College of Nursing
UNIVERSITY OF THE PHILIPPINES MANILA
The Health Sciences Center

N3 Anatomy and Physiology

The Endocrine System

Kenny-lynn B. Baccay, RN, MA(Nursing)

kbbacay@up.edu.ph

1

Objectives

1. Describe the development of endocrine glands during fetal development.
2. Compare control of body functions by the nervous system and endocrine system.
3. Distinguish between exocrine and endocrine glands.
4. Describe the two general mechanisms of hormone action.
5. Describe the mechanism of control of hormone secretion.
6. Describe the location, histology, hormone, and function of endocrine glands.
7. Describe how the body responds to stress.

2

Development of the endocrine system

- 3rd week – *pituitary gland* begins to develop from 2 different regions of the ectoderm
- 4th week – *thyroid gland* develops as a midventral outgrowth of endoderm; *parathyroid glands* from endoderm from the 3rd and 4th pharyngeal pouches
- 5th week – *adrenal cortex* develops from the same region of mesoderm that produces the gonads, while the *adrenal medulla* develops from ectoderm from neural crest cells; the *thymus* develops from endoderm
- 5th to 7th weeks – *pancreas* develops from 2 outgrowths of endoderm
- 7th week – *pineal gland* develops from ectoderm

3

Comparison of control by the nervous and endocrine system

TABLE 18.1

Comparison of Control by the Nervous and Endocrine Systems

CHARACTERISTIC	NERVOUS SYSTEM	ENDOCRINE SYSTEM
Mediator molecules	Neurotransmitters released locally in response to nerve impulses.	Hormones delivered to tissues throughout body by blood.
Site of mediator action	Close to site of release, at synapse; binds to receptors in postsynaptic membrane.	Far from site of release (usually); binds to receptors on or in target cells.
Types of target cells	Muscle (smooth, cardiac, and skeletal) cells, gland cells, other neurons.	Cells throughout body.
Time to onset of action	Typically within milliseconds (thousandths of a second).	Seconds to hours or days.
Duration of action	Generally briefer (milliseconds).	Generally longer (seconds to days).

4

Endocrine glands

- ***Exocrine glands*** secrete their products into ducts that carry the outer surface of the body while ***endocrine glands*** secrete their products (hormones) into the interstitial fluid surrounding the secretory cells rather than into the ducts
- Endocrine glands include pituitary, thyroid, parathyroid, adrenal, and pineal glands.
- Several organs and tissues contain cells that secrete hormones such as hypothalamus, thymus, pancreas, ovaries, testes, kidneys, stomach, liver, small intestine, skin, heart, adipose tissue, and placenta.

5

Hormone activity

The role of hormone receptors:

- **Hormone receptors** – protein receptors that bind hormones
- **Down-regulation** – if a hormone is present in excess, the number of target-cell receptors may decrease
- **Up-regulation** – if a hormone is deficient, the number of target-cell receptors may increase

6

Circulating and local hormones

- **Circulating hormones** – hormones that pass from the secretory cells that make them into interstitial fluid and then into the bloodstream
- **Local hormones** – act locally on neighboring cells or on the same cell that secreted them without first entering the bloodstream
  - **Paracrines** – local hormones that act on the neighboring cells (i.e., interleukin-2)
  - **Autocrines** - local hormones that act on the same cell

7

Chemical classes of hormones

Lipid-soluble hormones	Water-soluble hormones
• Steroid hormones • Thyroid hormones (T3 and T4) • Nitric oxide	• Amine hormones • Peptide hormones and protein hormones • Eicosanoid hormones

8

Hormone transport in the blood

- Most water-soluble hormones circulate in plasma in a free, unattached form.
- Most lipid-soluble hormones bind to *transport proteins* to be carried in the blood.
- The transport proteins improve the transportability of lipid-soluble hormones by making them temporarily water-soluble, retard the passage of the small hormone molecules through the kidney filter thus slowing the rate of hormone loss in urine, and provide a ready reserve of the hormone already present in the blood.

9

Mechanisms of hormone action

The response to a hormone depends on both the hormone and the target cell; various target cells respond differently to different hormones.

