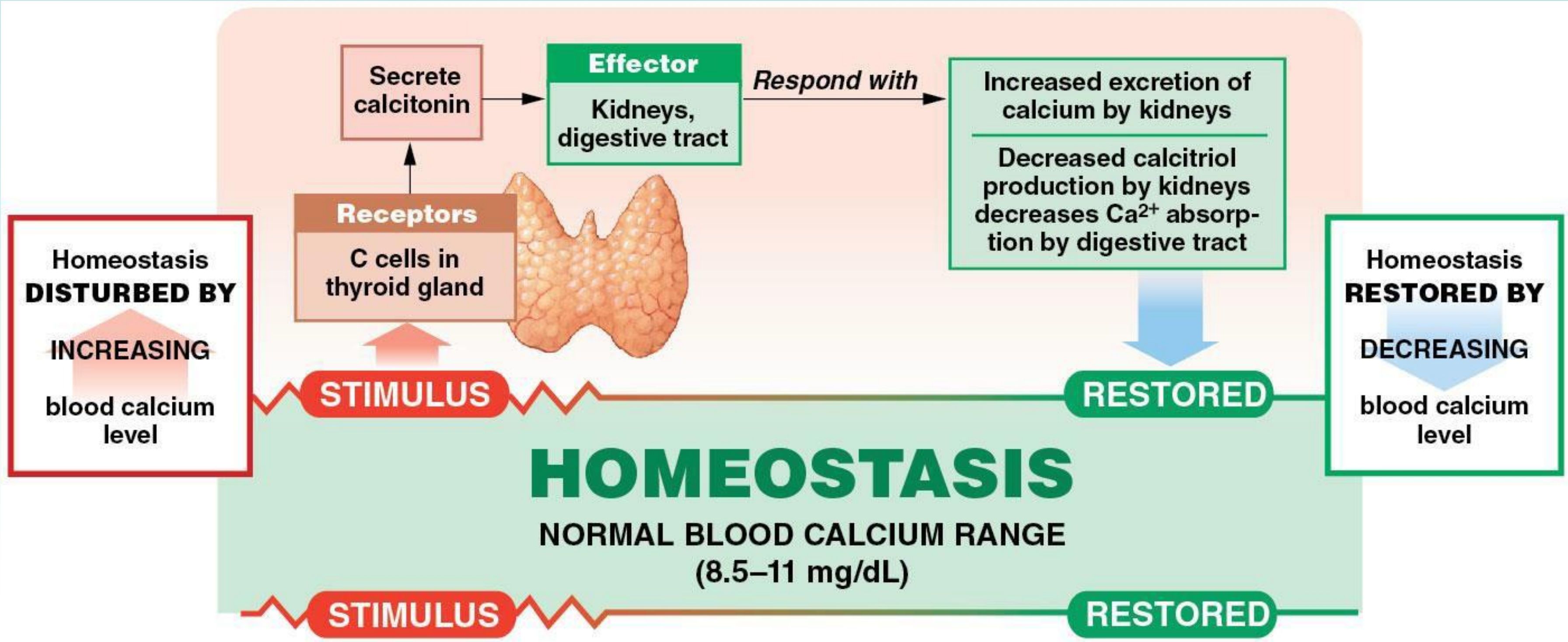
Thyroid Hormones

There are several metabolic disturbances caused by malfunctioning of the thyroid gland. Myxedema (hypothyroidism) is produced by hyposecretion in adults. It causes edema, obesity, slow heart rate, low blood pressure and body temperature, lethargy, hair loss, and muscles weakness. Endemic Goiter or an enlarge thyroid gland is due to soil poor in iodine. Eating a diet rich in iodine, such as shellfish, cures it. Cretinism is produced by hyposecretion in fetal development and infancy. Mental retardation, and a short disproportional body with physical deformities characterize it. Grave's disease is produced by hyper secretion in adults. It causes elevated metabolic rate, profuse sweating, rapid irregular heartbeat, nervousness, weight loss, goiter, and bulging eyes or exophthalmia.

Thyroid Hormones

Calcitonin (CT) is a hormone produced by the parafollicular cells in thyroid gland. It is released in response to high levels of calcium ions in the blood and stress from exercise. It helps regulate calcium ion concentrations in the body fluids. In children calcitonin stimulates bone growth, and mineral deposition in the skeleton.

In adults lowers blood calcium primarily by inhibiting osteoclast activity in the bones and secondarily by stimulating calcium excretion by the kidneys and preventing absorption of calcium ions from the digestive tract.



Secrete calcitonin
Effector
Kidneys, digestive tract
Respond with
Increased excretion of calcium by kidneys
Decreased calcitriol production by kidneys decreases Ca2+ absorption by digestive tract
Receptors
C cells in thyroid gland
Homeostasis DISTURBED BY INCREASING blood calcium level
STIMULUS
RESTORED
Homeostasis RESTORED BY DECREASING blood calcium level
HOMEOSTASIS
NORMAL BLOOD CALCIUM RANGE (8.5–11 mg/dL)
STIMULUS
RESTORED

Parathyroid Hormone

The major effect is PTH is to increase osteoclasts activity, to release calcium ions from the bones into the blood. Secondarily, in the kidneys increases calcium reabsorption reducing urine calcium loses and it increases formation and secretion of calcitriol by the kidneys, which causes calcium and phosphate absorption from the intestines. Overall increases calcium concentration in the blood. The Disorders of these glands include: 1- Hyperparathyroidism that produces high concentration of calcium in the body fluids. This causes thin and brittle bones due to bone demineralization, depression of the nervous system, muscle weakness, and formation of kidney stones. 2- Hypoparathyroidism that leads to low concentration of calcium in the body fluids that produces an elevated state of excitement of nerves and muscles. This in turn, causes tetany, respiratory paralysis, muscles twitches, convulsions, loss of sensation, and death.

