Endocrine Glands
• Endocrinology: The study of hormones, the endocrine system, and their role in the physiology of the body

• The Endocrine System: The body’s slow chemical communication system; a set of glands that secrete hormones into the blood stream.
Principal functions of the endocrine system

- Maintenance of the internal environment in the body (maintaining the optimum biochemical environment)
- Integration and regulation of growth and development
- Control, maintenance and instigation of sexual reproduction, including gametogenesis, coitus, fertilization, fetal growth and development and nourishment of the newborn
Hormones

- A chemical released from living cells that travels some distance to target tissues to have a biological effect
  - Secreted in very small amounts
  - Transported, usually, in the blood
  - Target cells have specific receptors
The endocrine system broadcasts its hormonal messages to essentially all cells by secretion into blood and extracellular fluid.

Like a radio broadcast, it requires a receiver to get the message - in the case of endocrine messages, cells must bear a receptor for the hormone being broadcast in order to respond.
A cell is a target because it has a specific receptor for the hormone

Most hormones circulate in the blood, coming into contact with essentially all cells. However, a given hormone usually affects only a limited number of cells, which are called **target cells**. A target cell responds to a hormone because it bears **receptors** for the hormone.
<table>
<thead>
<tr>
<th>Gland</th>
<th>Hormones produced</th>
<th>Effect of Hormone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineal gland</td>
<td>Melatonin</td>
<td>Affects reproductive development and daily physiologic cycles.</td>
</tr>
<tr>
<td>Pituitary gland</td>
<td>Growth hormone</td>
<td>Controls growth of bones and muscles.</td>
</tr>
<tr>
<td></td>
<td>Anti-diuretic hormone</td>
<td>Increases reabsorption of water in kidneys.</td>
</tr>
<tr>
<td></td>
<td>Gonadotrophins</td>
<td>Controls development of ovaries and testes.</td>
</tr>
<tr>
<td>Thyroid gland</td>
<td>Thyroxine</td>
<td>Controls rate of metabolism and rate that glucose is used up in respiration, and promote growth.</td>
</tr>
<tr>
<td>Adrenal gland</td>
<td>Adrenaline</td>
<td>Prepares the body for emergencies.</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Insulin</td>
<td>Converts excess glucose into glycogen in liver.</td>
</tr>
<tr>
<td></td>
<td>Glucagon</td>
<td>Converts glycogen back to glucose in liver.</td>
</tr>
<tr>
<td>Ovaries</td>
<td>Oestrogen</td>
<td>Controls ovulation and secondary sexual characteristics.</td>
</tr>
<tr>
<td></td>
<td>Progesterone</td>
<td>Prepares the uterus lining for receiving an embryo.</td>
</tr>
<tr>
<td>Testes</td>
<td>Testosterone</td>
<td>Controls sperm production and secondary sexual characteristics.</td>
</tr>
<tr>
<td>Thymus</td>
<td>Thymosin</td>
<td>Promotes production and maturation of white blood cells.</td>
</tr>
</tbody>
</table>
Hypothalamus

- Part of brain
  - Regulates ANS, emotions, feeding/satiety, thirst, body temperature, etc.
  - Hormones related to these functions
    - “Releasing hormones”
    - Axonal transport to posterior lobe
Hypothalamic Hormones

- **Release Inhibiting Hormones**
  - Somatostatin
  - Prolactin release inhibiting hormone-PIH

- **Releasing Hormones**
  - Thyrotropin releasing hormone-TRH
  - Growth hormone releasing hormone-GHRH
The Pituitary Gland

- A sort of master gland
- It is a cherry-sized endocrine gland
- The hormones it secretes affect the growth and secretion of other endocrine glands
- The real boss is the hypothalamus
Anterior and Posterior Pituitary

- Embryologically distinct
- Release different hormones
  - Anterior Pituitary releases Luteinizing hormone and growth hormone
  - Posterior Pituitary releases Oxytocin
Anterior Pituitary

1. “Releasing” hormones regulate adeno hypophysis “glands” “under” “growth”

2. All proteins
   - TSH (thryoid stimulating hormone/thyrotropin)
   - ACTH (adrenocorticotropic hormone)
   - FSH (gonadotropin)
   - LH (gonadotropin)
     - Tropins/tropic hormones
Anterior Pituitary
Tropic Effects Only
FSH, follicle-stimulating hormone
LH, luteinizing hormone
TSH, thyroid-stimulating hormone
ACTH, adrenocorticotropic hormone

