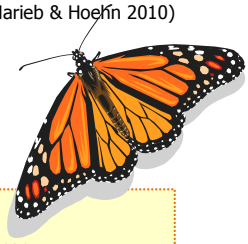
Chapt. 16: The Endocrine System



IMPORTANT DIFFERENCES BETWEEN HORMONAL AND NEURAL CONTROLS OF BODY FUNCTIONING:

Indicate whether the following statements pertain to the nervous system or the endocrine system:

✓ regulates the activity of muscles and glands via electrochemical impulses:

✓ influences metabolic activity by means of hormones:

✓ produces a response within milliseconds:

✓ initiates responses that typically occur after a lag period of seconds to days:

✓ initiates responses that tend to be much more prolonged:

Characterize exocrine and endocrine glands with respect to what they produce and whether or not they have a duct system:

※ **exocrine**:

※ **endocrine**:

- endocrine glands release their hormones into what?
- do they have a rich vascular and lymphatic drainage?
- how are most hormone -producing cells in endocrine glands arranged?
- what does the arrangement maximize?
- observe the endocrine glands shown in Fig. 16.1
- list examples of the many organs that also contain scattered endocrine cells or small clusters of endocrine cells:
- hormones are long-distance chemical signals that travel in blood or lymph throughout the body
  - define **autocrines**:
  - define **paracrines**:

HORMONES

THE CHEMISTRY OF HORMONES

- define **hormones** (p. 596):
- nearly all of them can be classified chemically as what?

- most hormones are what?
- what are the steroids synthesized from?

• list the two types of **eicosanoids**:
- these biologically active lipids made from arachadonic acid are released by what?

- what do <u>leukotrienes</u> mediate?

- some effects of <u>prostaglandins</u>:
  - necessary for blood clotting; promote fever, inflammation and pain; stimulate contraction of the uterus
- eicosanoids are considered hormonelike chemicals; why don't eicosanoids fit the definition of the true hormones?

Aspirin and related NSAIDs <u>interfere with the synthesis of prostaglandins</u>. So…does it make sense that people take aspirin to decrease blood clot formation, fever, pain and inflammation?!

MECHANISMS OF HORMONE ACTION

• the cells where hormones have an effect are called **target cells**
• a hormonal stimulus typically produces one or more of what 5 changes?

Hormones circulate through the blood to most parts of the body. So, why don't they have an effect on <u>all</u> of the cells they come in contact with? Receptors! If a cell is a target cell for a specific hormone, then it will have receptors for that hormone. The hormone will have no effect on cells without specific receptors. ✯ The type of receptor varies, depending on whether or not a hormone can pass through a cell membrane:

• <u>water soluble hormones</u> (all amino acid-based hormones except thyroid hormone) act on receptors in what?
- what are these receptors coupled to?

• <u>lipid-soluble hormones</u> (steroid and thyroid hormones) act on what type of receptors?

🗝 **Plasma Membrane Receptors and Second-Messenger Systems**
✧ all amino acid-based hormones except thyroid hormone exert their signaling effects through what?

✧ these hormones are complex molecules that <u>cannot</u> pass through the cell membrane

✧ they require a receptor on the cell membrane of the target cell and a second messenger (such as **cAMP**) to cause an effect (see Fig. 16.2)(insulin and other growth factors, however, do not require a second messenger)

The Cyclic AMP Signaling Mechanism:

List the headings (in bold print) of the steps on p.597 that outline how water soluble hormones bring about an effect on their target cells:

①

- what is the hormone acting as?

②

- G protein is associated with the cell membrane

So…Why would it be useless for a target cell of a protein hormone to have an intracellular receptor for that hormone?

③

④

⑤

- The activated protein kinases trigger some sort of effect in the cell (e.g., activate other enzymes, activate genes, stimulate the release of cellular secretions, cause a change in membrane permeability to cause muscle contraction, etc.).

Intracellular Receptors and Direct Gene Activation

✧ the lipid-soluble hormones (steroid and thyroid hormones) diffuse through the phospholipid bilayer of cell membranes into cells and activate genes directly (see Fig. 16.3)

✧ if a cell is a target cell, it will have an intracellular receptor specific for that lipid-soluble hormone

List the headings (in bold print) of the steps on in Fig. 16.3 on p.599 that outline how water soluble hormones bring about an effect on their target cells:

①

②

③

④

⑤

- the protein that forms acts as an enzyme to carry out the effect of the hormone by catalyzing a certain chemical reaction in the target cell

TARGET CELL SPECIFICITY

Target cell activation by hormone-receptor interaction depends equally on what three factors:

(1)

(2)

(3)

- do all three factors change rapidly in response to various stimuli and changes within the body?
- are receptors dynamic (constantly synthesized and broken down)?
  - describe **up-regulation**:

  - describe **down-regulation**:

    - down regulation involves the loss of receptors and prevents what?