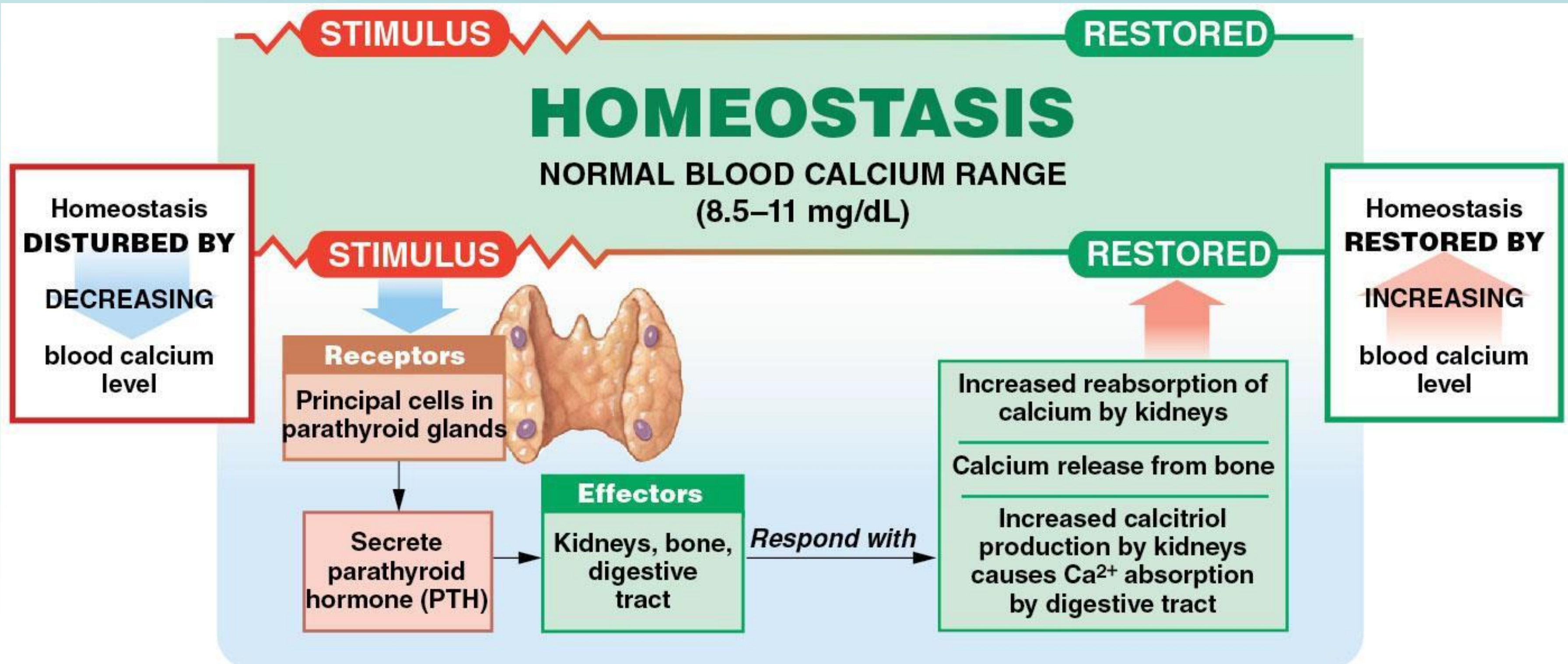

STIMULUS
RESTORED
HOMEOSTASIS
NORMAL BLOOD CALCIUM RANGE
(8.5–11 mg/dL)
Homeostasis
DISTURBED BY
DECREASING
blood calcium level
STIMULUS
RESTORED
Homeostasis
RESTORED BY
INCREASING
blood calcium level
Receptors
Principal cells in parathyroid glands
Secrete parathyroid hormone (PTH)
Effectors
Kidneys, bone, digestive tract
Respond with
Increased reabsorption of calcium by kidneys
Calcium release from bone
Increased calcitriol production by kidneys causes Ca^{2+} absorption by digestive tract

Table 18-4 Hormones of the Thyroid Gland and Parathyroid Glands.

Table 18–4 Hormones of the Thyroid Gland and Parathyroid Glands				
Gland/Cells	**Hormone**	**Target**	**Hormonal Effect**	**Regulatory Control**
THYROID GLAND				
Follicular epithelium	Thyroxine (T_4) Triiodothyronine (T_3)	Most cells	Increases energy utilization, oxygen consumption, growth, and development	Stimulated by TSH from the anterior lobe of the pituitary gland
C cells	Calcitonin (CT)	Bone, kidneys	Decreases Ca^{2+} concentrations in body fluids	Stimulated by elevated blood Ca^{2+} levels; actions opposed by PTH
PARATHYROID GLANDS				
Parathyroid (chief) cells	Parathyroid hormone (PTH)	Bone, kidneys	Increases Ca^{2+} concentrations in body fluids	Stimulated by low blood Ca^{2+} levels; PTH effects enhanced by calcitriol and opposed by calcitonin

Hormones of the Adrenal Glands

The **Zona glomerulosa** of the adrenal cortex releases:

1- Mineralocorticoids: primarily **Aldosterone** which stimulates sodium ions conservation, and potassium elimination by the kidneys. The renin-angiotensin mechanism is the major regulator of aldosterone secretion. It triggers aldosterone release when there is a drop in blood sodium ions, blood volume, or blood pressure and when blood potassium ions rise. ACTH stimulates release of aldosterone. Atrial natriuretic peptide inhibits aldosterone release.

