Chapter 10 Endocrine System

The two major systems responsible for the regulation of homeostasis (performed by *all* the organ systems) are the ***nervous system*** and the ***endocrine system***. While the nervous system acts more quickly it has ***short-term*** effects. The ***endocrine system***, which is composed of a group of glands placed throughout the body, releases chemicals (hormones) that must travel through the circulatory system to reach a target tissue or organ causing that tissue or organ to effect a regulatory change. This is a much slower process but the effect is more ***long-term***.

I. **Main Functions**
   A. **Growth, metabolism, and maturation** of many tissues and organs
   B. **Ionic Regulation** – regulates ion concentrations in the blood (blood chemistry)
   C. **Water Balance** – regulates water balance by controlling solute concentrations
   D. **Heart rate & Blood Pressure Regulation**
   E. **Blood Glucose Regulation**
   F. **Immune System Regulation**
   G. **Reproductive Function Control**
   H. **Uterine Contractions & Milk Release**

II. **Chemical Signals (ligands)** – are molecules released from one location that move to another location to produce a response – 2 classes
   A. **Intracellular** – are produced in one part of a cell and travel to another part of the same cell
   B. **Intercellular** – are produced and released by one cell, carried in intercellular (interstitial) fluid, and bind to receptors on *some* other cells (not all cells have the same receptor sites) – these ligands are placed in functional categories on the basis of the tissue they are secreted from and the tissue/s they regulate
      1. **Autocrine** – are secreted (released) by cells to have a local effect influencing the activity of the same cell type that secreted them – examples ***eicosanoids*** (prostaglandins, thromboxanes, prostacylins, and leukotrienes) released from smooth muscle and platelets in response to inflammation, causing blood vessel dilation and blood clot formation
      2. **Paracrine** – produced and secreted by a wide variety of tissues to effect other tissue types in the same area (locally) – examples ***histamine*** and ***prostaglandins***

* Because certain chemicals function in several of the above categories they are studied in conjunction with Endocrine and Neuro-chemicals

      3. **Neuromodulators & Neurotransmitters** – **related to the nervous system** – produced and secreted by neurons – released across the synaptic cleft or small extracellular spaces to influence postsynaptic cells – examples ***acetylcholine*** and ***epinephrine***
      4. **Pheromones** – secreted into the environment (outside the body) to modify physiology and behavior of other individuals – mostly seen in animals and relate to reproduction
      5. **Neurohormones** (produced by neurons and function like a hormone – examples ***oxytocin*** and ***antidiuretic hormone***) **and Hormones** (examples – ***thyroid hormone***, ***growth hormone***, ***insulin***, ***epinephrine***, ***estrogen***, ***progesterone***, ***testosterone***) – **related to endocrine system** - secreted into the blood , travel some distance to a target tissue/organ to influence specific activities

III. **Hormones** – chemical messengers in the ***endocrine system*** – *intercellular* chemical signals produced within and secreted by the endocrine glands – transported by blood some distance to target tissues/organs – attach to receptor sites (molecules) on the target to effect a change in activity – broken down in the liver and excreted in the urine

A. **Hormone Chemistry** – 2 basic chemical base types

1. **Proteins** – which can range from; a simple ***amino acid***, to a ***polypeptide*** (20 to less than 100 *amino acids*), to a full protein (greater than 100 *amino acids*) – most bind to membrane bound receptors (exception- peptide hormones secreted by the thyroid that diffuse) – when bound to its receptor on a cell membrane one of two things happens: ¹ it alters the permeability of the cell membrane; ² it can activate a *"first messenger-second messenger"* system where the ***protein hormone*** is the ***first messenger*** bound to the cell membrane activating a ***regulatory substance*** as the ***second messenger*** which activates *enzymes* that effect a change by ***catalyzing*** (changing the rate at which reactions occur) chemical reactions
2. **Lipid** (steroids) – derived from ***cholesterol*** – have structures that vary only slightly among the different types – produced mostly by the ***adrenal cortex*** and ***gonads*** (ovaries and testes) – **all** diffuse across the cell membrane and bind to ***intracellular receptors*** in the cytoplasm or nucleus (activates genes in the DNA of the nucleus, which activate synthesis of mRNA that, through transcription and translation, produce a protein) - steroid hormones are mostly responsible for initiating or changing the rate of protein synthesis
    a. **Eicosanoids** – are derived from the fatty acid ***arachidonic acid*** and include; prostaglandins (Paracrine), thromboxanes, prostacylins, and leukotrienes
3. **Four Main Effects of Hormones on Target Tissues**
    a. Initiates Protein Synthesis
    b. Changes Rate of Protein Synthesis
    c. Changes Rate of Secretions of Cells
    d. Alters the Permeability of the cell membrane allowing certain substances to move in and/or out of the cell