Non-tropic Effects Only
Prolactin
MSH, melanocyte-stimulating hormone
Endorphin

Non-tropic and Tropic Effects
Growth hormone

Hormone System Overview:
- Neurosecretory cells of the hypothalamus
- Portal vessels
- Hypothalamic releasing hormones (red dots)
- Endocrine cells of the anterior pituitary
- Pituitary hormones (blue dots)

Outline Levels:
- Fourth Level
- Third Level
- Second Level
- First Level

Outline:
- HORMONE
  - FSH and LH
  - TSH
  - ACTH
  - Prolactin
  - MSH
  - Endorphin
  - Growth hormone
- TARGET
  - Testes or ovaries
  - Thyroid
  - Adrenal cortex
  - Mammary glands
  - Melanocytes
  - Pain receptors in the brain
  - Liver
  - Bones
Anterior P. Homeostatic Imbalances

Growth hormone (GH or hGH)
- Promotes mitosis, cell division
- Elongation of long bones, etc.
- Healing of wounds Lack of hGH retards growth
- Hypersecretion in youth produces giantism
- Hyposecretion in childhood produces pituitary dwarfism
- Hypersecretion in adult produces acromegaly
Pituitary Disorders

• Hyperfunction
  • Increased production of GH
  • Giantism- caused by overgrowth of long bones
  • Acromegaly- overgrowth of cartilage and joints
• Hypofunction
GH as Juvenile
GH as an Adult
GH = pituitary dwarfism
Pituitary—Posterior lobe

- **Oxytocin**
  - Stimulates smooth muscle contraction of uterus & mammary glands.

- **Antidiuretic H.**
  - Stimulates water reabsorption in collecting ducts.
  - Stimulates vasoconstriction (vasopressin)
  - Lack diabetes insipidus
Posterior Pituitary Homeostatic Imbalances

ADH

- Hyposcretion produces diabetes insipidus “tasteless”
- Excessive thirst and urination
  - central or neurogenic DI
  - gestagenic or gestational DI
  - nephrogenic DI
  -ipsogenic DI

Click to edit the outline text format

- Second Outline Level
  - Third Outline Level
    - Fourth Outline Level

Diabetes Insipidus Foundation, Inc.
<table>
<thead>
<tr>
<th>Hormone</th>
<th>Target Organ</th>
<th>Principal Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anterior Pituitary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSH: Follicle-stimulating</td>
<td>Ovaries, testes</td>
<td>Female: Growth of ovarian follicles and secretion of estrogen</td>
</tr>
<tr>
<td>hormone</td>
<td></td>
<td>Male: Sperm production</td>
</tr>
<tr>
<td>LH: Luteinizing hormone</td>
<td>Ovaries, testes</td>
<td>Female: Ovulation, maintenance of corpus luteum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male: Testosterone secretion</td>
</tr>
<tr>
<td>TSH: Thyroid-stimulating</td>
<td>Thyroid gland</td>
<td>Growth of thyroid, secretion of hormone</td>
</tr>
<tr>
<td>hormone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACTH: Adrenocorticotropin</td>
<td>Adrenal cortex</td>
<td>Growth of adrenal cortex, secretion of glucocorticoids</td>
</tr>
<tr>
<td>hormone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRL: Prolactin</td>
<td>Mammary glands, testes</td>
<td>Female: Milk synthesis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male: Increased LH sensitivity and testosterone secretion</td>
</tr>
<tr>
<td>GH: Growth hormone (somatotropin)</td>
<td>Liver</td>
<td>Somatomedin secretion, widespread tissue growth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Posterior Pituitary</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADH: Antidiuretic hormone</td>
<td>Kidneys</td>
<td>Water retention</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OT: Oxytocin</td>
<td>Uterus, mammary glands</td>
<td>Labor contractions, milk release; possibly involved in ejaculation, sperm transport,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and sexual affection</td>
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<td></td>
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</tr>
</tbody>
</table>
Thyroid Gland

- Location in neck
  - Inferior to larynx
  - Anterior & lateral to trachea

- Composed of follicles
  - Follicle cells produce thyroglobulin
    - Throxin (T4)
    - Triiodothyronine (T3)
      - Both “thyroid hormone”, body’s major metabolic hormone
B. Negative Feedback

- Most common control mechanism
- Level of hormone in blood or body’s return to homeostasis shuts off loop at hypothalamus and pituitary
Thyroid Problems

- What would happen if the thyroid could no longer produce T3 and T4?