Hyperaldosterone or aldosteronism causes high blood pressure and loss of potassium, which can disrupt cardiac, neural and kidney function.

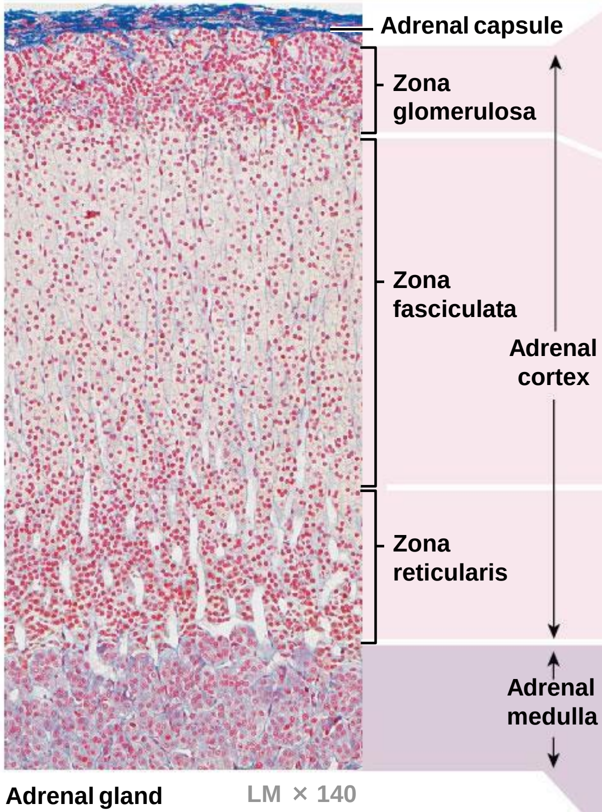
Hypoaldosteronism causes loss of sodium and water, which lead to low blood volume and pressure.

2. The **Zona fasciculata** produces **Glucocorticoids:** include cortisol (95%), corticosterone, and cortisone. They increase glucose synthesis and glycogen formation in the liver. They also cause the release of amino acids from skeletal muscles, and lipids from adipose tissue. Promote fat utilization. High levels of these hormones depress the immune system and have an anti-inflammatory effect. ACTH is the major stimulus for release of glucocorticoids. Disorders of these hormones include: 1- Cushing's disease caused by hypersecretion of glucocorticoids due to pituitary tumors, or malignancy in liver, pancreas, kidneys or adrenal cortex tumor. It produces a persistent hypertension, spindle arms and legs, moon face, back hump, flushed skin, weak skeletal muscles, osteoporosis, and reduced resistance to infection or stress. 2- Addison's disease caused by glucocorticoid hyposecretion. It causes, lethargy, loss of weight, low blood pressure and glucose, and weakness.

3. **Zona reticularis: Androgens** (male sex hormones) are released throughout life. They are masculinizing hormones that stimulate development of pubic hair during puberty. In females they are believed to stimulate sexual drive and some are converted to estrogens in the bloodstream. ACTH exerts regulatory control over them. Hypersecretion in women has masculinizing effects.
4. **The Adrenal Medulla** produces the **Catacholamines:** Epinephrin (75% to 80%)and Norepinephrin (20% to 25%). These hormones in skeletal muscles and liver increase glycogen breakdown and in general accelerate blood glucose breakdown. In adipose tissue cause breakdown of stored. In the heart, speed and strengthens muscles contractions which increases heart rate and blood pressure. Sympathetic activation regulates their release. Pheochromocytoma is a tumor of chromaffin cells that produces hypersecretion. It causes hypoglycemia, high metabolic and heart rate, hypertension, intense nervousness and sweating.

The Adrenal Hormones

Region/Zone	Hormones	Primary Target	Hormonal Effects	Regulatory Control
Adrenal cortex: Zona glomerulosa	Mineralocorticoids, primarily aldosterone	Kidneys	Increase renal reabsorption of Na^+ and water (especially in the presence of ADH), and accelerate urinary loss of K^+	Stimulated by angiotensin II, elevated blood K^+ or fall in blood Na^+; inhibited by ANP and BNP
Adrenal cortex: Zona fasciculata	Glucocorticoids (cortisol, corti-costerone, and cortisone)	Most cells	Increase rates of glucose and glycogen formation by the liver; release of amino acids from skeletal muscles, and lipids from adipose tissues; promote peripheral utilization of lipids; anti-inflammatory effects	Stimulated by ACTH from the anterior lobe of the pituitary gland
Adrenal cortex: Zona reticularis	Androgens	Most cells	Adrenal androgens stimulate the development of pubic hair in boys and girls before puberty.	Androgen secretion is stimulated by ACTH.
Adrenal medulla	Epinephrine (E), norepinephrine (NE)	Most cells	Increases cardiac activity, blood pressure, glycogen breakdown, blood glucose levels; releases lipids by adipose tissue	Stimulated by sympathetic preganglionic fibers



c The major regions and zones of an adrenal gland and the hormones they produce

Hormones of the Pancreas

1. **Glucagon:** released by alpha cells when blood glucose levels decrease. It stimulates liver cells to synthesize and release glucose (gluconeogenesis) It also stimulates the skeletal muscle and liver to breakdown glycogen in order to elevate blood glucose. It stimulates the breakdown of fat in adipocytes.
2. **Insulin:** it is released by the beta cells in response to increased blood glucose levels, parasympathetic stimulation, and high levels of some amino acids. It increases the rate of glucose transport, uptake and metabolism or use in most body cells; the storage of lipids and glycogen; and amino acid absorption and protein synthesis.