A. Action of lipid-soluble hormone

1. Lipid-soluble hormones bind to and activate receptors within cells.
2. The activated receptors then alter gene expression which results in the formation of new proteins.
3. The new proteins alter the cells activity and result in the physiological responses of those hormones.

10

Mechanisms of hormone action

B. Action of Water-Soluble Hormones

1. *Water-soluble hormones* alter cell functions by activating plasma membrane receptors, which set off a cascade of events inside the cell.
   a. The water-soluble hormone that binds to the cell membrane receptor is the *first messenger*.
   b. A *second messenger* is released inside the cell where a hormone-stimulated response takes place.
2. A typical mechanism of action of a water-soluble hormone using cyclic AMP as the second messenger is as follows:
   a. The hormone binds to the membrane receptor.
   b. The activated receptor activates a membrane *G-protein* which turns on *adenylate cyclase*.
   c. *Adenylate cyclase* converts ATP into *cyclic AMP* which activates *protein kinases*.
   d. *Protein kinases* phosphorylate enzymes which catalyze reactions that produce the physiological response.
3. Since hormones that bond to plasma membrane receptors initiate a cascade of events, they can induce their effects at very low concentrations

Mechanisms of hormone action

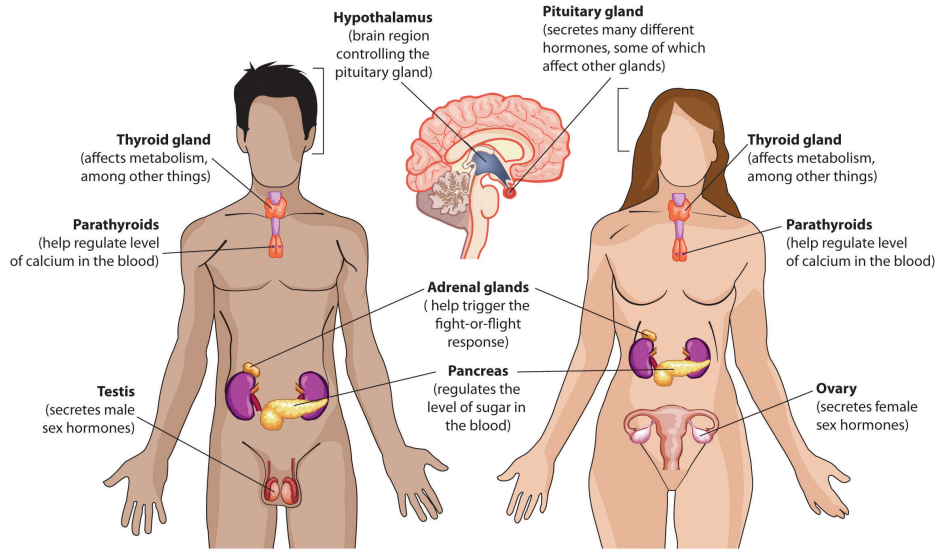
Hormonal Interactions

- The responsiveness of a target cell to a hormone depends on the hormone's concentration, the abundance of the target cells' hormone receptors, and influences exerted by other hormones.
- Three hormonal interactions are the *permissive effect*, the *synergistic effect*, and the *antagonist effect*.

Control of hormone secretion

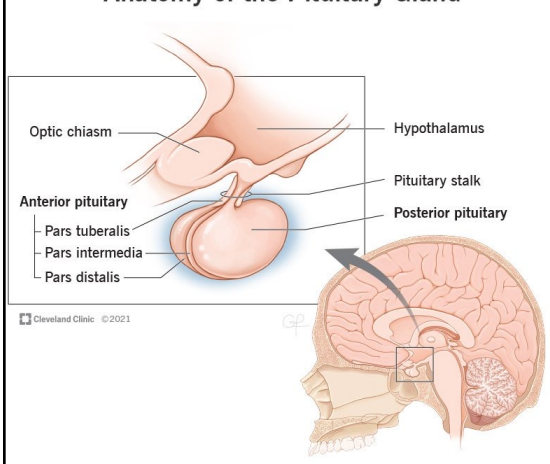
- Most hormones are released in short bursts, with little or no release between bursts. Regulation of hormone secretion normally maintains homeostasis and prevents overproduction or underproduction of a particular hormone; when these regulating mechanisms do not operate properly, disorders result.
- Hormone secretion is controlled by signals from the nervous system, by chemical changes in the blood, and by other hormones.
- Most often, *negative feedback systems* regulate hormonal secretions.