HALF-LIFE, ONSET, AND DURATION OF HORMONAL ACTIVITY

- hormones circulate in the body in what two forms?

  - how do most lipid-soluble hormone molecules travel in the blood stream?

  - most water-soluble hormone molecules circulate without protein carriers

- the concentration of a circulating hormone in blood at any time reflects what two things?
  (1)

  (2)

    - some hormones are rapidly degraded by what?

    - what happens to most hormones?

INTERACTION OF HORMONES AT TARGET CELLS

• can multiple hormones act on the same target at the same time?

• describe **permissiveness**:

• describe **synergism**:

• describe **antagonism**:

CONTROL OF HORMONE RELEASE

• the synthesis and release of most hormones are regulated by what?
- summarize what happens in such a system:

🗝 Endocrine Gland Stimuli

list the three major types of stimuli that trigger endocrine glands to manufacture and release their hormones:

✧ HUMORAL STIMULI
- some endocrine glands secrete their hormones in direct response to what?

- give an example:

✧ NEURAL STIMULI
- nerve fibers stimulate hormone release
- give the classic example of neural stimuli:

✧ HORMONAL STIMULI
- many endocrine gland release their hormones in response to what?

- give an example:

🗝 Nervous System Modulation

• the nervous system can modify what?

• for example, the action of insulin and several other hormones normally keeps blood glucose levels at 90 to 110 mg/100ml of blood. However, what happens when your body is under severe stress?

THE PITUITARY GLAND AND HYPOTHALAMUS

• what is another name for the pituitary gland?
• what is it "seated" in?
• its size and shape are similar to what?
• what is its stalk called?
  - what does the infundibulum connect the pituitary gland to superiorly?
• study the structure of the pituitary gland & its relationship with the hypothalamus in Fig. 16.5.
• name the <u>two major lobes</u> of the pituitary gland (and read about them on p. 601):

PITUITARY-HYPOTHALAMIC RELATIONSHIPS

<u>THE POSTERIOR LOBE OF THE PITUITARY AND THE HYPOTHALAMUS</u>:
• the **posterior lobe** is actually part of the brain; it is derived from a downgrowth of what?

• it maintains its connection with the hypothalamus via a nerve bundle (a bundle of axons) called what?

• this tract arises from neurons in the hypothalamus; read about the neurosecretory cells there; we will get back to them…

<u>THE ANTERIOR LOBE OF THE PITUITARY AND THE HYPOTHALAMUS</u>:
• the glandular **anterior lobe** originates from what?

• although it loses it connection with the oral mucosa, there is a vascular connection:
  - a primary capillary plexus in the infundibulum near the hypothalamus communicates inferiorly with what?

  - so, list the parts of the **hypophyseal portal system**:

  - via this portal system, <u>releasing and inhibiting hormone</u> secreted by neurons in the hypothalamus circulate to what?

☆ so, the hypothalamus, by secreting releasing and inhibiting hormones, regulates the secretion of the cells in the anterior pituitary!

ANTERIOR PITUITARY HORMONES

• why has the anterior pituitary been called the "master endocrine gland"?

• what controls the activity of the anterior pituitary?
• there are how many distinct anterior pituitary hormones?
• are they proteins or steroids?

•there are five different types of cells that produce the six anterior pituitary hormones; from Table 16.1 on pages 606 and 607, write the name of the hormone(s) produced by each type of cell in the table below:

type of anterior pituitary cell	*hormone produced*
somatotrophs	
thyrotrophs	
corticotrophs	
gonadotrophs	
lactotrophs	

• what are **tropins** (**tropic hormones**)?