Table 18-5 Hormones Produced by the Pancreatic Islets.

Table 18–5 Hormones Produced by the Pancreatic Islets				
Structure/Cells	**Hormone**	**Primary Targets**	**Hormonal Effect**	**Regulatory Control**
PANCREATIC ISLETS				
Alpha cells	Glucagon	Liver, adipose tissue	Mobilizes lipid reserves; promotes glucose synthesis and glycogen breakdown in liver; elevates blood glucose concentrations	Stimulated by low blood glucose concentrations; inhibited by GH–IH from delta cells
Beta cells	Insulin	Most cells	Facilitates uptake of glucose by target cells; stimulates formation and storage of lipids and glycogen	Stimulated by high blood glucose concentrations, parasympathetic stimulation, and high levels of some amino acids; inhibited by GH–IH from delta cells and by sympathetic activation
Delta cells	GH–IH (somatostatin)	Other islet cells, digestive epithelium	Inhibits insulin and glucagon secretion; slows rates of nutrient absorption and enzyme secretion along digestive tract	Stimulated by protein-rich meal; mechanism unclear
F cells	Pancreatic polypeptide (PP)	Digestive organs	Inhibits gallbladder contraction; regulates production of pancreatic enzymes; influences rate of nutrient absorption by digestive tract	Stimulated by protein-rich meal and by parasympathetic stimulation

Figure 18–17 Homeostatic Regulation of the Blood Glucose Concentration (Part 1 of 2).