13



14

Hypothalamus and pituitary gland



- The *hypothalamus* is the major integrating link between the nervous and endocrine systems.
- The hypothalamus and the pituitary gland (hypophysis) regulate virtually all aspects of growth, development, metabolism, and homeostasis.
- The pituitary gland is in the sella turcica of the sphenoid bone and is differentiated into the *anterior pituitary* (*adenohypophysis*), and the *posterior pituitary* (*neurohypophysis*).

15

Anterior Pituitary Gland (Adenohypophysis)

A. Hormones of the anterior pituitary are controlled by releasing or inhibiting hormones produced by the hypothalamus.
B. The blood supply to the anterior pituitary is from the *superior hypophyseal arteries*.
C. Hormones of the anterior pituitary and the cells that produce them are as follows.
   1. *Human growth hormone* (*hGH*) is secreted by *somatotrophs*.
   2. *Thyroid-stimulating hormone* (*TSH*) is secreted by *thyrotrophs*.
   3. *Follicle-stimulating hormone* (*FSH*) and *luteinizing hormone* (*LH*) are secreted by gonadotrophs.
   4. *Prolactin* (*PRL*) is secreted by *lactrotrophs*.
   5. *Adrenocorticotrophic hormone* (*ACTH*) and *melanocyte-stimulating hormone* (*MSH*) are secreted by *corticotrophs*.
D. Secretion of anterior pituitary gland hormones is regulated by *hypothalamic regulating hormones* and by *negative feedback* mechanisms.

16

Anterior Pituitary Gland (Adenohypophysis)

Human Growth Hormone and Insulin-like Growth Factors

- *Human growth hormone* (*hGH*) is the most plentiful anterior pituitary hormone.
- It acts indirectly on tissues by promoting the synthesis and secretion of small protein hormones called *insulin-like growth factors* (*IGFs*).
- IGFs stimulate general body growth and regulate various aspects of metabolism**.**
- Various stimuli promote and inhibit hGH production.
- One symptom of excess hGH is hyperglycemia (diabetogenic effect).

17

Anterior Pituitary Gland (Adenohypophysis)

***Thyroid-stimulating hormone* (*TSH*)** regulates thyroid gland activities and is controlled by TFH (thyrotropin-releasing hormone)

***Follicle-Stimulating Hormone* (*FSH*)**

1) In females, FSH initiates follicle development and secretion of estrogens in the ovaries.
2) In males, FSH stimulates sperm production in the testes.

***Luteinizing Hormone* (*LH*)**

1) In females, LH stimulates the secretion of estrogen by ovarian cells to result in ovulation and stimulates the formation of the corpus luteum and secretion of progesterone.
2) In males, LH stimulates the interstitial cells of the testes to secrete testosterone.

18

Anterior Pituitary Gland (Adenohypophysis)

***Prolactin* (*PRL*),** together with other hormones, initiates and maintains milk secretion by the mammary glands.

***Adrenocorticotrophic hormone* (*ACTH*)** controls the production and secretion of hormones called glucocorticoids by the cortex of the adrenal gland.

***Melanocyte-stimulating hormone* (*MSH*)** increases skin pigmentation although its exact role in humans is unknown.

Posterior Pituitary Gland (Neurohypophysis)

- Although the posterior pituitary gland does not synthesize hormones, it does store and release two hormones.
- The neural connection between the hypothalamus and the posterior pituitary is via the *hypothalamohypophyseal tract* from the supraoptic and paraventricular nuclei.