- name the four out of six hormones produced by the anterior pituitary that are tropins:

Growth Hormone

◦ what is the abbreviation for growth hormone? what is it also called?
◦ name the cells that produce GH:
◦ what are the major targets of GH and what are its effects on these targets?

direct actions of GH:

targets:	effects
• adipose tissue	• increases fat breakdown and release, increasing blood levels of fatty acids
• hepatocytes of the liver	• increases glycogen breakdown and release of glucose, which increases blood levels of glucose

indirect actions of GH:

• GH stimulates cells of the liver, skeletal muscle, bone and other tissues to produce a family of growth-promoting proteins called what?

targets of IGFs:
• skeletal muscles & the tissues of the skeleton
actions of IGFs: stimulate what two actions required for growth of muscles and bones?
(1)

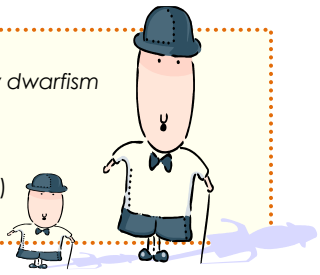
(2)

◦ secretion of GH is regulated chiefly by two hormones produced where?

hyposecretion of GH
⌑ during childhood: causes slow bone growth; premature closure of the epiphyseal plates → *pituitary dwarfism*

hypersecretion of GH
⌑ during childhood: causes abnormal growth in length of long bones → *pituitary giantism*

⌑ during adulthood: causes increased thickness of bones (e.g., bones of the hands, feet, jaw, cheeks) and enlargement of other tissues (e.g., nose, tongue, lips; thickening of the skin) → *acromegaly*



Thyroid-Stimulating Hormone

◦ what is the abbreviation for thyroid-stimulating hormone?
- what is it also called?

◦ it is secreted by cells called what?

target: the thyroid gland
effect: stimulates the follicle cells to secrete thyroid hormones

◦ does the hypothalamus produce a releasing hormone to trigger the release of TSH from the anterior pituitary?

Adrenocorticotropic Hormone

◦ what is the abbreviation for adrenocorticotropic hormone?
- what is it also called?

◦ secreted by cells called what?

target: adrenal cortex
effect: stimulates the cortex of the adrenal gland to synthesize and release what type of hormones?

◦ what elicits the secretion of ACTH?

GONADOTROPINS

★Note: The next two hormones, **FSH** and **LH**, are called **gonadotropins** because they are hormones that stimulate the gonads to produce their hormones. What organs are called gonads?

★the release of the gonadotropins is stimulated by **gonadotropin-releasing hormone** (GnRH):
GnRH is produced by the hypothalamus
target of GnRH = gonadotrophs of the anterior pituitary
effect = stimulates the gonadotrophs to secrete FSH and LH

Follicle-stimulating hormone

◦ what is the abbreviation for follicle stimulating hormone?
◦ name the target and effects of follicle-stimulating hormone in females?

☆See Table 16.1 for the target and effects of FSH and LH!

◦ name the target and effects of follicle-stimulating hormone in males?

Luteinizing hormone

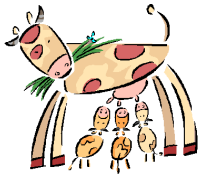
◦ what is the abbreviation for luteinizing hormone?
◦ name the target and effects of luteinizing hormone in females?

◦ name the target and effects of luteinizing hormone in males?

Prolactin

◦ what is the abbreviation for prolactin?
◦ name the cells of the anterior pituitary that produce prolactin:
◦ the target is the breasts (mammary glands)
◦ what is the only well-documented effect in humans?

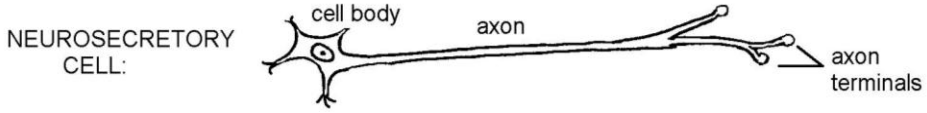
◦ does the hypothalamus regulate prolactin secretion?