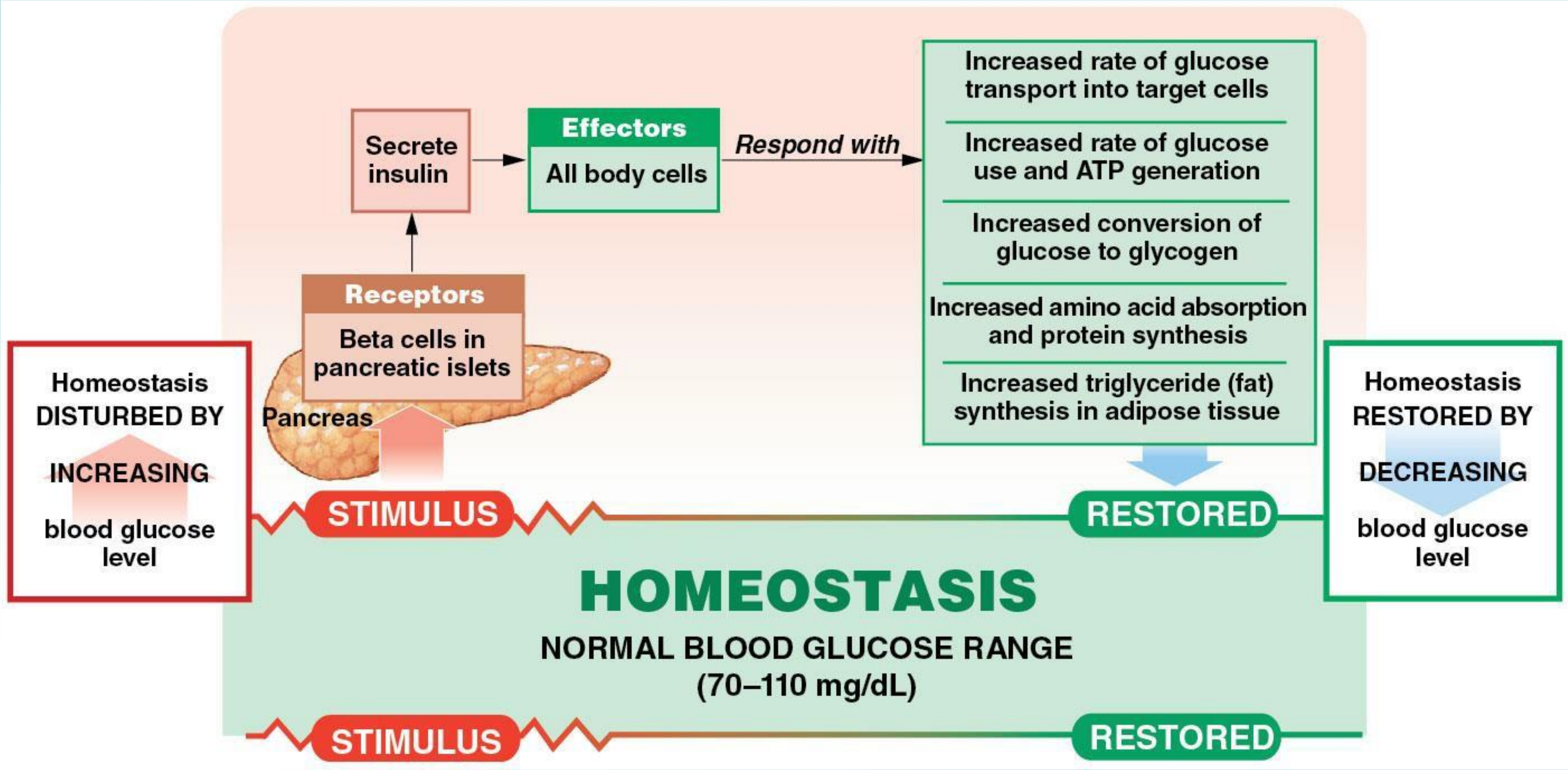
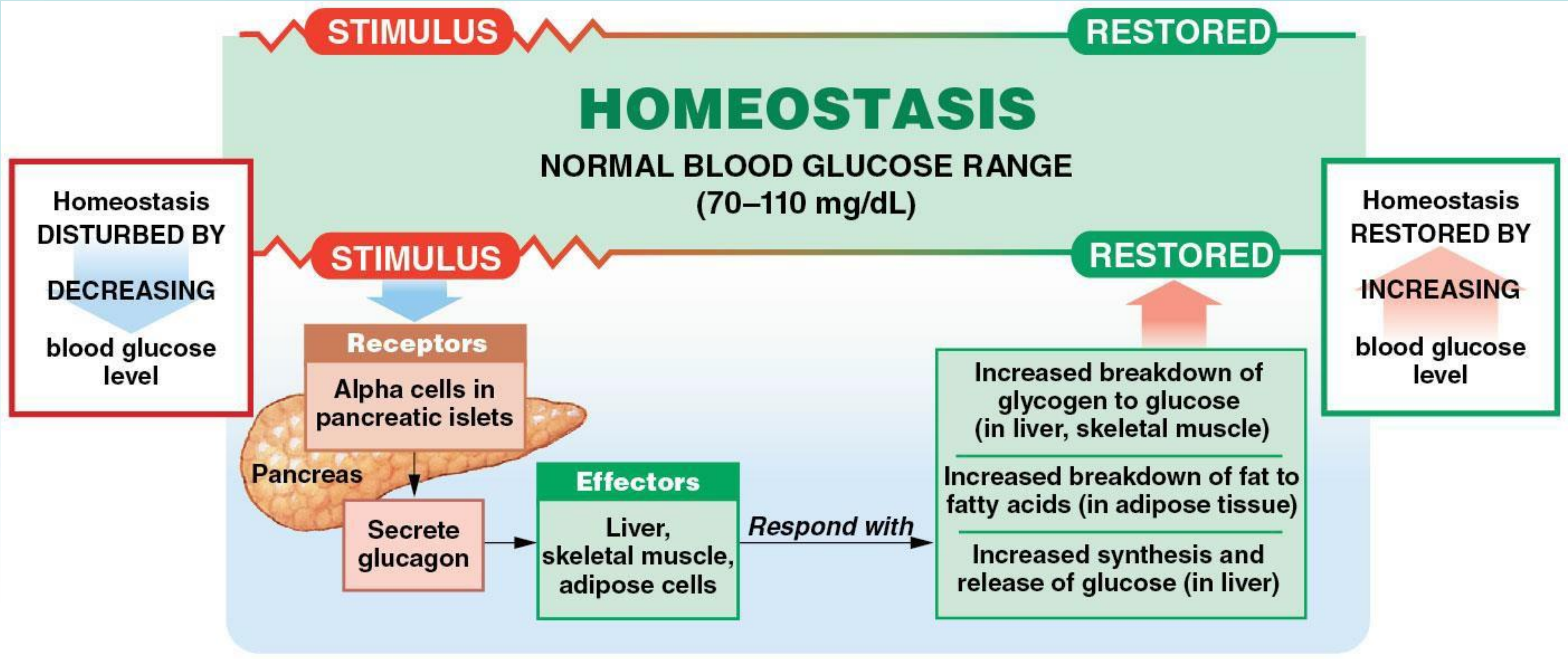


Figure 18–17 Homeostatic Regulation of the Blood Glucose Concentration (Part 2 of 2).



Homeostatic imbalances of the Hormones of the Pancreas

The major disorder of this hormone is diabetes mellitus, which is characterized higher than normal blood glucose levels or hyperglycemia. This leads to by polyuria or large urine output, polydipsia or excessive thirst, and polyphagia or excessive hunger. There are two types of diabetes, type 1 which is always insulin dependent and type 2 with insulin resistance.

Type 1 diabetes mellitus: it is characterized by hyposecretion or deficiency of insulin production by the pancreatic beta cells. Patients require daily insulin injections or continuous infusion of insulin. It consist of only 5% of diabetes cases.

It may be caused by an autoimmune disease produced by a virus or substance that destroys the beta cells. It generally develops in children and young adults. The major symptoms include long-term vascular damage that can lead to arteriosclerosis, strokes, early heart attacks (3 to 5 times more likely); tissue damage due to reduced blood flow which leads to tissue death, ulceration, infection, gangrene, and amputation; peripheral neural problems with loss of sensation (neuropathy); retinal damage; leading to blindness (retinopathy); kidney damage leading to kidney failure (nephropathy); ketoacidosis; high blood cholesterol; and in males, impotence.

Type 2 Diabetes or non-insulin dependent: it is caused by body cells non responsive or resistant to insulin. It usually develops during adulthood, and frequently in obese people. Its symptoms are similar to those of type I diabetes, but with normal levels of insulin at first, then later with high levels of insulin (hyperinsulinism). If not treated it can develop into insulin dependency. It is the most common type of diabetes (95%). It is milder and easier to control it than type I diabetes. In many cases, proper weight control by diet and exercise can cure it.