Posterior Pituitary Gland (Neurohypophysis)

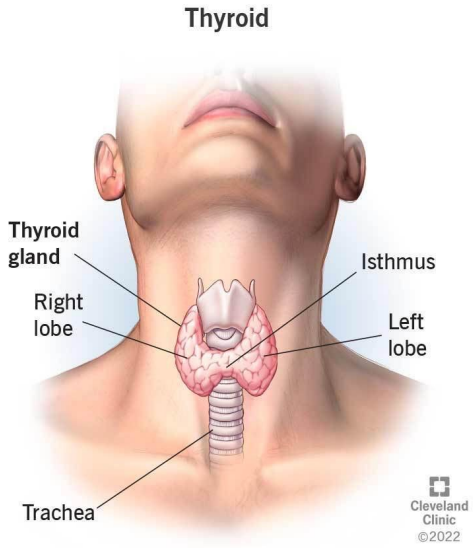
Hormones made by the hypothalamus and stored in the posterior pituitary are *oxytocin* (*OT*) and *antidiuretic hormone* (*ADH*).

1. ***Oxytocin*** stimulates the contraction of the uterus and ejection (let-down) of milk from the breasts. It is regulated by positive feedback. Nursing a baby after delivery stimulates oxytocin release promoting uterine contractions and the expulsion of the placenta.
2. ***Antidiuretic hormone*** stimulates water reabsorption by the kidneys and arteriolar constriction.
   a) The effect of ADH is to decrease urine volume and conserve body water. It can also raise blood pressure.
   b) ADH is controlled primarily by the osmotic pressure of the blood.

21

Thyroid gland

- The *thyroid gland* is located just below the larynx and has right and left lateral lobes.
- Histologically, the thyroid consists of the thyroid follicles composed of *follicular cells*, which secrete the thyroid hormones *thyroxine* (T_4) and *triiodothyronine* (T_3), and *parafollicular cells*, which secrete *calcitonin* (*CT*).



22

Thyroid gland

Formation, storage, and release of thyroid hormones:

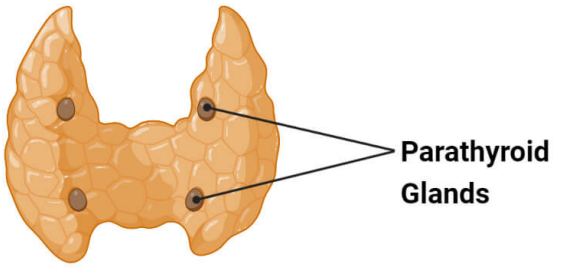
1. Thyroid hormones are synthesized from iodine and tyrosine within a large glycoprotein molecule called *thyroglobulin* (*TGB*) and are transported in the blood by plasma proteins, mostly thyroxine-binding globulin (TBG).
2. The formation, storage, and release steps include iodide trapping, synthesis of thyroglobulin, oxidation of iodide, iodination of tyrosine, coupling of T_1 and T_2, pinocytosis and digestion of colloid, secretion of thyroid hormones, and transport in blood.

Thyroid gland

- Thyroid hormones regulate oxygen use and basal metabolic rate, cellular metabolism, increase body temperature, stimulate protein synthesis and lipolysis, enhance some action of catecholamines, and regulate the growth and development of nervous tissue and bones.
- Secretion of thyroid hormone is controlled by the level of iodine in the thyroid gland and by negative feedback systems involving both the hypothalamus and the anterior pituitary gland.
- ***Calcitonin*** lowers the blood level of calcium. Secretion is controlled by calcium levels in the blood.

Parathyroid glands

The *parathyroid glands* are embedded on the posterior surfaces of the lateral lobes of the thyroid and contain *principal cells*, which produce *parathyroid hormone*, and *oxyphil cells*, whose function is unknown.