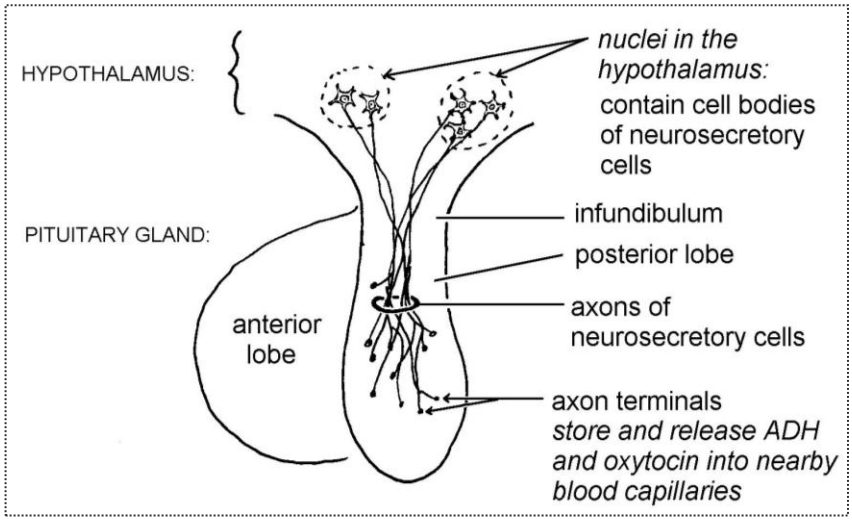


THE POSTERIOR PITUITARY and HYPOTHALAMIC HORMONES

• the posterior pituitary does NOT synthesize hormones
• it stores and releases two hormones (ADH and oxytocin) that are synthesized in the cell bodies of neurosecretory cells in the nuclei of the hypothalamus of the brain.
• what is the posterior pituitary largely made up of?

• study Fig. 16.5(A) and the sketches below. Note the different parts of the **neurosecretory cells** and their location
  - cell bodies of the neurosecretory cells are in "nuclei" in the hypothalamus of the brain
  - there axons form a bundle called the hypothalamic-hypophyseal tract that runs from the hypothalamus through the infundibulum to the posterior pituitary
  - axon terminals of the neurosecretory cells are in the posterior lobe of the pituitary gland; they store the two hormones and release them into nearby blood capillaries





Oxytocin

◦ from Table 16.1, fill in the two targets and the effects of oxytocin below:

targets effects

Milk Ejection (Milk Let-Down Reflex):

baby suckles on the nipple of the mammary gland

↓

sensory nerve impulses are conducted to the neurosecretory cells of the hypothalamus that produce oxytocin

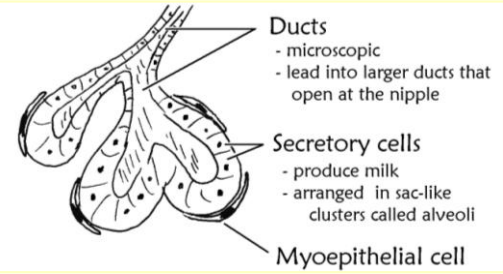
↓

impulses are conducted along the axons to the axon terminals of the neurosecretory cells and initiate the release of oxytocin from axon terminals of the posterior pituitary into nearby blood capillaries

↓

when oxytocin circulates through the mammary glands, it stimulates contraction of the **myoepithelial cells** (which surround the secretory cells and ducts) This action causes the milk that accumulates in the ducts to be available for the child at the mother's nipples and is known as **milk ejection** (milk let-down)

(The effect is similar to squeezing an orange so that all of the juice in the nooks and crannies of the orange are available to drink!)



Antidiuretic Hormone

◦ define *diuresis*:

◦ define an *antidiuretic*:

from Table 16.1, fill in the target and the effects of ADH below:

targets effects

- what is the effect of alcohol on secretion of ADH?

◦ another target of antidiuretic hormone is the arterioles

- ADH causes vasoconstriction of arterioles, which increases blood pressure

THE THYROID GLAND

Location and Structure

- describe the shape and location of the thyroid gland:

- how many lobes is it composed of?
- identify the thyroid gland in Fig. 16.8 and study the microscopic thyroid follicles, formed mainly of follicle cells
- describe colloid:

- there are also parafollicular cells (C cells) associated (in smaller numbers) with the follicles
  - what hormone do the parafollicular cells produce?

Thyroid Hormone

- the term "thyroid hormone" (TH) includes the 2 hormones produced by the follicle cells:

1. **thyroxine (T_4)**
   - is the major hormone produced by the follicle cells, but it gets converted to T4 at the target tissues

2. **triiodothyronine (T3)**
   - the more active form

- T3 and T4 are constructed from what?

  - why do you think T_4 is called T_4?

  - why do you think T_3 is called T_3?

