Endocrine System

http://arbl.cymbs.colostate.edu/hbooks/pathphys/endocrine/index.html
http://www.endocrineweb.com/index.html

Unlike exocrine glands that secrete substances through ducts, endocrine glands are ductless. They secrete chemical hormones into the bloodstream where they affect certain tissue cells, called target cells, some distance from the glands themselves. Hormones are either amino acid based (amines, peptides, proteins) or steroids (synthesized from cholesterol). The effect a hormone has on a cell depends on the type of cell but typically one or more of the following changes are produced: opening or closing ion channels on plasma membranes, stimulating the synthesis of proteins (particularly enzymes), activating or deactivating enzymes, inducing secretions, stimulating mitosis.

In order for a target cell to respond to a hormone, it must have specific protein receptors on the plasma membrane. The synthesis and release of most hormones are usually regulated by some type of negative feedback system. As hormones levels rise the glands are inhibited from further release of the hormone. Hormones are generally secreted in very specific amounts. Hypo- and hypersecretions result in imbalance that have serious (and even lethal) consequences.

Pituitary Gland (Hypophysis)
The pituitary is a pea-sized gland connected to the hypothalamus by the infundibulum. It lies in the sella turcica of the sphenoid bone. It is bilobed. The posterior pituitary (neurohypophysis) is composed of nervous tissue and stores and releases hormones previously made in the hypothalamus. The anterior lobe (adenohypophysis) is glandular tissue which may be stimulated or inhibited to manufacture or secrete hormones by other hormones originating in the hypothalamus. Four of the six anterior pituitary hormones are tropic hormones which are hormones that regulate the secretion of other endocrine glands.

Anterior Pituitary Lobe Secretions
Growth Hormone (GH) The principle targets of GH are the bones and skeletal muscles. Stimulation of the epiphyseal plate induces long bone growth. Stimulation of skeletal muscle promotes increased muscle mass. Hypersecretion in children results in gigantism and the person becomes abnormally tall. Hypersecretion after the epiphyseal plates are closed results in acromegaly, characterized by overgrowth of bony areas particularly in the hands, feet and face. A hyposecretion of GH causes pituitary dwarfism. Individuals with this deficiency grow to about 4 ft. and are normally proportioned.

Thyroid Stimulating Hormone (TSH) TSH is a tropic hormone that stimulates normal development and secretory activity of the thyroid gland. (See thyroid gland)

Adrenocorticotropic Hormone (ACTH) ACTH stimulates the adrenal cortex to release corticosteroid hormones that help the body to resist stressors.

Gonadotropins There are two gonadotropins that regulate ovarian and testicular function. In both sexes, follicle-stimulating hormone (FSH) stimulates gamete production and luteinizing hormone (LH) stimulates the production of gonadal hormones (estrogen, progesterone and testosterone). LH and FSH are both involved in egg maturation in females.

Prolactin (PRL) stimulates milk production in the breasts.

Posterior pituitary Lobe Secretions
Oxytocin Oxytocin stimulates uterine contractions. Distension of the uterus and cervix late in pregnancy stimulates the release of oxytocin. There is a positive feedback mechanism whereby rises in blood levels will stimulate more release until birth. It also initiates milk “letdown” in lactating women. Oxytocin also plays a role in sexual arousal in both sexes and is also important in social bonding.

Antidiuretic Hormone (ADH) ADH is important in water balance. Osmoreceptors in the hypothalamus monitor the solute concentration of the blood. If too concentrated, there is a release of ADH which targets the kidney tubules which respond by reabsorbing more water from the filtrate and returning it to the

bloodstream. Alcohol is dehydrating because it inhibits ADH. ADH deficiency may cause diabetes insipidus characterized by the output of copious amounts of urine. The opposite condition, SIADH, is characterized by water retention.

Thyroid and Parathyroid Glands
The thyroid gland is found inferior to the larynx. It has two lobes situated on either side of the trachea. The lobes are connected by a narrow isthmus. It is composed of hollow, colloid-filled follicles surrounded by epithelial cells called follicle cells. When stimulated by TSH from the pituitary, the follicle cells produce the body's major metabolic hormone, thyroid hormone (TH). TH is actually a combination of two chemically similar hormones, T_3 and T_4. They have a similar effect on target cells. The main difference between the two is the number of iodine atoms. TH stimulates enzymes involved in carbohydrate production thereby controlling the basal metabolic rate and heat production. It also plays a role in maintaining blood pressure, the regulation of tissue growth, and is necessary in a number of developmental processes. As TH blood levels fall, TSH is released from the pituitary.

A deficiency of TH in adults is called myxedema and is characterized by a low metabolic rate, feeling cold, edema, constipation, lethargy, and mental sluggishness. If the myxedema is a result of an iodine deficiency, the thyroid gland enlarges to what is referred to as an endemic goiter. Hypothyroidism in children is called cretinism characterized by a short body, thick neck and tongue, and mental retardation. Grave's disease (an autoimmune disease) is the result of hyperthyroidism and is characterized by in increased metabolic rate, sweating, rapid heartbeat, nervousness, weight loss, and sometimes exophthalmia.

Another kind of cell of the thyroid gland is the parafollicular cell, which produces an entirely different kind of hormone, calcitonin. Calcitonin inhibits osteoclast activity in the skeleton and stimulates Ca^{2+} uptake into the bone (thereby dropping Ca^{2+} blood levels). Its effects are most important in childhood. On the posterior aspect of the thyroid gland are four tiny parathyroid glands within which are the chief cells that produce parathyroid hormone (PTH). PTH release is stimulated by falling Ca^{2+} levels in the blood. PTH stimulates osteoclasts to release Ca^{2+} into the blood. It also enhances the reabsorption of calcium by the kidneys and the absorption of calcium in the intestine by activating vitamin D. Rising Ca^{2+} blood levels inhibits PTH secretion. Precise blood levels are necessary for proper nerve impulse transmission, muscle contraction and blood clotting. Hyperparathyroidism results in excessive calcium in the blood characterized by depression of the nervous system, abnormal reflexes, muscle weakness, and sometimes kidney stones. Hypoparathyroidism lowers blood calcium and results in loss of sensation, muscle twitches and convulsions.