25

Parathyroid glands

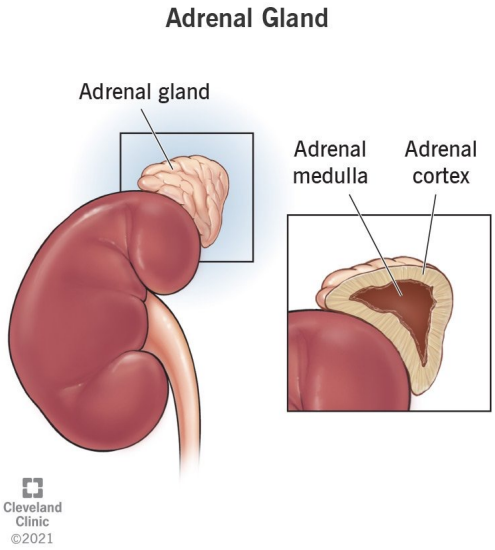
Parathyroid hormone (*PTH*) regulates the homeostasis of calcium and phosphate by increasing blood calcium levels and decreasing blood phosphate levels.

1. PTH increases the number and activity of osteoclasts, increases the rate of Ca^{+2} and Mg^{+2} from reabsorption from urine, and inhibits the reabsorption of HPO_4^{-2} so more is secreted in the urine and promotes the formation of calcitriol, which increases the absorption of Ca^{+2}, Mg^{+2}, and HPO_4^{-2} from the GI tract.
2. Blood calcium level directly controls the secretion of calcitonin and parathyroid hormone via negative feedback loops that do not involve the pituitary gland.

26

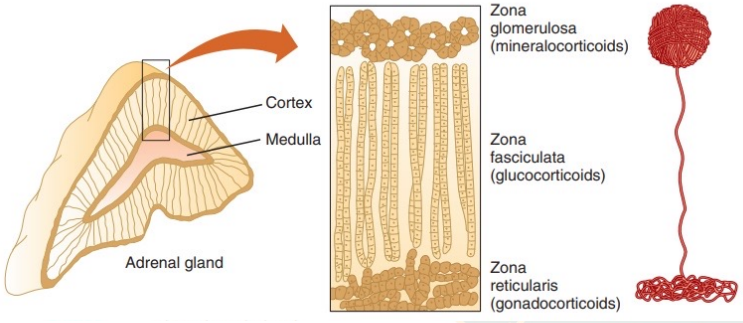
Adrenal glands

- Adrenal glands, also known as suprarenal glands, are small, triangular-shaped glands located on top of both kidneys.
- Adrenal glands produce hormones that help regulate metabolism, immune system, blood pressure, response to stress and other essential functions.
- Adrenal glands are composed of two parts — the cortex and the medulla — which are each responsible for producing different hormones.



27

Adrenal cortex



28

Adrenal glands

Adrenal Cortex

- Mineralocorticoids
  a. *Mineralocorticoids* (e.g., aldosterone) increase sodium and water reabsorption and decrease potassium reabsorption, helping to regulate sodium and potassium levels in the body.
  b. Secretion is controlled by the renin-angiotensin pathway and the blood level of potassium.
- Glucocorticoids
  a. *Glucocorticoids* (e.g., cortisol) promote the breakdown of proteins, formation of glucose, lipolysis, resistance to stress, anti-inflammatory effects, and depression of the immune response.
  b. Secretion is controlled by CRH (corticotropin-releasing hormone) and ACTH (adrenocorticotropic hormone) from the anterior pituitary.
- Androgens secreted by the adrenal cortex usually have minimal effects.