- are most cells affected by thyroid hormone?
  (so the targets of T_3 and T_4 are most cells of the body)

- effects of thyroid hormone:

1. increases basal metabolic rate by stimulating the use of cellular oxygen to produce ATP (increase cellular metabolism of organic compounds)
   - basal metabolic rate = the rate of oxygen consumption under standard conditions
   - when basal metabolic rate increases, cellular metabolism of carbohydrates, lipids and proteins increases

therefore, cells produce and use more ATP, so more heat is given off and body temperature rises

- define **calorigenic effect**:

2. promotes glucose catabolism and stimulates protein synthesis
3. enhances effects of the sympathetic nervous system
4. critical for normal development and maturation of what two systems?

Synthesis

• the thyroid gland has a unique ability among the endocrine glands to do what?

• *Next to the numbers below, write the steps of thyroid hormone synthesis listed in* ***bold print*** *on p. 609 to p.610 and see Fig. 16.9:*

(1)

· follicle cells synthesize thyroglobulin (TGB), which is a large glycoprotein that contains the amino acid tyrosine; it is packaged into secretory vesicles and released into the lumen of the follicle by exocytosis

(2)

· iodide ions (I^-) are taken from the blood into the follicle cells by active transport, then move into the lumen of the follicle by facilitated diffusion

(3)

· iodide ions (I^-) are oxidized to iodine molecules (I_2)
· where does this occur?

(4)

· iodine reacts with the tyrosines of thyroglobulin, forming colloid that is stored in the lumen of the thyroid follicles

(5)

· T_3 and T_4 are stored in the colloid as part of thyroglobulin

(6)

· when thyroid hormone levels decrease in the blood, droplets of colloid reenter the follicle cells by pinocytosis

(7)

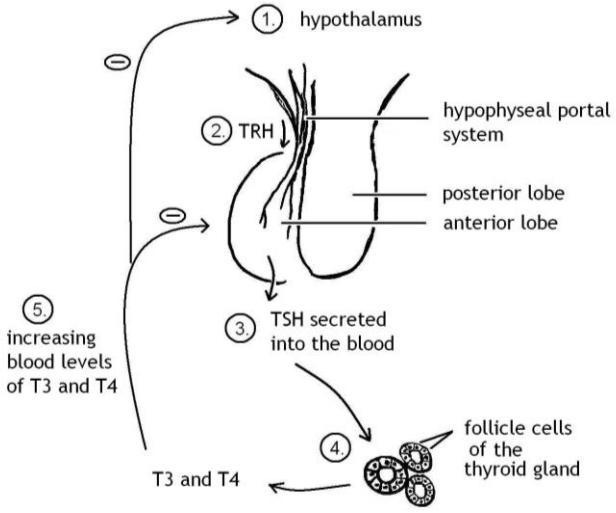
Transport and Regulation

· most released T_3 and T_4 molecules are transported in the blood bound to transport proteins, most importantly called what?

• which regulates blood levels of thyroid hormones, a positive feedback loop or a negative feedback loop?

Regulation of thyroid hormone:

1. Chemoreceptors in the hypothalamus of the brain detect low blood levels of thyroid hormone (T_3 and T_4).
2. **TRH** (**thyrotropin releasing hormone**) is released from the hypothalamus into capillaries → hypophyseal portal system → capillaries of the anterior pituitary.
3. TRH stimulates **thyrotrophs** of the anterior pituitary to secrete **TSH** (**thyroid stimulating hormone**; **thyrotropin**) into capillaries to the general circulation.
4. TSH circulates to the thyroid gland and stimulates **follicle cells** of the thyroid gland to synthesize and secrete **thyroid hormone** (T_3 and T_4).
5. Rising blood levels of T_3 and T_4 have a negative feedback on the hypothalamus and the cells of the anterior pituitary, inhibiting further release of TRH by the hypothalamus and of TSH by the anterior pituitary. With a decrease in TSH, the follicle cells of the thyroid gland stop releasing T_3 and T_4.
   As blood levels of T_3 and T_4 decrease, this is detected by the chemoreceptors in the hypothalamus....See step 1 again!



Calcitonin

• what cells of the thyroid gland produce calcitonin?

• does it raise or lower blood calcium ion levels?

• describe its effects on the skeleton:

• so, do you think calcitonin is released when blood calcium levels are too high or too low?

THE PARATHYROID GLANDS

- describe the appearance and location of the parathyroid glands:

- a person usually has how many parathyroid glands?
- contain **chief cells** that secrete what hormone?
- parathyroid hormone is the single most important hormone controlling what?
  - its release is triggered by what?
  - its release is inhibited by what?

