

The Endocrine System

no clear distinction between nervous and endocrine systems

= **neuroendocrine system**

they are intimately interrelated

- complement each other
- two ends of a single spectrum

The Neuroendocrine System	
Nervous System	Endocrine System
localized effects: cell to cell	widespread effects: throughout body
targets: neurons, muscle cells or glands	targets: all organs and tissues
transmission by nerve impulses	transmission as hormone through blood
uses chemical signals only cell to cell	uses only chemical signals
immediate response (ms to seconds)	gradual response (seconds to hours)
short lived (ms to minutes)	longer lived (minutes to days)
Both	
both involved in coordination & control	
both produce biologically active chemicals	
some parts of brain are glands/some glands are nervous tissue	
some responses begin as nervous reflex and end as hormonal responses	

General Characteristics of Hormones

1. a chemical is considered a **hormone** if it is secreted and transported in the blood

same chemical can also be a neurotransmitter, or lymphokine, etc

the major hormones are secreted from **ductless glands** directly into blood

(exocrine vs endocrine glands)

all major endocrine glands are richly supplied with blood capillaries

2. most, if not **all**, organs produce hormones

"officially" the endocrine system consists of several major glands and many minor glands

3. Hormones are secreted in response to **specific stimuli**

3 mechanisms: **neural, humoral, hormonal**

A. Humoral

hormones secreted in direct response to changing blood levels of certain chemicals in blood

affect endocrine gland directly

B. Neural

hormones secreted due to direct nervous stimulation

C. Hormonal

Anterior Pituitary = master gland

secretes several hormones that control the secretion of other endocrine glands

→ **Tropic Hormones**

4. Many endocrine glands secrete more than one hormone

hormones can be secreted independently of one another

5. hormone effects are highly specific to "target organ"

→ requires specific binding site (receptor proteins)

even though every hormone comes in contact with every cell

receptor can be on the surface of the target cell or inside the target cell

target cells respond only to specific hormones

6. At the **cellular level** each hormone can affect a target cell in only a few ways:

a. can change in cell membrane permeability

eg. change in secretory activity of a cell

b. can alter metabolic pathway(s)

eg. enzymes activated or inactivated
 → make new products
 → cease making product

c. can change rate of cell division

eg. speed up or slow down

Maybe different effects in different target cells for same hormone

7. Most cells have receptors for more than one type of hormone

hormones can interact with each other

→ **synergistic effects**

= presence of 1 enhances effects of other

→ **antagonistic effects**

= 1 counteracts effects of other

→ **permissive effects**

= one hormone "primes" target organ for another hormone;

8. Hormones don't accumulate in blood

those that bind to target cells are destroyed

→ half-life ~ seconds – 30 minutes

excess are continually cleared by **liver and kidney**

therefore for prolonged effect

→ hormones must be continuously secreted

Major Endocrine Glands

Pituitary Gland (=Hypophysis)

small but extremely important structure

attached to a stalk (infundibulum) at base of **hypothalamus**

housed in **sella turcica** of **sphenoid bone**

consists of two separate glands

Anterior Pituitary Gland

master gland

secretes tropic (or trophic) hormones:

a. **Thyroid Stimulating Hormone (TSH)**

→ stim development and secretions from thyroid gland

b. **Adrenocorticotropic Hormone (ACTH)**

→ normal growth and development of adrenal cortex

c. **Follicle Stimulating Hormone (FSH)**

Human Anatomy & Physiology: Endocrine System; Ziser, 2010.4

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→ in women: stimulates follicles to begin growing to ovulation

→ in men: stimulates development of seminiferous tubules and sperm cells

d. **Leutinizing Hormone (LH)**

→ in women:
final maturation of follicle

stimulates formation of corpus luteum

[a temporary endocrine gland of pregnancy]

promotes secretion of progesterone

→ in men:
stimulates interstitial cells to secrete hormone = testosterone

if pituitary gland is removed by radiation or surgery, need hormone treatment rest of life or some other glands will shut down

in addition to tropic hormones, Ant Pit also secretes some other (nontropic) hormones:

e. **Growth Hormone (GH)**

promotes growth of bone and soft tissue

Human Anatomy & Physiology: Endocrine System; Ziser, 2010.4

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→ stim protein synthesis

amt of GH secreted decreases with age

HYPERSECRETION of GH

during childhood → gigantism
during adulthood → acromegaly

enlargement esp of bones of hands, feet, jaws and cheeks

HYPOSECRETION of GH

during childhood → dwarfism

f. **Prolactin (PRL; = Lactogenic Hormone)**

affects female:

→ induces breast development during pregnancy

→ initiates milk secretion after childbirth

prl release is stimulated by suckling

no significant functions in males

Human Anatomy & Physiology: Endocrine System; Ziser, 2010.4

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Posterior Pituitary Gland

hormones released by direct nervous stimulation of posterior pituitary

a. **Antidiuretic Hormone (ADH, =vasopressin)**

(=against production of urea)

ADH is released whenever receptors indicated dehydration

ie. decreases urine output
conserves water

b. **Oxytocin**

(=swift childbirth)

stimulates contraction of uterine muscles during labor

causes milk ejection into ducts as result of nursing infant [let down reflex]

triggered by neural stimulus: suckling

functions in "societal memory": affects ability to recognize & trust others

[deficiency *may* be correlated with autism]

Human Anatomy & Physiology: Endocrine System; Ziser, 2010.4

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Pineal Gland

located behind the midbrain and 3rd ventricle
attached to roof of third ventricle

not sure of all its functions in humans but seems to regulate cyclic activities

Rene Descartes (1596-1650) thought it was the seat of the human soul

is light sensitive → monitors photoperiod

a. Melatonin

main hormone it secretes is **melatonin**
light suppresses production
dark stimulates production

→ secretion rises at night, fluctuates seasonally and with changing day length

in lower animals it helps regulate cyclic activities:
hibernation
estrous
migration

In humans:

→ may help regulate menstrual cycle
→ inhibits onset of puberty in males

may be related to seasonal affective disorder and PMS

Thymus

a temporary endocrine gland

behind sternum, below thyroid

large in fetus and child
maximum size at puberty
degenerates in adult (replaced with fat)

functions as endocrine gland and as part of immune system

secretes **thymosin** and related hormones

→ stimulates development of lymphatic organs

→ induces maturation and development of WBC's particularly T-lymphocytes

Thyroid Gland

the largest endocrine gland in adults

surrounds trachea just below larynx

consists of 2 lobes → usually described as butterfly shaped

Hormones:

a. Thyroid Hormones (T₃, T₄)

activated by TSH from Ant Pit

contain Iodine atoms

98% of body's Iodine is in the thyroid gland

inadequate iodine in diet → **goiter**

thyroid hormones help to regulate metabolism in all cells:

- increases metabolic rate & ATP production
- increase oxygen consumption and bld O₂ levels
- promotes maturation and development of the nervous system
- increases protein synthesis
- help maintain normal reproductive function

many environmental stimuli can inhibit secretions of this gland:

cold temp, physical stressors, noxious stimuli

HYPERSECRETION of Thyroid Hormones

→ **Graves disease**

up to 30% increase in Metabolic Rate
Δ appetite
weight loss
nervous irritability

HYPOSECRETION of Thyroid Hormones

During growing years

→ **cretinism**

low metabolic rate
retarded growth and sexual devel
often mentally retarded

As adult

→ **Myxedema**

loss of mental and physical vigor
weight gain
thickened skin

b. Calcitonin

decreases blood Ca⁺⁺ / promote bone deposition by
inhibiting **osteoclasts**
stimulating **osteoblasts**

its effects are significant only in children, negligible effect in adults

HYPOSECRETION of Calcitonin

can cause rickets in children
(but usually due to Ca⁺⁺ or Vit D deficiency)

Parathyroid Glands

small round bodies attached to the posterior surfaces of the thyroid gland

usually 4 or 5, but varies

a. Parathyroid Hormone (PTH)

helps maintain homeostasis of blood calcium

antagonist to calcitonin

raises blood Ca^{++} levels:

→ promotes Ca^{++} absorption by kidney tubules and intestine

→ stimulates osteoclasts to dissolve bone

since bone contains both calcium and phosphorus this releases both into blood

Calcium homeostasis is important in:

- neuromuscular function
- blood clotting
- synapses
- to activate certain enzymes
- affects cell membrane permeability

surgical removal of thyroid gland requires PTH hormone replacement therapy if all parathyroids are removed at the time

Pancreas

both an **exocrine** and **endocrine** gland

exocrine (98% of mass of pancreas):
secretes digestive enzymes

endocrine (<2% of mass of pancreas):
contains clusters of endocrine cells

= Islets of Langerhans

(~1 Million clusters; each up to several 1000 cells)

humoral regulation: monitors blood glucose conc & amino acid levels

mainly secretes:

insulin
glucagon } regulate blood sugar levels

both are proteins

a. Insulin

levels rise immediately after a meal

→ moves glucose, amino acids and fatty acids out of blood, into cells (except liver cells)

→ lowers blood glucose concentrations

only brain, liver and red blood cells do not need insulin to take up glucose

b. Glucagon

secretion rises between meals

acts mainly on liver

glucose synthesis
and release into blood

→ increases blood glucose concentration

antagonist to insulin

both hormones maintain constant blood glucose levels

→ to feed brain cells esp

→ to provide energy for all body cells

secretion of hormones directly controlled by blood sugar levels:

after meal → high blood sugar → insulin

fasting → low blood sugar → glucagon

Diabetes

diabetes is a general name for a group of diseases

two major varieties:
diabetes insipidus
diabetes mellitus (Types I & II)

Diabetes insipidus

a disease associated with Posterior Pituitary

deficiency in ADH causes low reabsorption of water

large volumes of dilute urine are produced:

(up to 10 gallons/day vs normal 1 qt/day)

leads to electrolyte imbalances etc

Diabetes mellitus

most common of all endocrine disorders

→ 18.2 Million (2004) diabetics in US,

5-6 Million more may be borderline diabetics

diabetes is 7th leading cause of death & leading cause of blindness in US

→ 40,000 die annually as result of disorder

diabetes is a group of disorders characterized by high blood glucose concentrations

caused by:

inadequate insulin secretion by beta cells in Islets
=Type I

lack of response by target cells to insulin
=Type II

10% = Juvenile Onset Diabetes (Type I)
90% = Maturity Onset Diabetes (Type II)

Type I: Insulin Dependent Diabetes Mellitus

usually develops during adolescence

is an autoimmune disorder triggered by 2 factors:

1. genetic component → susceptibility
2. environmental component → still unknown, may be viral

results in malfunction of Islet cells in pancreas
→dramatic decrease in the number of beta cells

→insulin is not produced in sufficient quantities

results in all body cells (target cells):

decreased glucose utilization

levels of glucose build up in blood

since glucose can't be used alternate fuels are mobilized:

increased fat mobilization

fats in blood rise to up to 5x's normal
as cells shift to fat catabolism
→ produce ketone bodies
→ lower blood pH = acidosis
→ acetone breath
→ increased risk of atherosclerosis

without insulin to stimulate protein synthesis they are instead broken down and converted to glucose in cells
→ tissue wasting

high levels of glucose in blood lead to large quantities of glucose spilling into urine

→ diagnostic test for disease
(used to taste it, now have chemical indicators)

→ this draws large amts of water into urine

Type 2, Non Insulin Dependent Diabetes Mellitus

target tissues become less responsive to insulin
= **insulin resistance**

causes are poorly understood:

most are obese → but its not obesity per se seems to be a strong genetic component also associated with a sedentary lifestyle

Immediate (Acute) Complications of both forms

hyperglycemia, ketoacidosis, electrolyte imbalances (as cations such as Na⁺ and K⁺ accompany ketones into urine)

Chronic Secondary Complications

often involve gradual changes over years

most common changes occur in vascular system

1. narrowing of large blood vessels in brain, heart and lower extremities
→ can result in stroke, heart attack or limb loss
2. lesions in microvasculature are common
leads to development of scar tissue
→ especially affect kidneys and eyes
3. impaired nerve function
esp autonomic fibers and peripheral sensory fibers
leads to altered GI , bladder function and impotence
and loss of sensation esp in lower limbs

effects:

reduces life expectancy by ~1/3rd
25 x's greater rate of blindness
17 x's greater rate of kidney disease
17 x's greater rate of gangrene
2 x's greater chance of heart attack