- No negative feedback to hypothalamus and anterior pituitary
Homeostatic imbalances

- Hypothyroidism results
  - Myxedema (in adults)
  - Goiter—low levels of iodine
  - Cretinism (in children)

- Hyperthyroidism results
  - Grave
Parathyroid Glands

- Four small glands embedded in posterior of thyroid
  - Parathyroid hormone (PTH)
  - Stimulates osteoclasts to free Ca2+ from bone
  - Stimulates Ca2+ uptake from intestine & kidney

Hormonal Regulation of Calcium
Parathyroid Homeostatic Imbalances

- Severe hyperparathyroidism causes massive bone destruction

- If blood Ca$^{2+}$ fall too low, neurons become overactive, resulting in tetany
Feedback Loop

- Negative feedback in calcium homeostasis. A rise in blood Ca\(^{2+}\) causes release of calcitonin from the thyroid gland, promoting Ca\(^{2+}\) deposition in bone and reducing reabsorption in kidneys.

- A drop in blood Ca\(^{2+}\) causes the parathyroid gland to produce parathyroid hormone (PTH), stimulating the release of Ca\(^{2+}\) from bone.

- PTH also promotes reabsorption of Ca\(^{2+}\) in kidneys and uptake of Ca\(^{2+}\) in intestines.
Pancreas

- Consists of two major types of secretory tissue which reflects its dual function
  - Exocrine gland
    - secretes digestive juice
    - localized in the acinar cells
  - Endocrine gland
    - releases hormones
    - localized in the islet cells (islets of Langerhans)
Pancreatic Islets

- “About a million” embedded in pancreas
- Control centers for blood glucose
  - Insulin from beta cells

Pancreatic acinar cells (exocrine)

α (glucagon-producing) cells
β (insulin-producing) cells
Pancreatic islet (of Langerhans)

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Insulin promotes food stores

- Glucose → Glycogen
- Glucose → Glycogen
- Glucose → Amino acid

Liver

- Glucose
- Fatty acids

Liver & Fat (white)

- Amino acids → Protein

Muscle

Blood

Glucagon catabolizes food stores

- Glucose
- Amino acids
- Fatty acids

Blood

- Glucose → Glycogen
- Amino acids → Protein
- Fatty acids → Fats

Blood

Glucagon

- Glucose
- Amino acids
- Fatty acids

Insulin
Islets of Langerhans

- Insulin stimulates glucose uptake, glycogenesis

- Glucagon stimulates glycogenolysis, glucose release from liver (vs gluconeogenesis)
Feedback Loop

A rise in blood glucose causes release of insulin from beta cells in the pancreas, promoting glucose uptake in cells and storage as glycogen in the liver.

A fall in blood glucose stimulates alpha cells in the pancreas to secrete glucagon, which causes the liver to break down glycogen and release glucose.
Pancreas Homeostatic Imbalances

Diabetes *siphon* mellitus *mel= "honey"

Symptoms:
- Polyuria
- Polydipsia
- Polyphagia

<table>
<thead>
<tr>
<th>Type I and Type II Diabetes</th>
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</thead>
<tbody>
<tr>
<td><strong>TYPE I</strong></td>
</tr>
<tr>
<td>Insulin level</td>
</tr>
<tr>
<td>Onset</td>
</tr>
<tr>
<td>% Diabetics</td>
</tr>
<tr>
<td>Basic defect</td>
</tr>
<tr>
<td>Obesity?</td>
</tr>
<tr>
<td>Ketosis?</td>
</tr>
<tr>
<td>Treatment</td>
</tr>
</tbody>
</table>

Outline Level

Blood Level Regulation in Diabetics
Overview of Reproductive System

• Primary sex organs (gonads)
  - Produce gametes (testes or ovaries)
  - Gametogenesis - spermatogenesis or oogenesis

• Secondary sex organs
  - Male - ducts, glands, penis deliver sperm cells
  - Female - uterine tubes, uterus and vagina receive sperm and nourish developing fetus