B. **Regulation of Secretions** – operate on a ***negative feedback mechanism*** that keeps the body functioning within a narrow range of values (margin) - regulated by one or more of 3 methods

1. **Body Chemistry Levels** – secretion of some hormones is triggered by levels of certain chemicals in blood (examples – ***insulin*** is triggered by blood glucose levels, ***parathyroid hormone*** is triggered by calcium blood levels)
2. **Hormones** – secretion of some hormones is triggered by other hormones (example – ***pituitary hormones*** trigger release of ***sex hormones***)
3. **Nervous System** – secretion of some hormones is controlled by the nervous system (example – nervous stimulation of the ***adrenal medulla*** triggers release of ***epinephrine***)

IV. **Endocrine Glands & Their Hormones** – consist of *ductless* glands that secrete hormones directly into the circulatory system

A. **Pituitary Gland (hypophysis)** – about the size of a pea – sits in the ***sella turcica*** (Turkish saddle – see cranial bones) – connected to the ***hypothalamus*** by the ***infundibulum*** – historically though to be the *master* gland –is divided into 2 lobes – releases 9 different hormones

1. **Anterior Pituitary** (adenohypophysis) – made of glandular epithelial cells derived from the embryonic oral cavity – secretion of hormones controlled by ***releasing factors*** (neurohormones) produced by nerve cells in the

hypothalamus which travel to the *anterior pituitary* by the ***hypothalamic-hypophyseal portal system*** (a group of capillaries and veins within the anterior portion of the *pituitary gland* and the *infundibulum*) - 7 main hormones secreted

a. **Growth Hormone (GH)** – *target tissue* is most tissues of the body – *effects*; increasing protein synthesis, breaking down of fats, and releasing of fatty acids from cells – influences the liver to produce and secrete ***somatomedins*** (protein chemical signals, which bind to cells of other tissue (like bone and cartilage) stimulating growth), neurons synapse with capillaries by releasing vesicles filled with *releasing factors* that disperse into the capillaries by *exocytosis* and are carried to the *anterior pituitary gland* – stimulates uptake f amino acids into cells giving them more raw materials to manufacture tissues with **(3 main tissues effected; muscle, bone, and adipose)**
   - **hyposecretion** – causes ***pituitary dwarfism*** (normal proportionally, just remaining small)
   - **hypersecretion** – causes ***giantism*** (increased bone length) during growth phase or ***acromegaly*** (increased bone diameter) after adult hood is reached

b. **Prolactin (PRL)** – *target tissue* the ***mammaries*** (modified apocrine sweat glands) in the breast – *effects*; stimulates milk production in females before giving birth, stimulates interstitial cells in the testes to become more sensitive to *ICSH or LH* in males

c. **Thyroid stimulating hormone (TSH)** – *target tissue* the *thyroid gland* – *effect*, causes the *thyroid* to secrete more thyroid hormones – *activated by* (driver) iodine levels in the blood

d. **Adrenocorticotropic hormone (ACTH)** – *target tissue* the ***adrenal cortex*** of the *adrenal gland* – *effect*, to increase secretion of hormones by the *adrenal cortex* (mainly cortisol) – *activated by* (driver) stress