Untreated diabetes mellitus disrupts metabolic activities throughout the body. Clinical problems arise because the tissues involved are experiencing an energy crisis—in essence, most of the tissues are responding as they would during chronic starvation, breaking down lipids and even proteins because they are unable to absorb glucose from their surroundings. Problems involving abnormal changes in blood vessel structure are particularly dangerous. An estimated 23.6 million people in the United States have some form of diabetes.

Retinal Damage

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

Early Heart Attacks

Degenerative blockages in cardiac circulation can lead to early heart attacks. For a given age group, heart attacks are three to five times more likely in diabetic individuals than in nondiabetic people.

Kidney Degeneration

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

Peripheral Nerve Problems

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

Diabetes Mellitus

Diabetes mellitus (mel-Ī-tus; *mellitum*, honey) is characterized by glucose concentrations that are high enough to overwhelm the reabsorption capabilities of the kidneys. (The presence of abnormally high glucose levels in the blood in general is called **hyperglycemia** [hī-per-glī-SĒ-mē-ah].) Glucose appears in the urine (**glycosuria**; glī-kō-SOO-rē-a), and urine volume generally becomes excessive (**polyuria**).

subdivided into

Type 1 Diabetes

Type 1 (insulin dependent) diabetes is characterized by inadequate insulin production by the pancreatic beta cells. Persons with type 1 diabetes require insulin to live and usually require multiple injections daily, or continuous infusion through an insulin pump or other device. This form of diabetes accounts for only around 5% –10% of cases; it often develops in childhood.

Type 2 Diabetes

Type 2 (non-insulin dependent) diabetes is the most common form of diabetes mellitus. Most people with this form of diabetes produce normal amounts of insulin, at least initially, but their tissues do not respond properly, a condition known as insulin resistance. Type 2 diabetes is associated with obesity, and weight loss through diet and exercise can be an effective treatment.

Peripheral Tissue Damage

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

Table 18-8 Clinical Implications of Endocrine Malfunctions (Part 1 of 2).

Table 18–8 Clinical Implications of Endocrine Malfunctions

Hormone	Underproduction or Tissue Insensitivity	Principal Signs and Symptoms	Overproduction or Tissue Hypersensitivity	Principal Signs and Symptoms
Growth hormone (GH)	Pituitary growth failure	Retarded growth, abnormal fat distribution, low blood glucose hours after a meal	Gigantism, acromegaly	Excessive growth
Antidiuretic hormone (ADH) or vasopressin (VP)	Diabetes insipidus	Polyuria, dehydration, thirst	SIADH (syndrome of inappropriate ADH secretion)	Increased body weight and water content
Thyroxine (T_4), triiodothyronine (T_3)	Hypothyroidism, infantile hypothyroidism, myxedema	Low metabolic rate; low body temperature; impaired physical and mental development	Hyperthyroidism, Graves disease	High metabolic rate and body temperature
Parathyroid hormone (PTH)	Hypoparathyroidism	Muscular weakness, neurological problems, formation of dense bones, tetany due to low blood $Ca2^+$ concentrations	Hyperparathyroidism	Neurological, mental, muscular problems due to high blood Ca^{2+} concentrations; weak and brittle bones
Insulin	Diabetes mellitus (Type 1)	High blood glucose, impaired glucose utilization, dependence on lipids for energy; glycosuria	Excess insulin production or administration	Low blood glucose levels, possibly causing coma