• Secondary sex characteristics
  - pubic, axillary and facial hair, scent glands, body morphology and low-pitched voice in males
Gonads

- Ovaries
- Estrogens
- Progesterone
- Testes
- Testosterone
Male Reproductive Physiology
Spermatogenesis

- Spermatogonia produce 2 kinds of daughter cells
  - Type A remain outside blood-testis barrier and produce more daughter cells until death
  - Type B differentiate into primary spermatocytes
    - Meiosis I 2 secondary spermatocytes
    - Meiosis II 4 spermatids
Brain-Testicular Axis

- Testicular regulation involves three sets of hormones:
  - **GnRH** - gonadotropin-releasing hormone
    - Secreted by hypothalamus
    - Stimulates secretion of anterior pituitary secretion hormones (FSH/LH)
  - **FSH and LH** - Follicle stimulating hormone and leuteinizing hormone
    - LH acts as Interstitial Cell Stimulating Hormone
    - Secreted by anterior pituitary
    - Directly stimulate the testes
      - FSH - stimulates formation of ABP (androgen binding protein) by nurse cells
      - LH - stimulates interstitial cells to secrete testosterone
Hormonal Regulation of Testicular Function

- Feedback inhibition on the hypothalamus and pituitary results from:
  - Rising levels of testosterone
  - Increased inhibin
Testosterone

- Most from interstitial cells of testes with small amounts from adrenal glands and sustentacular cells
- Causes enlargement and differentiation of male genitals and reproductive duct system
- Necessary for sperm cell formation
- Required for descent of testes
- Hair growth on certain parts of the body
- Skin is rougher and coarser
- Quantity of melanin increases
- Increases rate of secretion of sebaceous glands
- Hypertrophy of larynx
- Increases metabolic rate
Female Reproductive Physiology
Establishing the Ovarian Cycle

- During childhood, ovaries grow and secrete small amounts of estrogens that inhibit the hypothalamic release of GnRH
- As puberty nears, GnRH is released; FSH and LH are released by the pituitary, which act on the ovaries
- These events continue until an adult cyclic pattern is achieved and menarche occurs
Ovarian Cycle

- Monthly series of events associated with the maturation of an egg
- Follicular phase – period of follicle growth (days 1–14)
- Luteal phase – period of corpus luteum activity (days 14–28)
- Ovulation occurs midcycle
Sexual Cycle

- Averages 28 days, ranges from 20 to 45
- Hormone cycle: hierarchy of control
  - hypothalamus  pituitary  ovaries  uterus
- Follicular phase (2 weeks)
  - menstruation occurs during first 3 to 5 days of cycle
  - uterus replaces lost endometrium and follicles grow
- Luteal phase (2 weeks)
  - corpus luteum stimulates endometrial thickening
  - endometrium lost without pregnancy
Hormonal Interactions During the Ovarian Cycle

- Day 1 – GnRH stimulates the release of FSH and LH
- FSH and LH stimulate follicle growth and maturation, and low-level estrogen release
- Rising estrogen levels:
  - Inhibit the release of FSH and LH
  - Prod the pituitary to synthesize and accumulate these gonadotropins
- Estrogen levels increase and high estrogen levels have a positive feedback effect on the pituitary, causing an increase in LH
Hormonal Interactions During the Ovarian Cycle

- The LH spike stimulates the primary oocyte to complete meiosis I, and the secondary oocyte continues on to metaphase II
- Day 14 – LH triggers ovulation
- LH transforms the ruptured follicle into a corpus luteum, which produces inhibin, progesterone, and estrogen
Hormonal Interactions During the Ovarian Cycle

- These hormones shut off FSH and LH release and declining LH ends luteal activity
- Days 26-28 – decline of the ovarian hormones
  - Ends the blockade of FSH and LH
  - The cycle starts anew
Follicular Phase

- The primordial follicle, directed by the oocyte, becomes a primary follicle
- Primary follicle becomes a secondary follicle
  - The theca folliculi and granulosa cells cooperate to produce estrogens
  - The zona pellucida forms around the oocyte
  - The antrum is formed
Follicular Phase

- The secondary follicle becomes a vesicular follicle
  - The antrum expands and isolates the oocyte and the corona radiata
  - The full size follicle (vesicular follicle) bulges from the external surface of the ovary
  - The primary oocyte completes meiosis I, and the stage is set for ovulation
Menstruation (day 1) to ovulation (14) (variable)

