Chapter 18: The Endocrine System

Chapter Objectives

ENDOCRINE GLANDS
1. List the general functions of hormones.
2. List the organs that secrete hormone as their first function and those organs that secrete hormones as a secondary function.

HORMONE ACTIVITY
3. Describe how hormones interact with receptor cells.
4. Distinguish between circulating and local hormones.
5. List the hormones that are lipid soluble.
6. List the hormones that are water soluble.

MECHANISMS OF HORMONE ACTION
7. Describe the mechanism of action of lipid-soluble hormones.

HYPOTHALAMUS AND PITUITARY GLAND
9. Discuss the importance of the hypothalamus to pituitary gland function.
10. List the seven major hormones secreted by the anterior pituitary gland.
11. Examine the two ways in which secretions of the anterior pituitary hormones are regulated.
12. Discuss the actions of and controls over each of the anterior pituitary gland hormones.
13. Discuss the actions of and controls over each of the posterior pituitary gland hormones.

THYROID GLAND
14. Describe the location and histology of the thyroid gland.
15. Explain the actions of thyroid hormones.
16. Describe the formation, storage, and release of thyroid hormones.

PARATHYROID GLANDS
17. Describe the location and histology of the parathyroid glands.
18. Discuss the functions of parathyroid hormone.

ADRENAL GLAND
19. Describe the location of the adrenal gland and its division into two parts.
20. Describe the three zones of the adrenal cortex and know which hormone is secreted by which zone and the functions of those hormones.

PANCREATIC ISLETS
21. Describe the location and histology of the pancreas.
22. List the hormone-secreting cells of the pancreatic islet, the hormones they produce, and the functions of those hormones.

23. Discuss the causes and symptoms of diabetes mellitus.

OVARIES AND TESTES

24. Describe the locations, hormones, and functions of the hormones of the gonads.

PINEAL GLAND

25. Describe the location, histology, hormones, and functions of the hormones of pineal gland.

THYMUS GLAND

26. List the hormones produced by the thymus gland.

EICOSANOIDS AND GROWTH FACTORS

27. Explain the actions of eicosanoids.

28. List seven important growth factors.

Chapter Lecture Notes

The Endocrine System

The endocrine system controls body activities by releasing mediator molecules called hormones

- Hormones released into the bloodstream travel throughout the body
- Results may take hours, but last longer
- Hormones have powerful effects when present in very low concentrations

General functions of hormones

- Help regulate:
  - extracellular fluid
  - metabolism
  - contraction of cardiac & smooth muscle
  - glandular secretion
  - some immune functions
  - growth & development
  - reproduction

Endocrine glands (Fig 18.1)
Primary function is as endocrine gland

- pituitary
- thyroid
- parathyroid
- adrenal
- pineal

Secondary function is as endocrine gland (Table 18.11)

- hypothalamus
- thymus
- pancreas
- ovaries
- testes
- kidneys
- stomach
- liver
- small intestine
- skin
- heart
- placenta
- adipose tissue

Hormone Receptors

Although hormones travel in blood throughout the body, they affect only specific target cells

Target cells have specific protein or glycoprotein receptors to which hormones bind

Synthetic hormones that block the receptors for particular naturally occurring hormones are available as drugs

Circulating and Local Hormones
Endocrines (circulating hormones) - hormones that travel in blood and act on distant target cells

(Local hormones - hormones that act locally without first entering the blood stream

Paracrines - hormones that act on neighboring cells

Autocrines – hormones that act on the same cell that secreted them

Chemical Classes of Hormones

Lipid-soluble hormones (Table 18.2)

steroids
thyroid hormones
nitric oxide – a local hormone in several tissues

Water-soluble hormones

amines
epinephrine
norepinephrine
melatonin
seratonin
peptides, proteins, and glycoproteins
insulin
growth hormone
ADH
eicosanoids
prostaglandins
leukotrienes

Action of Lipid-Soluble Hormones

Lipid-soluble hormones bind to and activate receptors within cells
The activated receptors then alter gene expression which results in the formation of new proteins. (Fig 18.3)

The new proteins alter the cell's activity and result in the physiological responses of those hormones.

Action of Water-Soluble Hormones

Water-soluble hormones alter cell functions by activating plasma membrane receptors, which set off a cascade of events inside the cell.

First messenger - the water-soluble hormone that binds to the cell membrane receptor

Second messenger – a chemical activated inside the target cell

Cyclic AMP - a typical second messenger of a water-soluble hormone (Fig 18.4)

Some hormones exert their influence by increasing the synthesis of cAMP

ADH, TSH, ACTH, glucagon and epinephrine

Some exert their influence by decreasing the level of cAMP

growth hormone inhibiting hormone (somatostatin)

Other substances can act as 2nd messengers

calcium ions

cGMP

PI₃

Tyrosine kinase

A hormone may use different 2nd messengers in different target cells

Hypothalamus and Pituitary Gland

The hypothalamus is the major integrating link between the nervous and endocrine systems

Hypothalamus receives input from cortex, thalamus, limbic system & internal organs

Hypothalamus controls pituitary gland with releasing & inhibiting hormones

Secretion of anterior pituitary gland hormones is regulated by hypothalamic regulating hormones and by negative feedback mechanisms
The hypothalamus and the pituitary gland (hypophysis) regulate virtually all aspects of growth, development, metabolism, and homeostasis.