Adrenal Glands

on top of kidneys

divided into cortex and medulla which function as two separate glands

Adrenal Cortex

cortex = outer layer of adrenal gland
→ comprises 80 -90% of adrenal gland

absolutely essential for life

regulated mainly by ACTH from Ant. Pituitary

secretes 30 - 50 different hormones

all hormones secreted by adrenal cortex are **steroids**

all are made from cholesterol

these hormones can be categorized as 3 different kinds:

a. Mineralocorticoids (90% = aldosterone)

→ aldosterone increases salt and water reabsorption by kidneys

maintains constant blood Na⁺ levels
by reabsorbing Na⁺ in kidney if needed

and excreting K⁺

3. this also indirectly regulates water reabsorption

[more salt reabsorbed → more water reabsorbed]

HYPOSECRETION by Adrenal Cortex
Addison's Disease
due to inadequate mineralocorticoids & glucocorticoids

b. Glucocorticoids (95% = cortisol (hydrocortisone))

affect every cell in body

secretion follows circadian rhythm

→ highest ~8:00am; lowest ~12:00am

1. generally raise blood glucose levels:
2. inhibit inflammation and tissue destruction also immunosuppressive
3. additional effects on
blood pressure
immunity
wound healing
fetal level of brain and lungs

HYPOSECRETION of Mineralocorticoids
Addison's Disease

Kennedy had mild form
low ACTH may also produce this symptoms:

bronzing of skin
kidney impairment
water retention
increased blood pressure
weight loss
apathy
cannot cope with stress
immunosuppression
hypoglycemia
lethargy and muscle weakness

HYPOSECRETION of Mineralocorticoids
Cushing's Syndrome

weakens skin and muscles

c. **Sex Hormones** (=gonadocorticoids; eg. DHEA, estrogen, progesterone, testosterone)

androgens:

promote protein synthesis
normally not masculinizing

female hormones:

HYPERSECRETION of gonadocorticoids

women in early puberty:
adrenogenital syndrome
masculinizing effect

Adrenal Medulla

unlike cortex, is **not** essential for life

secretes **epinephrine** and **norepinephrine**
(=catecholamines)

also neurotransmitters of sympathetic NS

→affect same structures as sympathetic NS:

heart
smooth muscle
glands

serves to prolong or increase effects initiated by sympathetic NS.

Ovaries & Testes

endocrine and reproductive function

secrete steroid hormones

the same gonadotropins that are found in adrenal cortex

affect development and maturation of reproductive organs and reproductive behavior

Steroid Abuse

Taking large amounts of Androgens (steroids):

has negative feedback effect on FSH & LH
→ almost shuts down
→ decreased sperm production
→ temporary or permanent sterility
→ increased cancer risk

also when large amounts are taken some is transformed into estrogen

→ breast enlargement

Minor/Temporary Endocrine Glands

Kidneys

secrete most (85%) **erythropoietin**

→ stimulates RBC production in bone marrow

Liver

secretes ~ 15% of body's **erythropoietin**
stimulates RBC formation

Heart

atria contain some specialized muscle cells that secrete **Atrial Natriuretic Peptide (ANP)**

→ reduces blood volume, pressure, Na⁺ conc

Stomach & Duodenum

mucosal lining secretes several hormones to help control digestion:

gastrin
enterogastrone
secretin
cholecystokinin

regulates secretion of:
gastric juices
pancreatic enzymes
bile

Adipose Tissue

releases **leptin**

after uptake of glucose and lipids which is converted to fat

leptin binds to CNS neurons in hypothalamus
→ produces sensation of satiety

Placenta

acts as temporary endocrine gland during pregnancy

releases 3 hormones:

a. **chorionic gonadotropic hormone (CGH)**

→ maintains hormonal activity of ovary
pregnancy test

b. **estrogens & progesterone**