e. **Gonadotropins** – *target tissue* the ***gonads*** (testes and ovaries) – *effect*, to regulate the growth, development, and function of the *gonads* – *activated by* (driver) a single releasing hormone from the hypothalamus – 2 hormones (3 names)
   - **Luteinizing hormone (LH)** – in females *targets* the *ovaries* to ***ovulate*** (release of an oocyte) and increase secretion of ***estrogen*** and ***progesterone*** – in males *LH* is called ***interstitial cell-stimulating hormone (ICSH)*** which *targets* the *interstitial cells of the testes* to secrete more ***testosterone***
   - **Follicle-stimulating hormone (FSH)** – stimulates the development of ***follicles*** (maturation into an oocyte) in the *ovaries* and ***sperm*** (increased production) in the *testes*

f. **Melanocyte-stimulating hormone (MSH)** – *targets* melanocytes – *effect*, synthesis of melanin (in fetus only)

2. **Posterior Pituitary (neurohypophysis)** – made of nervous tissue – nerve cell bodies in the *hypothalamus nuclei* (nuclei detect and regulate ionic and chemical levels in the body) have axons extending down through the *infundibulum* to the *posterior pituitary* – production of the 2 hormones released by the *posterior pituitary* happen in the *nuclei of the hypothalamus* and are transported down the axons where they synapse with capillaries in the *posterior pituitary*

   a. **Antidiuretic hormone (ADH)** – *target tissue* the ***kidneys*** – *effects*; increased water reabsorbtion in the kidneys = decreased urine output, ***vasopressin*** (blood vessel constriction) – *activated by* (driver)low blood pressure

b. **Oxytocin (OT)** – *target tissue* the ***smooth muscle of the uterus*** and ***melanocytes in the mammaries*** - *effects*; uterine contractions for birth and milk "let-down"

B. **Parathyroid Glands** – four small glands embedded in the posterior wall of the *thyroid gland* – secrete 1 hormone
   1. **Parathyroid hormone (PTH)** – *target tissue* the ***osteoclasts*** of the bone***, digestive system, and kidneys*** – *effect*: increase calcium (Ca^{2+}) levels by; increased bone break down by the *osteoclasts*, increased Ca^{2+} absorption in the *digestive system* by increasing active vitamin D synthesis (calcium uptake is dependent on vitamin D), increased reabsorption of Ca^{2+} in the *kidneys* – functions on a *negative feedback loop* – *activated by* (driver) low blood or serum calcium (Ca^{2+})

C. **Thyroid Gland** – is highly vascular - works in a *negative feedback* mechanism with the *hypothalamus* – formed by 2 lobes, located on either side of the *trachea* and connected by a narrow band called the ***isthmus***, consisting of many ***follicles*** (small hollow spheres of *simple cuboidal epithelium* each filled with a protein-rich colloid called ***thyroglobin*** that the hormones T_3 and T_4 are attached to – storage area for hormones), between the *follicles* is a network of loose connective tissue, capillaries, and ***parafollicular cells*** (produce the hormone *calcitonin*)
   1. T_3 **and** T_4 - *produced* by the ***follicular cells*** of the *follicles* – *target tissue*; most tissues of the body – *effect*; regulate cellular *metabolism* (influencing heart rate & contraction strength and respiratory rate to meet oxygen and nutrient needs, stimulates appetite and brake down of nutrients) – *activated by TSH* (hormone produced by the *anterior pituitary*) with the driver being ***iodine levels*** (*hypothalamus* monitors *serum iodine levels*) – requires *iodine* for synthesis (iodine added to salt)
      a. **Tetraiodothyroxine (T_4)** – most abundant of the 2 – contains 4 iodine atoms – also called ***Thyroxine***
      b. **Triiodothyroxine (T_3)** – most potent of the 2 – contains 3 iodine atoms
   2. **Calcitonin** – *produced by* the *parafollicular cells* – *target tissue* the bone (inhibits *osteoclasts* and stimulates *osteoblasts*) – *effect*; to lower blood calcium

