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

Similarities

a. both coordinate and control

b. both produce biologically active chemicals
   Neurotransmitters vs hormones
   → in some cases use same chemical

c. hormones affect nervous system/ nervous system affects hormone releases

d. some major parts of brain are glands:
   pineal
   anterior pituitary
   posterior pituitary

e. some endocrine glands are effector organs for brain
   adrenal medulla
   posterior pituitary

f. some responses begin as nervous reflexes and end as hormonal responses:
   eg. emergency and adrenal medulla
   eg. digestive physiology

Differences:

Nervous

localized effects: cell to cell
targets: → other neurons,
         → muscle cells,
         → glands,
transmits long range information by nerve impulses
uses chemical signals (= neurotransmitters)
only cell to cell
neurotransmitter only produced by neurons
immediate response
short lived (ms – minutes)

**Endocrine**
- widespread effects
- targets: all organs and tissues
- transmits long range information as chemical signals only
  = hormones, through circulatory system
- gradual response (seconds – hours)
- longer – lived effects (minutes – days)

**General Characteristics of Hormones**

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

   same chemical can be a neurotransmitter

   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

   three major mechanisms:
   a. **Humoral**
   b. **Neural**
   c. **Hormonal**

   some endocrine glands respond to multiple stimuli

   a. **Humoral**

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

   affect endocrine gland directly

   **eg. pancreas**

   insulin and glucagon secreted in response to blood sugar concentrations
b. Neural

hormones secreted due to direct nervous stimulation

eg. adrenal gland
directly stimulated by sympathetic fibers of ANS produces same effects as Sympathetic NS but lasts 10 times longer:

eg. Posterior Pituitary
secretes oxytocin in direct response to nerve impulses from hypothalamus

c. Hormonal

Anterior Pituitary = master gland

secretes several hormones that control the secretion of other endocrine glands

→ Tropic Hormones

each tropic hormone has a target gland which it stimulates to produce its characteristic hormones

eg. TSH, ACTH, FSH LH

The release of trophic hormones is controlled by hypothalamus:

Hormones are switched off by negative feedback mechanisms

4. Many endocrine glands secrete more than one hormone

hormones can be secreted independently of one another

5. Hormones are transported to target organs in the blood and body fluids

hormones often circulate in blood attached to transport protein (inactive form)

6. hormone effects are highly specific to “target organ”

→ requires specific binding site (receptor proteins)

even though every hormone comes in contact with every cell

target cells respond only to specific hormones
7. Mechanism of Hormone Action on Target Cell

depends on hormone structure and location of receptors on target cell

A. Steroid Hormones (\& thyroxine)
receptors are located inside cytoplasm and nucleus
\rightarrow intracellular receptors
hormone enters cell and binds to receptor and activates it
\rightarrow triggers transcription

therefore: steroid hormones have a direct effect on DNA activity

B. Amino Acid Derivatives and Peptides
cannot enter cell
use "second messenger" to produce effect on target cells
hormones attaches to specific receptor site on target cell
\rightarrow generates second messenger

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

hormones can interact with each other
\rightarrow **synergistic effects**
= presence of 1 enhances effects of other
\rightarrow **antagonistic effects**
= 1 counteracts effects of other
\rightarrow **permissive effects**
= one hormone "primes" target organ for another hormone;
Major Endocrine Glands

Pituitary Gland

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)**
   → 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

      (in males also called ICSH=interstitial cell stimulating hormone)

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 nontropic hormones:

e. **Growth Hormone (GH)**
   promotes growth of bone and soft tissue

   amt of GH secreted decreases with age

<table>
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<tr>
<th>HYPERSECRETION</th>
<th>HYPOSECRETION</th>
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<tr>
<td>during childhood</td>
<td>gigantism</td>
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<tr>
<td>during adulthood</td>
<td>acromegaly</td>
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<tr>
<td></td>
<td>enlargement esp of bones of hands, feet, jaws and cheeks</td>
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   **f. Prolactin (PRL; = Lactogenic Hormone)**

   affects female:
   ➔ induces breast development during pregnancy
   ➔ initiates milk secretion after childbirth

   prl release is stimulated by suckling

   **Posterior Pituitary Gland**

   released by direct nervous stimulation of posterior pituitary

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

      (=against production of urea)

      ADH is released whenever receptors indicated dehydration

      prevents formation of large volumes of urine

      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

input from other areas of the brain can also affect oxytocin release:
  sound of baby crying stimulates
  fear or apprehension inhibits

**Pineal Gland**

located behind the midbrain and 3\textsuperscript{rd} ventricle attached to roof of third ventricle

not sure of all its functions

is light sensitive $\rightarrow$ monitors photoperiod

  in lower animals is called “3\textsuperscript{rd} eye”
  some reptiles actually have 3\textsuperscript{rd} eye in skull directly above pineal gland