Difficult to predict date of ovulation

Contains menstrual and preovulatory phases
Ovarian Cycle - Preantral Phase

- Discharge of menstrual fluid (days 1-5)
- Before follicle develops antrum
  - primordial and primary follicles
Ovarian Cycle - Antral Phase

- Day 6 to 14, one dominant follicle advances to mature (graafian) follicle; secretes estrogen
Histology of Ovarian Follicles

- Granulosa cells
- Oocyte (egg)
- Oocyte nucleus
- Zona pellucida
- Cumulus oophorus
- Antrum
- Theca folliculi

Scale: 100 μm
Ovulation

- Ovulation occurs when the ovary wall ruptures and expels the secondary oocyte
- Mittelschmerz – a twinge of pain sometimes felt at ovulation
- 1-2% of ovulations release more than one secondary oocyte, which if fertilized, results in fraternal twins
Mature follicle ruptures, releases oocyte influenced by LH
Pituitary-Ovarian Axis

1. Maturing follicle secretes estrogen.
2. Estrogen stimulates hypothalamus and anterior pituitary.
3. Hypothalamus secretes GnRH.
4. GnRH and estrogen stimulate pituitary to secrete LH and FSH.
5. Oocyte completes meiosis I; follicle rapidly enlarges and then ovulates.

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Luteal Phase

- After ovulation, the ruptured follicle collapses, granulosa cells enlarge, and along with internal thecal cells, form the corpus luteum.
- The corpus luteum secretes progesterone and estrogen.
- If pregnancy does not occur, the corpus luteum degenerates in 10 days, leaving a scar (corpus albicans).
- If pregnancy does occur, the corpus luteum produces hormones until the placenta takes over that role (at about 3 months).
- Corpus luteum - forms from ruptured follicle, under influence of LH; secretes progesterone
Menstrual Cycle - Proliferative Phase

- Day 6-14 rebuild endometrial tissue
  - mitosis occurs in stratum basalis
  - result of estrogen from developing follicles
Menstrual Cycle - Secretory Phase

- Further thickening of endometrium due to secretion and fluid accumulation -- not mitosis
- Due to progesterone stimulation of glands
Menstrual Cycle Premenstrual Phase

- Involution of corpus luteum, progesterone falls
  - spiral arteries constrict causes endometrial ischemia
  - stratum functionalis sloughs
Menstrual Cycle - Menstrual Phase

- Third Outline Level
  - Blood, serous fluid and endometrial tissue are discharged

- Fourth Outline Level

- Fifth Outline Level
Feedback Mechanisms in Ovarian Function

Key:
- = Stimulates
- = Inhibits

1. Hypothalamus
2. Anterior pituitary
3. Slightly elevated estrogen level and rising inhibin levels
4. High estrogen level
5. LH, FSH surge
6. Ovulation
7. Estrogen, progesterone, and inhibin
8. Corpus luteum

Growing follicle
Mature follicle
Uterine (Menstrual) Cycle

- Series of cyclic changes that the uterine endometrium goes through each month in response to ovarian hormones in the blood
  - Days 1-5: Menstrual phase – uterus sheds all but the deepest part of the endometrium
  - Days 6-14: Proliferative (preovulatory) phase – endometrium rebuilds itself
  - Days 15-28: Secretory (postovulatory) phase – endometrium prepares for implantation of the embryo
Gonadotropins, Hormones, and the Ovarian and Uterine Cycles

(a) Fluctuation of gonadotropin levels

(b) Fluctuation of ovarian hormone levels
Gonadotropins, Hormones, and the Ovarian and Uterine Cycles

(c) Ovarian cycle
(d) Uterine cycle
Extrauterine Effects of Estrogens and Progesterone

- Estrogen levels rise during puberty
- Promote oogenesis and follicle growth in the ovary
- Exert anabolic effects on the female reproductive tract
  - Uterine tubes, uterus, and vagina grow larger and become functional
  - Uterine tubes and uterus exhibit enhanced motility
  - Vaginal mucosa thickens and external genitalia mature
Estrogen-Induced Secondary Sex Characteristics

- Growth of the breasts
- Increased deposition of subcutaneous fat, especially in the hips and breasts
- Widening and lightening of the pelvis
- Growth of axillary and pubic hair