The pituitary gland is located in the sella turcica of the sphenoid bone and is differentiated into the anterior pituitary (adenohypophysis), the posterior pituitary (neurohypophysis). (Fig 18.5)

Hormones of the anterior pituitary: (Table 18.3 & 18.4)

- Human growth hormone (hGH)
- Thyroid-stimulating hormone (TSH)
- Follicle-stimulating hormone (FSH)
- Luteinizing hormone (LH)
- Prolactin (PRL)
- Adrenocorticotrophic hormone (ACTH)
- Melanocyte-stimulating hormone (MSH)

Posterior pituitary gland does not synthesize hormones, but it does store and release two hormones made by the hypothalamus (Table 18.5)

- Oxytocin (OT)
- Antidiuretic hormone (ADH)

Also releases regulators of anterior pituitary hormone release made by the hypothalamus

Human Growth Hormone and Insulin-like Growth Factors

Human growth hormone (hGH) - the most plentiful anterior pituitary hormone

Insulin-like growth factors (IGFs) – small protein, local hormones that are produced in response to hGH and promote the tissue’s response to hGH

Target cells

- Liver
- Skeletal muscle
- Cartilage
Functions:

- increases cell growth & cell division
- increases cellular uptake of amino acids
- increases synthesis of proteins
- stimulates triglyceride breakdown (lipolysis) in adipose so fatty acids used for ATP synthesis
- retards use of glucose for ATP production so blood glucose levels remain high enough to supply brain

Release factors from hypothalamus (Fig 18.7)

Promotes release - growth hormone releasing hormone (GHRH, somatocrinin)

Inhibits release - growth hormone inhibiting hormone (GHIH, somatostatin)

Thyroid Stimulating Hormone (TSH)

TSH stimulates the synthesis & secretion of T₃ and T₄ by the thyroid gland

Promotes release - thyrotropin releasing hormone (TRH) (Fig 18.12)

Inhibits release - growth hormone inhibiting hormone (GHIH, somatostatin) and negative feedback by elevated levels of T3 and T4

Follicle Stimulating Hormone (FSH)

FSH functions

- initiates the formation of follicles within the ovary
- stimulates follicle cells to secrete estrogen
- stimulates sperm production in testes

Promotes release - gonadotropin releasing hormone (GnRH)

Inhibits release - negative feedback by elevated levels of sex hormones

Luteinizing Hormone (LH)

In females, LH stimulates
secretion of estrogen
ovulation of 2nd oocyte from ovary
formation of corpus luteum
secretion of progesterone

In males, LH stimulates the interstitial cells of the testes to secrete testosterone

Release is mediated by GnRH and negative feedback by sex hormones like FSH

Prolactin

Prolactin (PRL) works together with other hormones to initiate and maintains milk secretion by the mammary glands

Suckling reduces levels of hypothalamic inhibition and prolactin levels rise along with milk production

Promotes release - prolactin releasing hormone (PRH)
Inhibits release - prolactin inhibiting hormone (PIH, dopamine)

Adrenocorticotrophic Hormone

Adrenocorticotrophic hormone (ACTH, corticotropin) controls the production and secretion of glucocorticoids (cortisol) by the cortex of the adrenal gland. (Fig 18.6)

Promotes release - corticotropin releasing hormone (CRH)
Inhibits release - negative feedback by elevated levels of glucocorticoids

Melanocyte-Stimulating Hormone

Melanocyte-stimulating hormone (MSH) increases skin pigmentation in animals

its exact role in humans is unknown

Promotes release - corticotropin releasing hormone (CRH)
Inhibits release - dopamine

Oxytocin

Target tissues
uterus
breasts

Oxytocin release enhances uterine muscle contraction during delivery and promotes the expulsion of the placenta after delivery (Fig 1.4)

Stimulates milk let-down during breast feeding

ADH

Antidiuretic hormone (vasopressin, ADH)

stimulates water reabsorption by the kidneys
stimulates constriction of arterioles
decreases urine volume
decreases sweating
increases blood pressure
conserves body water

ADH release is controlled primarily by osmotic pressure of the blood (Fig 18.9)

Thyroid Gland

The thyroid gland is located just below the larynx and has right and left lateral lobes (Fig 18.10)

Histology

Thyroid follicles secrete the thyroid hormones, thyroxine (T₄) and triiodothyronine (T₃)

Parafollicular cells secrete calcitonin (CT)

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).