D. **Adrenal Glands (suprarenal glands)** – 2 small glands located superior to each kidney and composed of 2 distinct types of tissue
   1. **Adrenal Cortex** – outer portion of the *adrenal gland* – composed of glandular tissue derived from the same epithelial tissue as the *gonads* embryonically – 3 basic classes of *steroid* hormones secreted
      a. **Glucocorticoids** – helps regulate blood nutrient levels – secretion levels controlled by the ***hypothalamus*** (which secretes a releasing hormone) in conjunction with the ***anterior pituitary*** (which secretes (ACTH) *adrenocorticotropic hormone*) – major hormone is ***cortisol*** (which functions in the increased breakdown of *protein* & *fat* converting them into *glucose* & *fatty acids* to be used as energy, also reduces the inflammatory response) – *target tissue* the *liver* (gluconeogenisis) – *drivers* stress and low blood glucose
      b. **Mineralocorticoids** – helps regulate blood volume and levels of potassium (K^+) and sodium (Na^+) in the blood – major hormone ***aldosterone*** (which causes the kidneys to retain Na^+ thereby retaining water which increases blood volume = increased blood pressure) – *target tissue* the *kidneys* (primarily), but also *intestines, sweat glands, and salivary glands* – *drivers* low blood pressure or high blood osmolality

- **The Renin-Angiotensin Mechanism:** *Kidneys* detect a drop in *blood pressure* → *kidneys* release *renin* (which acts as an enzyme) → converts *angiotensinogen* (a blood protein produced by the liver) into *angiotensin I* → *angiotensin I* is acted on by *angiotensin-converting enzyme* (produced in the lungs) converting it to *angiotensin II* (active version) which causes blood vessel constriction and increased *aldosterone* (mineralocorticoid produced by the *adrenal cortex*) → causes the *kidneys* to excrete K^+ and retain Na^+ → ↑ blood volume → ↑ B/P
- **3 targets of Angiotensin II**
    - The *hypothalamus* – to increase parasympathetic stimulation of the *salivary glands*
    - The *circulatory system* – systemic vasoconstriction
    - The *adrenal cortex* – ***release of aldosterone***

c. **Androgens** – derivatives of *estrogen* and *testosterone* – produced in minuet quantities – responsible for some male characteristics – increases female sex drive and influences some female characteristics (mainly hair growth in pubic and Axillary regions)

2. **Adrenal Medulla** – inner portion of the *adrenal glands* – derived from embryonic neuronal tissue – produces ***catacolamines*** (which prepare the body for vigorous physical activity) – called 'fight-or-flight' hormones – released in response to sympathetic stimulation by the autonomic nervous system – *drivers* are stress and low blood glucose levels – *effects*: [1] increased heart rate, [2] vasodilation of the vessels that supply blood to the muscles, [3] vasoconstriction (shunting) of blood vessels that supply the skin and internal organs, [4] increased break down of glycogen to glucose and release of fatty acids to increase metabolism, [5] increase of respirations
    a. **epinephrine** – principal hormone released by the *adrenal medulla* (80%) – also called adrenalin
    b. **norepinephrine** – used by *sympathetic postganglions* – makes up the other 20% of *catacolamines* released

E. **Pancreas** – primary function is *exocrine* (98% - 99%) as an accessory organ to the digestive system secreting digestive enzymes to aide in the break down of food – ***only 1% - 2% of its function is endocrine*** and this portion is performed by the ***islets of Langerhans*** or ***pancreatic islets*** dispersed (scattered) among the *exocrine* tissue they help regulate blood glucose levels (set point 80mg/dl to 120mg/dl) and consist of 2 cell types, each secreting a different hormone
    1. **Alpha cells** – secrete the hormone ***glucagon*** which targets the *liver* (which stores *glycogen*) increasing the breakdown of *glycogen* into *glucose* to increase blood glucose levels – *driver* is *low blood glucose* and *sympathetic stimulation*
    2. **Beta cells** – secrete the hormone ***insulin*** which targets the *liver* (primarily) but also *skeletal muscle*, *adipose tissue* and *satiety center* (appetite control center of the *hypothalamus*) – binds to cellular receptors on the cell membranes, making the membrane more permeable to *glucose* → the *glucose* then moves into the cell from the blood *lowering blood glucose* → within the cell glucose is converted into ATP – excess *glucose* (blood sugar) is converted by *insulin* into *glycogen* (energy storage molecule in the liver and muscles) – *driver* is *high blood glucose* and *parasympathetic stimulation* (associated with eating a meal)