Hormone of the Pineal Gland

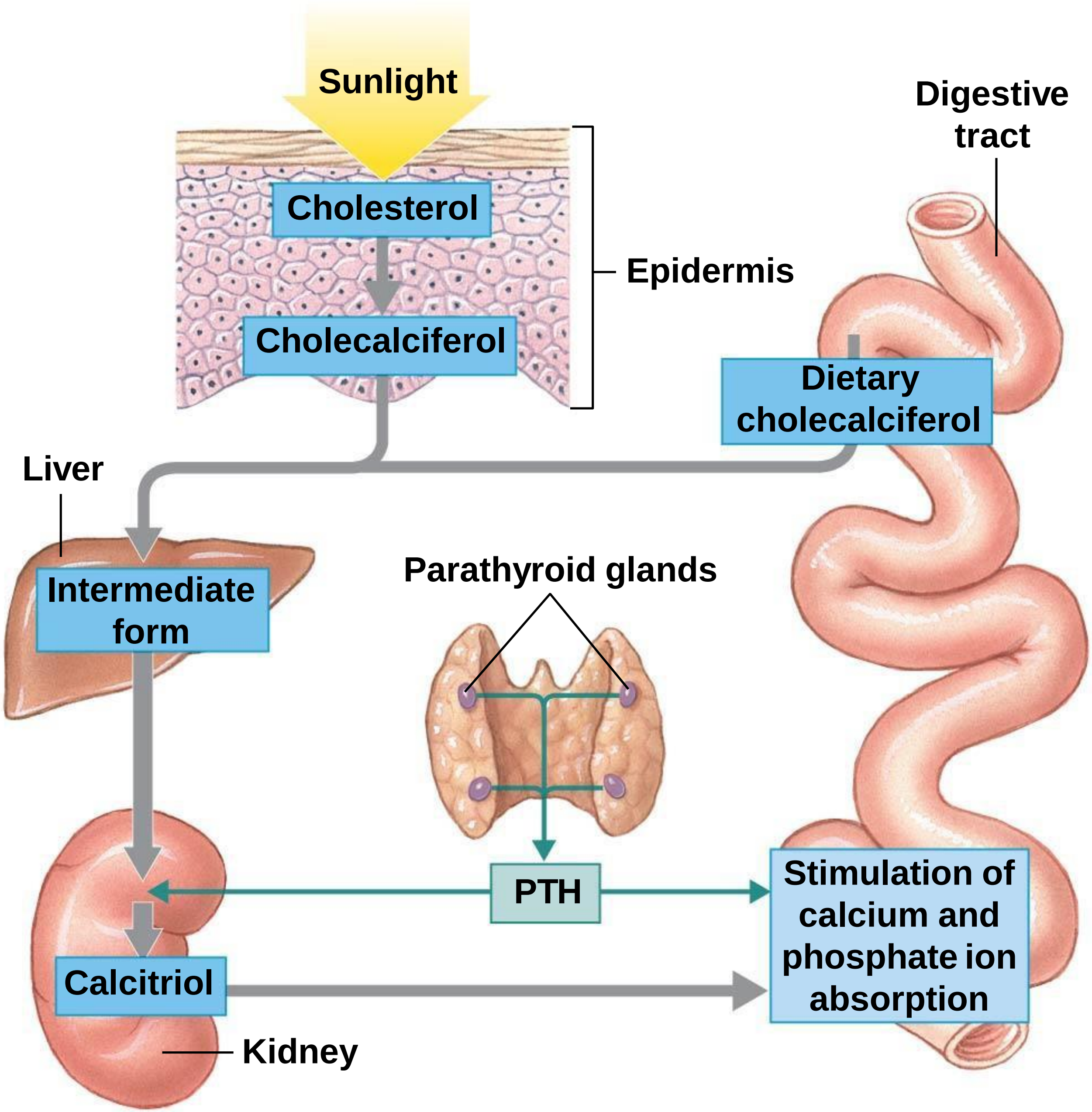
Melatonin

It is produced by the pineal gland. The functions of this hormone include: inhibits early sexual maturation; protects from free radical damage; and sets or influences the circadian rhythms or daily cycles.

Organs with Secondary Endocrine Functions

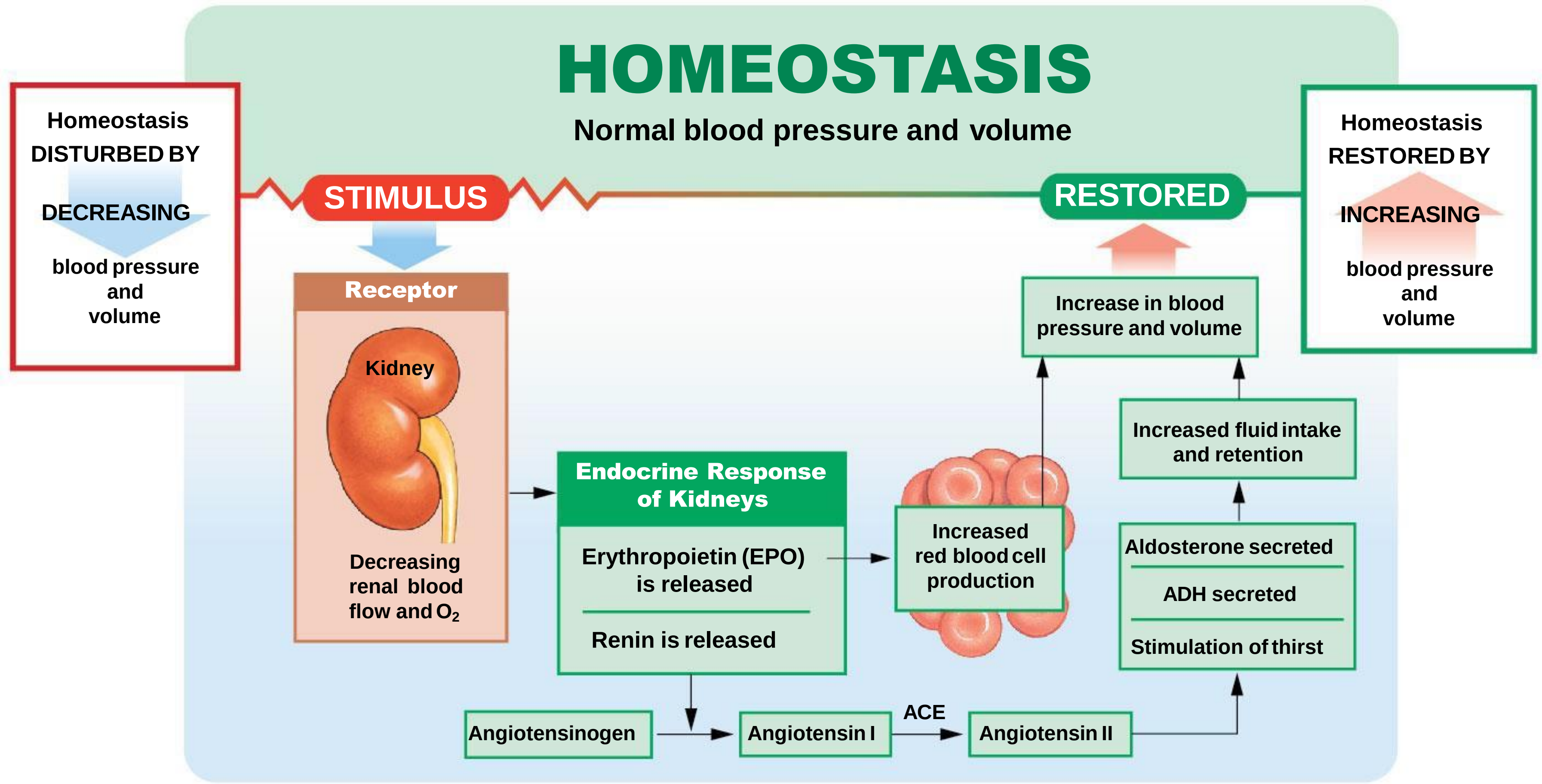
- **The Heart:** the heart endocrine cells produce natriuretic peptides (ANP and BNP) when blood volume increases above normal. Their action result in the reduction of blood volume and pressure in opposition to angiotensing II.
- **The Intestines:** different cell populations of the intestines produce hormones such as gastrin, secretin, serotonin and cholecystokinin, which help to coordinate digestive activities of the GI tract.
- **The Kidneys:** produce the hormones **erythropoietin (EPO)** and **calcitriol**. It also releases the enzyme renin which converts angiotensinogen to angiotensin I. In the lungs, angiotensin-converting enzyme converts angiotensin I to **angiotensin II.**
- **The Thymus:** produces thymosin which are a mixture of several hormones. They promote development and maturation of T lymphocytes.