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

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

In humans:
  $\rightarrow$ may help regulate menstrual cycle
  $\rightarrow$ inhibits onset of puberty in males

  *may* be related to seasonal affective disorder and PMS

**Thyroid Gland**

the largest endocrine gland in adults

surrounds trachea
  just below larynx

consists of 2 lobes
  $\rightarrow$ usually described as butterfly shaped

thyroid gland has an abundance of blood vessels

**Hormones:**
a. Thyroid hormones
b. Calcitonin

a. Thyroid Hormones (T3, T4)

activates by TSH from Ant Pit

contain Iodine atoms

→ thyroid gland accumulates most iodine
→ the body takes in (active transport → cytoplasm can contain up to 30 x’s the concentration in intercellular fluids)

inadequate iodine = goiter

thyroid hormones help to regulate metabolism in all cells:

→ increases metabolic rate & ATP production
→ increase oxygen consumption and bld O₂ levels
→ help maintain normal reproductive function

| HYPERSECRETION |
| Gravesh disease |
| up to 30% increase in Metabolic Rate |
| Δ appetite |
| weight loss |
| nervous irritability |

| HYPOSECRETION |
| During growing years |
| → cretinism |
| low metabolic rate |
| retarded growth and sexual devel |
| often mentally retarded |

As adult

| HYPOSECRETION |
| Myxedema |
| loss of mental and physical vigor |
| weight gain |
| thickened skin |

b. Calcitonin

decreases blood Ca⁺⁺ / promote bone deposition by

inhibiting osteoclasts
stimulating osteoblasts

| HYPOSECRETION |
| can cause ricketts 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:
   → stimulates osteoclasts to dissolve bone

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

**Thymus**

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

**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)

   main hormone concerned with salt and water balance;
   which affects blood volume & pressure
   → aldosterone increases salt and water reabsorption by kidneys

   this also indirectly regulates water reabsorption
   [more salt reabsorbed → more water reabsorbed]

   **HYPOSECRETION:**
   **Addison’s Disease**
   due to inadequate mineralocorticoids & glucocorticoids

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

   affect every cell in body

   secretion stimulated by:
   physical stress or trauma
   eg.: fractures, burns, surgery, infection, heavy exercise, etc
   psychological stress
   eg.: acute anxiety, anger, novel situations

   1. generally raise blood glucose levels:
      i. accelerate breakdown of proteins to amino acids
ii. shift from normal glucose catabolism to fat catabolism

2. inhibit inflammation and tissue destruction

**HYPOSECRETION:**

**Addisons Disease**
Kennedy had mild form
low ACTH may also produce this
symptoms:
- bronzing of skin
- kidney impairment
- water retention
- salt loss
- weight loss
- apathy
- cannot cope with stress
- poor resistance to infection
- lowers blood sugar levels
- lethargy and muscle weakness

**HYPOSECRETION:**

**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:
- males have 40 IU’s of estrogen in urine ~ 0.1 the amount in women’s urine during ovulation

**Adrenal Medulla**

unlike cortex, is not essential for life

cells are modified postganglionic neurons of ANS (Splanchnic nerve)

secretes epinephrine and norepinephrine (=catecholamines)

10x’s more epinephrine than norepinephrine

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.

**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

mainly secretes:

\[
\text{\begin{align*}
\text{insulin} & \quad \text{regulate blood sugar levels} \\
\text{glucagon} & \\
\end{align*}}
\]

a. **Insulin**

levels rise immediately after a meal

→ moves glucose into cells (except liver cells)
   → lowers blood 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

→ mobilization of glucose from liver
   liver breaks down glycogen to make glucose

antagonist to insulin
both 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

**Ovaries & Testes**

endocrine and reproductive function

secrete steroid hormones

affect development and maturation of reproductive organs and reproductive behavior

**Ovaries** (female):
  FSH & LH are both necessary for ovary to produce estrogen
cyclic hormone production and sex cell development
hormones produced by follicle cells & corpus luteum

**estrogen**
  stimulates growth and development of female reproductive tract
  promotes tissue growth esp in accessory sexual organs
    → sec sex characteristics
  promotes development of uterus and mammary glands

**Progesterone**
  often acts as a synergist to estrogen
  completes maturation of reproductive system in preparation for pregnancy

estrogen and progesterone also affect brain function:
estrogen can cross blood-brain barrier
  → regulates sexual arousal
  → reduces appetite
  may be relationship to anorexia
  → affects body temperature
    (body temp increases ~2° F at ovulation)

**Testes** (male):
  interstitial cells are endocrine portion
  secretes **testosterone**
→ stimulates spermatogenesis in seminiferous tubules
→ stimulates protein synthesis and growth
→ stim sexual development and secondary sex characteristics:

Testosterone also affects brain and behavior:
sexual arousal
agression
(no clear link between high testosterone and violent behavior)