- *using the information in Fig. 16.12, fill in the 3 target organs of parathyroid hormone and its effects on each target:*

Targets	*Effects of Parathyroid Hormone*

THE ADRENAL (SUPRARENAL) GLANDS

- study the location and structure of the paired adrenal glands in Fig. 16.13; describe their shape and location:

- describe the **adrenal medulla**:

- describe the **adrenal cortex**:

The Adrenal Cortex

- synthesizes steroid hormones collectively called what?

- are steroid hormones stored in cells?
- consequently, their rate of release in response to stimulation depends on what?

- the cells of the adrenal cortex are arranged in three zones:
  - zona glomerulosa (outer zone) produces mineralocorticoids, which are hormones that help control what?

  - zona fasciculata (middle zone) produces metabolic hormones called what?

  - zona reticularis (inner zone) produces small amounts of what?

Mineralocorticoids

- what is the essential function of mineralocorticoids?

- the major mineralocorticoid is **aldosterone**
  - indicate the target and effects of aldosterone from Table 16.3:

  - aldosterone secretion is stimulated by what? *(first column on p. 615)*:

  - name the mechanism that influences both blood volume and blood pressure by regulating the release of aldosterone and therefore Na+ and water reabsorption by the kidneys:

Glucocorticoids

- essential to life, the glucocorticoids do what?

  - under normal circumstances, how do glucocorticoids help the body adapt to intermittent food intake?

  - how do they maintain blood pressure?

- what is the only glucocorticoid that is produced in significant amounts in humans?
- what hormone produced by the anterior pituitary promotes the release of cortisol?
- read text on page 617 about glucocorticoids
- list the 3 effects of glucocorticoids from Fig. 16.16 on its targets (most cells of the body):

Gonadocorticoids

The inner zone of the adrenal cortex secretes small amounts of androgens and estrogens.

The Adrenal Medulla

- the hormone producing cells of the adrenal medulla, called **chromaffin cells**, are derived from the nervous system (modified sympathetic ganglionic neurons)
- list the two hormones called **catecholamines** synthesized by the chromaffin cells of the adrenal medulla:
- effects of epinephrine and norepinephrine: Responsible for the "fight or flight" response to short term stress *(along with the sympathetic nervous system, which we will get to later in the course)*.
  - list the six effects of epinephrine and norepinephrine shown in Fig. 16.16:

PINEAL GLAND

✓ describe the shape and location of the pineal gland:

✓ is the endocrine function of the pineal gland well-understood?

✓ what is its only major secretory product?

✓ melatonin is thought to affect the timing of puberty and to contribute to setting our "biological clock"

✓ changing melatonin levels may be a means by which the day/night cycles influence physiological process that show rhythmic variations, such as what three things?

OTHER ENDOCRINE GLANDS AND TISSUES

The Pancreas

- study the structure of the pancreas in Fig. 16.17
- *exocrine function:* most of the cells (acinar cells) of the pancreas form clusters called acini that produce pancreatic juice (including digestive enzymes); pancreatic juice is carried to the small intestine by a duct system; this will be covered with the digestive system
- *endocrine function:* has clusters of endocrine cells that form **pancreatic islets** (islets of Langerhans); the cells secrete insulin and glucagon (and other hormones)

• Cell Types in the Pancreatic Islets

1. **alpha (α) cells** – what hormone do they secrete?
2. **beta (β) cells** – what hormone do they secrete?

Glucagon

• released in response to low blood levels of glucose

target	effects
hepatocytes	◦ stimulates the breakdown of glycogen to glucose and the release of glucose into the blood ◦ this raises blood glucose levels

Insulin

• released in response to high blood levels of glucose

targets	effects
a. most cells of the body (especially skeletal muscle cells)	◦ enables the cells to uptake glucose (by facilitated diffusion) from the blood ◦ this lowers blood glucose levels
b. hepatocytes of liver	◦ stimulates the hepatocytes to uptake glucose from the blood and convert glucose to glycogen

The Gonads and Placenta

• list the two most important hormones produced by the ovaries:

• name the primary hormone produced b the testes:

• the placenta produces estrogens, progesterone and human chorionic gonadotropin

Hormone Secretion by Other Organs

Numerous other organs, produce hormones, even though they are not classically studied as part of the endocrine system! List the 7 organs in which hormone-producing cells occur (p. 624):

The End