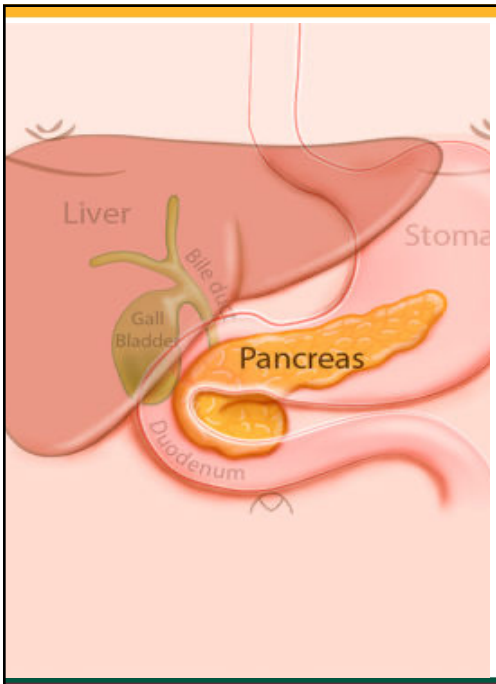
29

Adrenal glands

Adrenal Medulla

- The *adrenal medulla* consists of hormone-producing cells, called chromaffin cells, which surround large blood-filled sinuses.
- Medullary secretions are *epinephrine* and *norepinephrine* (NE), which produce effects similar to sympathetic responses.
- They are released under stress by direct innervation from the autonomic nervous system. Like the glucocorticoids of the adrenal cortex, these hormones help the body resist stress. However, unlike the cortical hormones, the medullary hormones are not essential for life.

30



Pancreatic islets

- The *pancreas* is a flattened organ located posterior and slightly inferior to the stomach and can be classified as both an endocrine and an exocrine gland.
- Histologically, it consists of *pancreatic islets* or *Islets of Langerhans* and clusters of cells (acini) which are enzyme-producing exocrine cells.

31

Pancreatic islets

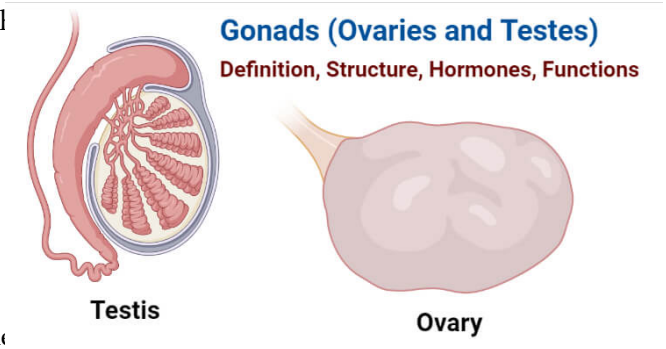
- Cell Types in the Pancreatic Islets
  1. *Alpha cells* secrete the hormone *glucagon* which increases blood glucose levels.
  2. *Beta cells* secrete the hormone *insulin* which decreases blood glucose levels.
  3. *Delta cells* secrete *growth hormone-inhibiting hormone* or *somatostatin*, which acts as a paracrine to inhibit the secretion of insulin and glucagon.
  4. *F-cells* secrete *pancreatic polypeptide*, which regulates the release of pancreatic digestive enzymes.
- Regulation of glucagon and insulin secretion is via negative feedback mechanisms.

32

Ovaries and Testes

Ovaries are located in the pelvic cavity and produce sex hormones (*estrogens* and *progesterone*) related to tl development and maintenance of female sexual characteristics, reproductive cycle, pregnancy, lactation, and normal reproductive functions. The ovaries also produce *inhibin* and *relaxin*.

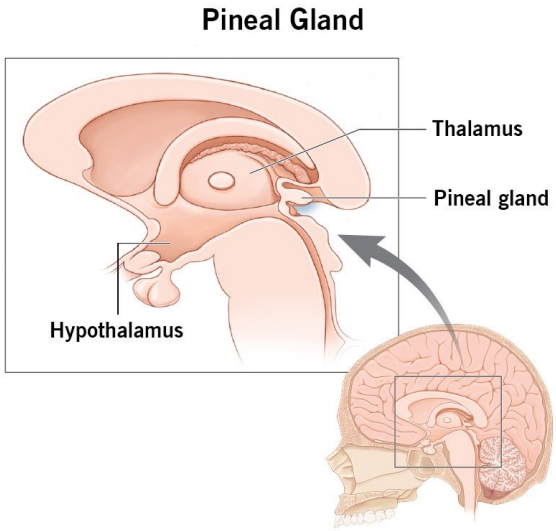
Testes lie inside the scrotum and produce sex hormones (primarily *testosterone*) related to the development and maintenance of mal sexual characteristics and normal reproductive functions. The testes also produce *inhibin*.