F. **Gonads (testes & ovaries)** – produce and secrete sex hormones (which target tissues responsible for sexual characteristics) along with production and/or maturation of *gametes* (sex cells; sperm and oocytes)

1. **Testes** – 2 of them – located in the <u>*scrotum*</u> (a flesh sac extending from the base of the penis) – produce and secrete the sex hormone *testosterone*
    a. **Testosterone** – steroid based hormone produced by the *interstitial cells of Leydig* (located between the *seminiferous tubules* which produce sperm) – *driver* release of *ICSH (LH)* by the *anterior pituitary* which is stimulated by release of *GnRH)* by the *hypothalamus* in a negative-feedback loop triggered by a drop in serum *testosterone* – ***prebirth*** is responsible for masculinizing the reproductive organs – ***no production from birth to puberty*** – ***puberty*** is responsible for enlarging the male reproductive system, beginning <u>*spermatogenesis*</u> (production of sperm by the *seminiferous tubule*s, of the testes, stimulated by the release of *FSH* by the *anterior pituitary*), development of <u>*secondary male sex characteristics*</u> (distribution of muscle mass, growth of facial and groin hair, deepening of male voice tone), and the male sex drive
2. **Ovaries** – 2 of them – located lateral posterior to the *uterus* – produce and secrete 2 hormones which contribute to the development and function of the female reproductive structures, <u>*female sex characteristics*</u> (enlargement of breasts, distribution of fat that influences the hips and breasts), and the <u>*menstrual cycle*</u> (caused by the cyclical release of ovarian sex hormones)
    a. **Estrogen** – steroid based hormone – primary hormone of the *ovaries* – produced by the <u>***granulose cells***</u> (surround the *immature oocyte*, also called a *follicle*) – causes *endometrium* build up – responsible for the *proliferative phase* of the menstrual cycle – *driver* the release of *FSH* – <u>***ovulation***</u> (caused by a spike in *estrogen* in a positive-feedback loop with the *hypothalamus* in the release of *GnRH* stimulating release of <u>*FSH*</u> (begins enlargement and maturation of several *follicles*)and <u>*LH*</u> (causes final maturation of one *follicle*) by the *anterior pituitary*) – greatly decreases after *ovulation* then levels off
    b. **Progesterone** – produced by the <u>***corpus luteum***</u> (formed from the *granulose cells*, after <u>*ovulation*</u> (release of the *oocyte*), under the influence of *LH*) – responsible for the *secretory phase* of the menstrual cycle causing the *endometrium* to secrete nutrients in preparation for implantation of a <u>*blastocyst*</u> (fertilized oocyte)

G. **Thymus Gland** – located in the upper part of the *thoracic cavity* in the mediastinum just superior to the heart – is a key player in the development of the *immune system* – is a large gland in children and shrinks with aging
    1. **Thymosin** – hormone secreted by the *thymus* – responsible for the maturation of <u>***T lymphocytes***</u> ***(T-cells)*** (produced in the red bone-marrow – migrate to the *thymus* for maturation – function in immunity)

H. **Pineal Gland** – located superior, posterior to the *thalamus* – associated with the *epithalamus*
    1. **Melatonin** – targets the hypothalamus – regulates sleep and wake cycles and contributes to the onset of puberty by suppressing *GnRH* production and release

V. **Other Hormones**
    A. **Erythropoietin** – secreted by the *kidneys* in response to <u>*hypoxia*</u> (low blood oxygen levels) – *target* is *bone marrow* to increase red blood cell production
    B. **Human Chorionic Gonadotropin** – produced and released by cells of the <u>***chorionic villi***</u> (fingerlike projections in the *endometrium*) within the *placenta* – similar to *LH*, targets the ovary (the one that released the oocyte) to influence the *corpus luteum* to remain functional (continue secreting *progesterone*) in order to maintain the endometrium during pregnancy (gestation) – secretion begins shortly after implantation – is the hormone tested for to indicate pregnancy