Actions of Thyroid Hormones (Table 18.6)

T₃ & T₄

Increase basal metabolic rate
Stimulate synthesis of Na⁺/K⁺ ATPase
Increase body temperature (calorogenic effect)
Stimulate protein synthesis
Increase the use of glucose and fatty acids for ATP production
Stimulate lipolysis
Enhance some actions of catecholamines
Regulate development and growth of nervous tissue and bones

Calcitonin
responsible for building of bone & stops resorption of bone (lowers blood levels of Calcium)

T₃ & T₄ are synthesized from iodine and tyrosine by a multi-step process (Fig 18.11)
Follicular cells produce a large glycoprotein molecule called thyroglobulin (TGB)
Iodine is added to TGB and then T₃ & T₄ are cut out of the larger protein
T₃ & T₄ (lipid soluble) are transported in the blood by plasma proteins, mostly thyroxine-binding globulin (TBG)

Parathyroid Glands
The parathyroid glands are embedded on the posterior surfaces of the lateral lobes of the thyroid
principal cells produce parathyroid hormone (Fig 18.13 & Table 18.7)
oxyphil cells - function is unknown
Parathyroid hormone (PTH) regulates the homeostasis of calcium and phosphate (Fig 18.14)
increase blood calcium level
decrease blood phosphate level
increases the number and activity of osteoclasts
increases the rate of Ca²⁺ and Mg²⁺ reabsorption from urine and inhibits the reabsorption of HPO₄²⁻ so more is secreted in the urine
promotes formation of calcitriol, which increases the absorption of Ca²⁺, Mg²⁺, and HPO₄²⁻ from the GI tract

Adrenal Glands
The adrenal glands are located superior to the kidneys (Fig 18.15)

Consists of an outer cortex and an inner medulla

Cortex produces 3 different types of hormones from 3 zones of cortex (Table 18.8)

The zona glomerulosa (outer zone)
- secretes mineralocorticoids (aldosterone)
  - increase reabsorption of Na\(^+\) with Cl\(^-\), bicarbonate and water following it
  - promotes excretion of K\(^+\) and H\(^+\)

The zona fasciculata (middle zone)
- secretes glucocorticoids (cortisol)
  - increase rate of protein catabolism & lipolysis
  - conversion of amino acids to glucose
  - stimulate lipolysis
  - provide resistance to stress by making nutrients available for ATP production
  - raise blood pressure by vasoconstriction
  - anti-inflammatory

The zona reticularis (inner zone)
- secretes androgens
  - insignificant in males
  - may contribute to sex drive in females
  - is converted to estrogen in postmenopausal females

Medulla produces epinephrine & norepinephrine

Pancreas

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

Histology

Exocrine acini - clusters of digestive enzyme-producing exocrine cells
Pancreatic islets (islets of Langerhans) (Fig 18.18 & Table 18.9)

Alpha cells (20%) produce glucagon
Beta cells (70%) produce insulin
Delta cells (5%) produce somatostatin
F cells produce pancreatic polypeptide

Functions of pancreatic hormones

Glucagon (Fig 18.19)

raises blood glucose levels
stimulates the liver to convert glycogen into glucose (glycogenolysis)
stimulates the liver to form glucose from lactic acid and certain amino acids (gluconeogenesis)

Insulin

lowers blood glucose levels
accelerates facilitated diffusion of glucose into cells
speeds conversion of glucose into glycogen (glycogenesis)
increases uptake of amino acids and increases protein synthesis
speeds synthesis of fatty acids (lipogenesis)
slowsls glycogenolysis
slowsls gluconeogenesis

Somatostatin

inhibits secretion of insulin and glucagon
slows absorption of nutrients from gastrointestinal tract

Pancreatic polypeptide

inhibits secretion of somatostatin
inhibits gall bladder contraction
inhibits secretion of pancreatic digestive enzymes
Pancreatic Disorders

Diabetes Mellitus

A group of disorders caused by an inability to produce or use insulin

Type I diabetes or insulin-dependent diabetes mellitus is caused by an absolute deficiency of insulin autoimmune disease

Type II diabetes or insulin-independent diabetes is caused by a down-regulation of insulin receptors occurrence increases with age and increased weight

Symptoms

- excessive urine production (polyuria)
- excessive thirst (polydipsia)
- excessive eating (polyphagia)

Ovaries and Testes

Ovaries (Table 18.10)

- produces estrogen, progesterone, relaxin & inhibin
- regulate reproductive cycle, maintain pregnancy & prepare mammary glands for lactation

Testes

- produce testosterone and inhibin
- regulate sperm production & 2nd sexual characteristics

Pineal Gland

Small gland attached to 3rd ventricle of brain

Consists of pinealocytes & neuroglia

Melatonin responsible for setting of biological clock

Associated with jet lag & seasonal affective disorder

Thymus Gland

Important role in maturation of T cells
Hormones produced by gland promote the proliferation & maturation of T cells

- thymosin
- thymic humoral factor
- thymic factor
- thymopoietin

**Eicosanoids**

Local hormones released by all body cells

Alter the production of second messengers, such as cyclic AMP

**Leukotrienes**

- influence WBCs function
- inflammation

**Prostaglandins** alter

- smooth muscle contraction
- glandular secretion
- blood flow
- platelet function
- nerve transmission
- metabolism

**Growth Factors**

Substances that promote cell division *(Table 18.12)*

Many act locally as autocrines or paracrines

- 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 (IGF)

Cytokines