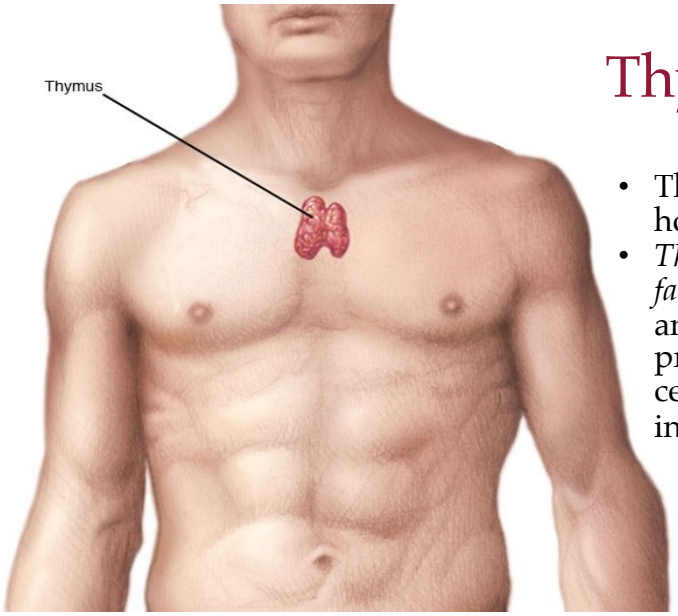
33

Pineal gland

- The *pineal gland* (*epiphysis cerebri*) is attached to the roof of the third ventricle, inside the brain.
- The pineal gland secrets *melatonin* in a diurnal rhythm linked to the dark-light cycle. Light inhibits its secretion. In the darkness, norepinephrine released by sympathetic fibers stimulates the synthesis and secretion of melatonin, which may promote sleepiness.



34



Thymus gland

- The *thymus gland* secretes several hormones related to immunity
- *Thymosin, thymic humoral factor, thymic factor,* and *thymopoietin* promote the proliferation and maturation of T cells, a type of white blood cell involved in immunity.

35

Other hormones and growth factors

Eicosanoids

- Eicosanoids, (*prostaglandins* [*PGs*] and leukotrienes [*LTs*]) act as paracrines and autocrines in most body tissues by altering the production of second messengers, such as cyclic AMP.
- Prostaglandins have a wide range of biological activity in normal physiology and pathology.
- Aspirin and related *nonsteroidal anti-inflammatory drugs* (*NSAIDs*), such as ibuprofen and acetaminophen, inhibit a key enzyme in prostaglandin synthesis and are used to treat a wide variety of inflammatory disorders.

Growth Factors

- Growth factors are hormones that stimulate cell growth and division.
- Examples include epidermal growth factor (EGF), platelet-derived growth factor (PDGF), fibroblast growth factor (FGF), nerve growth factor (NGF), tumor angiogenesis factors (TAFs), insulin-like growth factor (IFG), and cytokines.

36

The Stress Response

- **Eustress** – productive stress
- **Distress** – harmful stress
- **Stressor** – any stimulus that produces a stress response

37

The Stress Response

1. The **fight-or-flight response** – is initiated by nerve impulses from the hypothalamus to the sympathetic division of the autonomic nervous system and the adrenal medulla. This response rapidly increases circulation, promotes ATP production, and decreases nonessential activities.
2. The **resistance reaction** – is initiated by releasing hormones secreted by the hypothalamus, most importantly CRH, TRH, and GHRH. Resistance reactions are longer lasting and accelerate breakdown reactions to provide ATP for counteracting stress.
3. **Exhaustion** - results from depletion of body resources during the resistance stage.

Stress and disease - Stress may trigger certain diseases by inhibiting the immune system. An important link between stress and immunity is interleukin-l, produced by macrophages; it stimulates the secretion of ACTH.

38

References

Bradford, J., & Hopper, P. (2015). In *Understanding Medical Surgical Nursing, 5th ed* (pp. 871–886). F.A. Davis Company.

Tortora, G., & Derrickson, B. (2012). *Principles of Anatomy and Physiology, 3rd ed* (pp. 680-727). John Wiley & Sons, Inc.