Adrenal Glands
The adrenal glands are situated on the superior aspect of each kidney and so are also called the surprarenal glands. Each has two functional parts, the adrenal cortex and the adrenal medulla.

Adrenal Cortex The adrenal cortex, which produces a large number of hormones (collectively called corticosteroids), is made up of three layers or zones: the zona glomerulosa produces mainly mineralocorticoids that help control water and electrolyte balance in the blood; the zona fasciculata that mainly produces metabolic hormones; and the zona reticularis that mainly produce small amounts of adrenal sex hormones or gonadocorticoids.

The most important mineralocorticoid is aldosterone that maintains Na^+ balance. It stimulates the reabsorption of Na^+ mainly in the kidney tubules and to some extent it enhances reabsorption of Na^+ from sweat, saliva and gastric juice. Remember that where Na^+ goes, water follows so reabsorption of Na^+ leads to increases in blood volume and pressure. Aldosterone secretion is stimulated by low Na^+ blood levels and rising K^+ blood levels and inhibited by the reverse.

The most important glucocorticoid is hydrocortisone (cortisol). Its primary metabolic effect is to induce glucose formation from fats and proteins. It has other metabolic effects as well. Hydrocortisone release is stimulated by ACTH and rising hydrocortisone levels inhibits ACTH. Excessive amounts of glucocorticoids have anti-immune and anti-inflammatory effects on the body and glucocorticoid drugs are used to control a number of chronic inflammatory disorders. Prolonged use has serious side effects.

Hypersecretion of glucocorticoids causes Cushing's disease characterized by hyperglycemia, muscle and bone weakness, and water retention leading to edema and hypertension. Other symptoms include "moon" face (a rounded appearance of the face), fat redistribution to the back of the neck, bruising and poor wound healing. A hyposecretion of both glucocorticoids and mineralocorticoids results in Addison's disease characterized by weight loss, dehydration and hypotension

Most gonadocoticoids secreted by the zona reticularis are androgens which are converted to testosterone in males and estrogen in females. Their amounts are insignificant compared to amounts produced by the gonads in adults.

Adrenal Medulla The adrenal medulla is stimulated by the sympathetic (fight-or-flight) division of the autonomic nervous system to release two hormones synthesized there by chromaffin cells: epinephrine (adrenaline) and norepinephrine. Usually these two have the same general effects: increased heart rate, blood pressure, blood sugar, and metabolic rate, diversion of blood to the brain and skeletal muscles, and branchiole dilation.

Pancreas

We have already seen the pancreas function as an exocrine gland when it secretes pancreatic juice. Interspersed among the acinar cells of the pancreas are tiny clusters of cells called the islets of Langerhans. There are two kinds of cells in the islets: alpha (α) cells which synthesize the hormone glucagon, and beta (β) cells which produce the hormone insulin. Both are important in the regulation of blood sugar,

Most animals store glucose as the polysaccharide glycogen in the liver and muscles. (Plants store glucose as starch.) Glucagon causes the liver to breakdown glycogen into glucose and release it into the blood. It also stimulates the synthesis of lactic acid back into glucose. Generally glucagon is released in response to falling blood sugar levels but it can also be released by stimulation of sympathetic nerves.

Insulin targets almost all body cells (except brain, kidney and liver). Its main effect is to lower blood sugar by enhancing membrane transport of glucose into cells. It also inhibits the breakdown of glycogen to glucose, triggers the oxidation of glucose and the conversion of glucose to fat. Beta cells are stimulated to secrete insulin mainly by elevated blood sugar levels. Diabetes mellitus results from too little insulin in the blood causing blood sugar levels to remain high. This, in turn, causes elevated sugar levels in the urine. Sugar in the filtrate inhibits water reabsorption leading to large urine output, dehydration and thirst, all typical of diabetics. Since sugar cannot be utilized, the cells turn to metabolizing fat for energy. Fatty acid metabolites, called ketones, cause a drop in blood pH. The body responds by rapid deep breathing trying to blow off carbon dioxide. Diabetes can lead to vascular complications and neuropathies and increase the risk of infection. Of the two types of diabetes mellitus, insulin-dependent (IDDM) and non-insulin-dependent (NIDDM), most cases are of the latter. NIDDM is strongly correlated with obesity. IDDM is an autoimmune disease. Excessive insulin secretion, hyperinsulinism, results in a drop in blood sugar causing anxiety, nervousness, tremors and weakness and, if prolonged, coma and death.

Ovaries and Testes

The ovaries and testes, the gonads, produce several hormones the most important of which are estrogens and progesterone in the female and testosterone in the male. They are important in producing secondary sex characteristics in their respective sexes. Testosterone stimulates sperm production. Estogen and progesterone are important in the menstrual cycle. This will be treated in greater detail in lectures on the male and female reproductive systems.

Pineal Gland

The pineal gland lies on the roof of the third ventricle in the diencephalons. It secretes melatonin which is important in physiological processes involving circadian rhythms.

Thymus
The thymus gland lies deep to the sternum. It is large in children but diminishes in size throughout adulthood until just a few cells remain. It produces a number of hormones including thymosin which is important in the maturation of T lymphocytes.