Figure 18-19a Endocrine Functions of the Kidneys.



a The production of calcitriol

Figure 18–19b Endocrine Functions of the Kidneys.



b The release of renin and erythropoietin, and an overview of the renin-angiotensin-aldosterone system beginning with the activation of angiotensinogen by renin

Organs with Secondary Endocrine Functions

- **The Gonads:** the anatomy and most of the functions of the testis and ovaries will be discussed on the lessons on the reproductive system.

The testes interstitial endocrine cells produce androgens. The primary androgen is **testosterone**. The **Nurse cells** or Sertoli cells in the testes secrete the hormone **inhibin**, which inhibits the secretion of FSH, and may inhibit also the release of GnRH by the hypothalamus. These cells support differenciation and physical maturation of sperm.

The Ovaries: produce **estrogens** and **Progesterone**

Estrogens: FSH and LH control the secretion of these hormones. They are secreted by the follicular cells of the ovaries. **Estradiol** is the most important estrogen. They stimulate follicle maturation, the maturation of the female reproductive system, and development of the secondary sexual characteristics

Table 18-6 Representative Hormones Produced by Organs of Other Systems.

Table 18–6 Representative Hormones Produced by Organs of Other Systems			
Organ	**Hormone**	**Primary Target**	**Hormonal Effect**
Intestines	Many (secretin, gastrin, cholecystokinin, etc.)	Other regions and organs of the digestive system	Coordinate digestive activities
Kidneys	Erythropoietin (EPO) Calcitriol	Red bone marrow Intestinal lining, bone, kidneys	Stimulates red blood cell production Stimulates calcium and phosphate absorption; stimulates Ca^{2+} release from bone; inhibits PTH secretion
Heart	Natriuretic peptides (ANP and BNP)	Kidneys, hypothalamus, adrenal gland	Increase water and salt loss at kidneys; decrease thirst; suppress secretion of ADH and aldosterone
Thymus	Thymosins (many)	Lymphocytes and other cells of the immune response	Coordinate and regulate immune response
Gonads	*See Table 18–7*		
Adipose tissues	Leptin	Hypothalamus	Suppression of appetite; permissive effects on GnRH and gonadotropin synthesis

Organs with Secondary Endocrine Functions

Progesterone is the most important progestin. It is secreted by the corpus luteum which forms from follicle cells after ovulation in response to high blood levels of LH. It prepares the uterus for implantation, establishes the menstrual cycle, maintains pregnancy, and prepares the mammary glands for milk secretion.

- **The adipose tissue:** produces the hormone **leptin** (a peptide hormone) which help control appetite and maintains normal levels of GnRH and gonadotropin synthesis.

Table 18-7 Hormones of the Reproductive System.

Table 18–7	Hormones of the Reproductive System			
Structure/Cells	**Hormone**	**Primary Target**	**Hormonal Effect**	**Regulatory Control**
TESTES				
Interstitial cells	Androgens	Most cells	Support functional maturation of sperm, protein synthesis in skeletal muscles, male secondary sex characteristics, and associated behaviors	Stimulated by LH from the anterior lobe of the pituitary gland
Nurse cells	Inhibin	Pituitary gland	Inhibits secretion of FSH	Stimulated by FSH from the anterior lobe
OVARIES				
Follicular cells	Estrogens	Most cells	Support follicle maturation, female secondary sex characteristics, and associated behaviors	Stimulated by FSH and LH from the anterior lobe of the pituitary gland
	Inhibin	Pituitary gland	Inhibits secretion of FSH	Stimulated by FSH from anterior lobe
Corpus luteum	Progesterone	Uterus, mammary glands	Prepares uterus for implantation; prepares mammary glands for secretory activity	Stimulated by LH from the anterior lobe of the pituitary gland

Endocrine System movies and animations

http://www.youtube.com/watch?v=7W0cEySKgJA&feature=related
http://www.youtube.com/watch?v=YI2qYRWzSZ4
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